2025
Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS

WASHINGTON STATE UNIVERSITY

University of Idaho

Oregon State University

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Photo by Gagandeep Kaur

Welcome to our 2025 Field Day Abstracts!

2025 Dryland Field Day Abstracts: Highlights of Research Progress

Washington State University
Department of Crop and Soil Sciences
Technical Report 25-1

Oregon State University
Department of Crop and Soil Science
Technical Report OSU-FDR-2025

University of Idaho
Idaho Agricultural Experiment Station
TR 0025-1

WASHINGTON OILSEED CROPPING SYSTEMS
Part of the Washington State Biofuels Initiative

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WASHINGTON STATE UNIVERSITY

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For more information on Washington State University events, see the Events Calendar on the Dept. of Crop and Soil Sciences site: https://css.wsu.edu/events

Oregon State University

Pendleton Station Field Day - June 10
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For more information on Oregon State University events, see the 2025 Field Day page on the Columbia Basin Agricultural Research Center site: https://agsci.oregonstate.edu/cbarc/field-days/2025-field-days

University of Idaho

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For more information on University of Idaho events, see the Events page on the College of Agriculture and Life Sciences site: https://uidaho.edu/cals/news/calendar

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Photo by Tristan Blain.

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Part 1. Agronomy and Soils

Optimizing Soil pH: Lessons from the First Year of On-Farm Trials in Walla Walla 2023-24

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Soil pH is a fundamental property influencing nutrient availability, microbial activity, and overall crop productivity. Soil acidity is a growing concern in dryland wheat production systems, especially in the inland Pacific Northwest, where continuous cropping and ammonium-based fertilizers accelerate soil acidification. This poses a significant challenge to sustainable yield improvement. Suboptimal pH levels can lead to aluminum and manganese toxicity, reduce phosphorus availability, decrease nitrogen use efficiency, and impair root growth - ultimately constraining wheat yield potential and soil function. This trial evaluates the effectiveness of various liming products and soil amendments in correcting soil pH and improving chemical balance in acidic soils. The treatments include a range of liming agents and soil amendments including:

1. Ag-Grade Lime (1000 lb/ac) using finely ground prilled lime (200 µm size)
2. Ag-Grade Lime + Boron (B) (1000 lb lime + 4.8% B (1050 lb/ac))
3. Alkaline Biochar (10 tons/ac)
4. Calsync Maxx (6 gallons/ac) (ground $CaCO_3$ with boron and humic acid; 3 gal = 500 lb lime equivalent)
5. Regen Plus (rock phosphate coated with GSR calcium; 800 lb/ac).
6. Control

This report summarizes the setup and preliminary observations from the first year of trial, focusing on each amendment's potential to raise soil pH and support winter wheat yield in Walla Walla, WA. This trial was initiated in September 2023 with 6 treatments and 4 replications with each plot size 100 x 300 ft. Initial soil pH ranged from 4.77–5.34 in 0-4" and 4.72–5.05 in the 4-8" depth. Soil sampling was done on April 29, 2024, and March 28, 2025, from 3 depths (0-4, 4-8, and 8-12 in.). Soil samples were analyzed at Best-Test Analytical Services, Moses Lakes, WA for an array of soil properties but only soil pH, Al, Mn, B, and Fe are shown here. Crop yields were collected using weigh wagon during harvest. Grain samples were analyzed for protein, starch, gluten, zeleny (baking quality), and test weight. In addition, random 1-m cut was taken and analyzed for 1000 grain weight, spike density, and straw biomass. Among tested soil properties in 2024, only soil B varied under all treatments across all depths while pH, Al, Mn and Fe did not show any significant differences among treatments (Fig.1). In 2025, soil pH, Al and B varied significantly at $p<0.05$ while soil Fe and Mn varied at $p<0.1$ under different treatments. In 2025, Lime, lime with B, and alkaline biochar treatments increased the soil pH significantly as compared to control treatment with greatest increase under lime treatment in top 4 in. Control treatment also showed greater Al, Fe, and Mn concentrations in top 4 in. soil. Soil B was highest in treatment lime with B in both years across all depths. Lime, lime with B, and alkaline biochar treatments resulted in significantly lower Al, Fe and Mn concentrations as compared to control in 0-4 in depth in 2025.

In general, soil pH was higher in year 2025 than 2024 across all treatments showing various liming agents and soil amendments are slowly increasing soil pH.

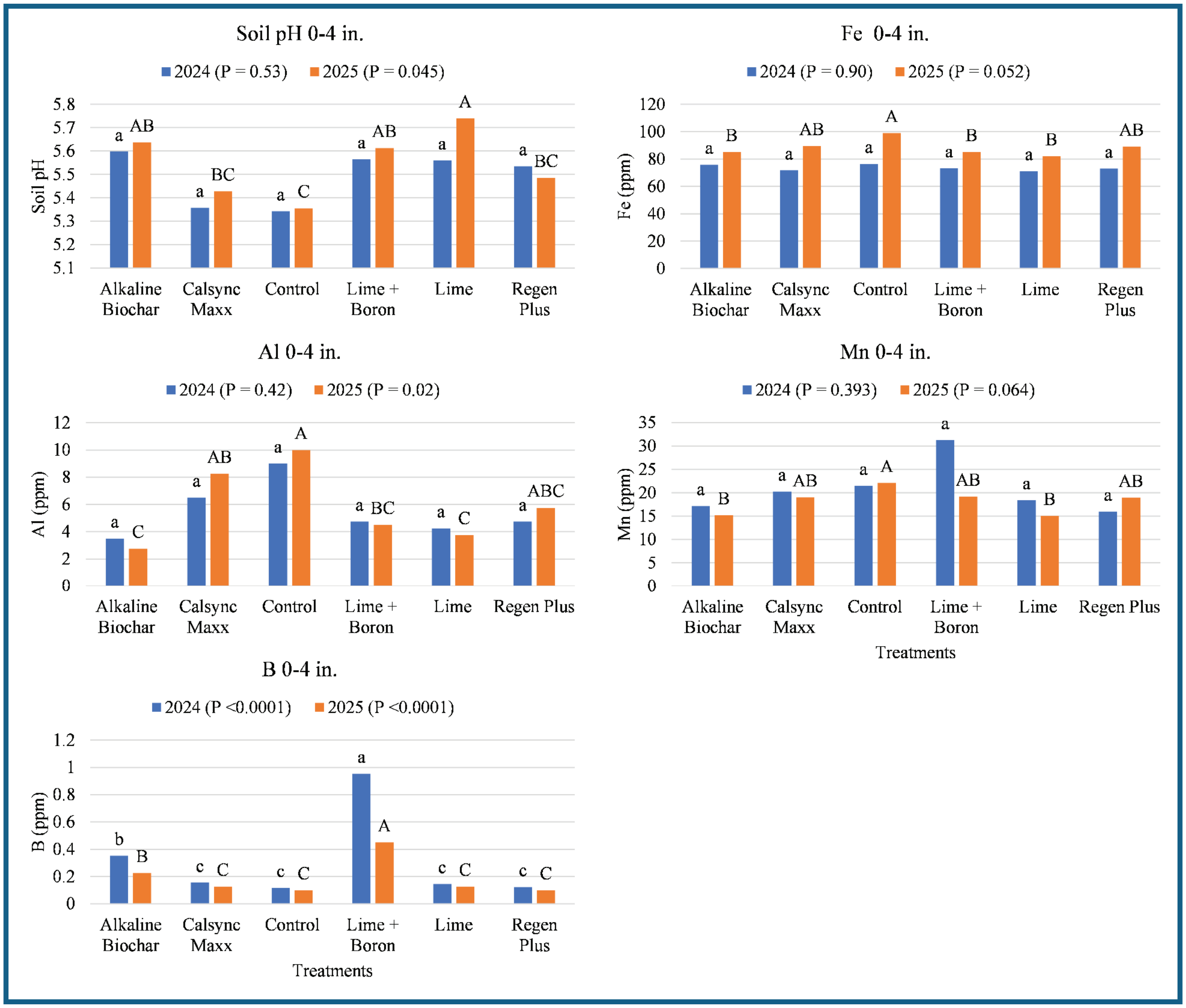

Figure 1. Soil pH, Fe, Al, Mn, and B under different treatments in 2024 and 2025. Bars with different lower-case letters show significant difference among treatments within year 2024. Bars with different capital letters show significant difference among treatments within year 2025.

Lime, lime with B, and Regen Plus showed significantly higher wheat yields ($p<0.1$) than control treatment (Fig. 2). Grain protein was highest in alkaline biochar treatment as compared to all the treatments. Test weight, 1000 grain weight, straw biomass and spike density

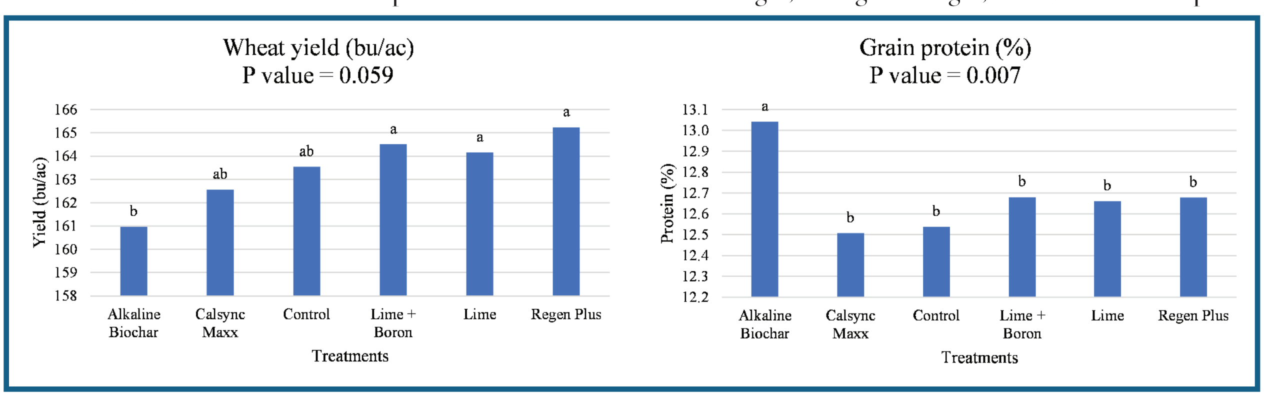

Figure 2. Wheat yields and grain protein under different liming treatments after one year of application. Different lower-case letters show significantly different means.

did not vary under any treatments (Table 1). The research team looks forward to monitoring the experiment to document long term effects of the different treatments. Upcoming data will include soil microbiology and also an economic analysis of the different treatments.

Table 1. Different yield components and grain properties under different liming treatments after one year of application.

Treatments	Starch (%)		Gluten (%)		Zeleny (Baking quality) (%)		Test wt. (lb)		Spike density (spike/ft²)		1000 grain wt. (g)		Straw biomass (lb/ac)	
Alkaline Biochar	71.5	b*	29.3	a	45.2	a	64.0	a	26.6	a	46.7	a	8234.5	a
Calsync Maxx	72.1	a	27.7	b	41.1	b	64.2	a	27.6	a	47.3	a	8431.2	a
Control	72.0	a	27.9	b	41.7	b	64.1	a	25.6	a	46.5	a	6755.1	a
Lime + Boron	71.9	a	28.2	b	42.5	b	64.2	a	30.7	a	47.8	a	8227.2	a
Lime	72.0	a	28.2	b	42.2	b	64.3	a	26.7	a	47.9	a	8754.7	a
Regen Plus	71.9	a	28.2	b	42.5	b	64.1	a	26.8	a	48.4	a	8726.0	a
p value	0.041		0.025		0.013		0.764		0.866		0.420		0.518	

*Different lower-case letters show significantly different means within column at $p<0.05$.

Understanding the Role of Cover Crops in Dryland Wheat Systems

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#Resilient Dryland Farming Alliance; Non-Assistance Cooperative Agreement 58-2074-3-006

The Resilient Dryland Farming Alliance (RDFA) is exploring how cover crops can benefit wheat growers in the inland Pacific Northwest. While cover crops are widely used in other regions to improve soil health and reduce the negative effects of fallow, research in regional dryland wheat systems has been limited. Recent findings show that wheat yields after cover crops can be comparable to or even better than those following fallow, depending on precipitation zone. Different cover crop species offer unique benefits—such as improving soil cover, fixing nitrogen, and enhancing soil health—making it important to understand which species or mixes work best over time. Current RDFA work is digging deeper into the dynamics of cover cropping in long-term wheat cropping systems research.

Dr. Curtis Adams sampling barley cover crop biomass at Starvation Farms, Morrow County, Oregon.

Soil Water and Cover Crops

Water is scarce in dryland farming, thus understanding how cover crops affect soil moisture is crucial. RDFA research is providing farmers with practical information on how cover crops influence soil water use, retention, and infiltration across different precipitation zones.

Soil Biology and Nutrient Availability

Healthy soils are key to productive wheat farming. Cover crops may stimulate or modify soil biology, helping to release important nutrients like nitrogen, phosphorus, and sulfur—potentially reducing fertilizer costs. RDFA is evaluating how different cover crops can boost soil microbial activity and enhance nutrient availability for future crops.

Integrated Weed Management

Weeds cost dryland wheat growers in the Pacific Northwest approximately $190 million annually. Integrated weed management strategies that combine cover crops with herbicides are being investigated in RDFA. This research aims to provide practical solutions for controlling weeds during the growing season while reducing future infestations and improving long-term farm sustainability.

Managing Soilborne Diseases

Soilborne diseases pose a major threat to winter wheat yields, especially with the rise of no-till practices. Initial RDFA research shows that short-term cover crop rotations do not reduce disease pressure and, in some cases, may increase pathogen levels. These findings highlight the need for long-term studies to understand whether cover crops can effectively manage soilborne diseases while promoting soil health.

In Conclusion

Through ongoing research, the RDFA is delivering actionable insights to help wheat producers make informed decisions about integrating cover crops into their farming systems for improved productivity and long-term resilience.

The WSU Wilke Research and Extension Farm Long-Term Rotation Summary

Aaron Esser and Derek Appel
WSU Extension

The WSU Wilke Research and Extension Farm is located on the eastern edge of Davenport, WA. Washington State University maintains and operates this facility. The farm is in a direct seed cropping system utilizing no-till fallow, winter wheat, spring cereals and broadleaf crops. Broadleaf crops are incorporated when weed pressures and market prices create opportunities for profitable production. The predominant cropping system practiced by farmers in this region is a 3-year rotation, which includes summer fallow, winter wheat, and spring cereals. Farmers are interested in intensifying rotations to reduce fallow years and increase crop diversity to improve long-term agronomic and economic stability.

The south side of the farm is divided into seven plots; three plots are in a traditional 3-year crop rotation that includes fallow, winter wheat and spring wheat. Four plots are in an intensified 4-year crop rotation that include fallow, winter wheat, spring broadleaf, and continuous winter wheat. The north side remains in an intensified rotation that forgoes summer fallow and is in a continuous crop production system. The field around the homesite of the farm was also brought into this rotation in 2023. Economic return over input costs (seed, fertilizer, pesticides, and crop insurance) is analyzed in three-year averages to help remove some of the year-to year variability (Fig.1). Fixed cost associated with the farm are not included because of the variability from farm to farm across the region. Over the last six years, the fouryear rotation and continuous rotation have averaged returns above input costs of $175 and $169 per acre, respectively, and are not significantly different. The three-year rotation has averaged $143/acre return above costs during this period and is significantly less than both the continuous rotation and the four-year rotation. More information and reports can be found at http://wilkefarm.wsu.edu/.

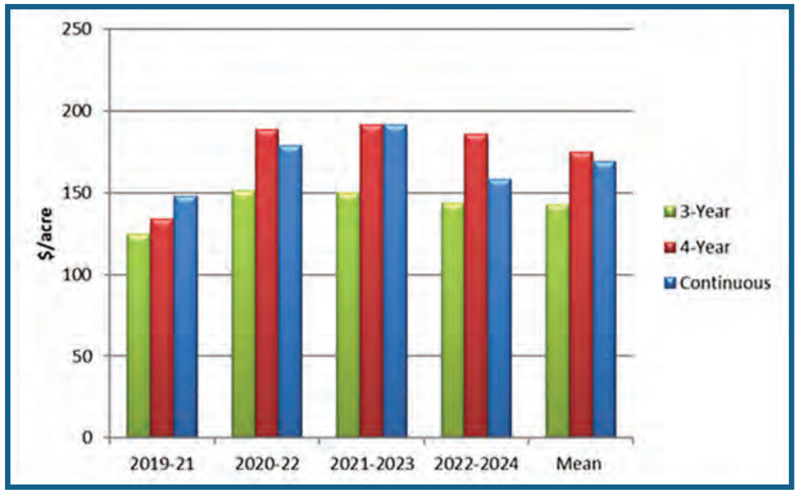

Figure 1. Three-year average economic return over input costs of 3-year, 4-year, and continuous cropping systems at the WSU Wilke Farm. Costs do not include fixed costs associated with the farm. Means within columns assigned different case letter are significantly different (P<0.10).

A Smartchip for Soil Health

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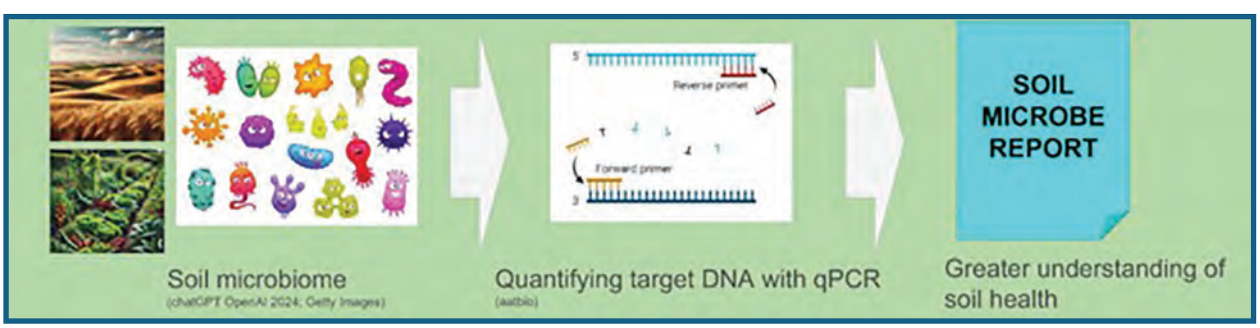
High-throughput, low-cost diagnostics are needed in order to manage soil biology in the interest of soil health. These assays are important to maximize the ability of researchers to understand soil health processes and for farmers to effectively adopt soil health management practices. Across many growing regions of WA, soilborne diseases are a major limitation and given their patchy nature a large number of samples is required to detect their presence in fields. This project will optimize a high-throughput low-cost molecular screen for disease-causing agents, focusing on those relevant to (1) dryland cereal-legume-oilseed cropping systems in E WA and (2) organic production systems in W WA. We focus on the pathogens *Phytophthora, Pythium, Rhizoctonia, Verticillium, Fusarium,* and *Plasmodiophora brassicae*. The platform we are focusing on is the Takara SmartChip, which can run over 5,000 samples at once, allowing a high degree of parallelization as well as completely customizable primer sets that could be expanded to screen for any desired sequence-based marker. Testing is currently underway and we hope to have results to share with the community soon!



Hyperspectral Imaging and Liming Performance Evaluation in Low Soil pH Wheat Production

Kwaku Opuku-Ware[1], Johnny Li[1], Tristan Blain[2], and Kurtis Schroeder[2]
[1]Dept. of Soil and Water Systems, UI; [2]Dept. of Plant Sciences, UI

Aluminum toxicity in wheat plants grown in acidic soils remains a persistent challenge for wheat productions in the Pacific Northwest region. We are investigating whether modern sensing technologies can help evaluate wheat varietal responses to liming amendments in low soil pH conditions in the Palouse region. Our field trials near Lenville, Idaho examined two contrasting winter wheat varieties -- Eltan (aluminum-sensitive) and UI/WSU Huffman (aluminum-tolerant) -- under four different liming rates (0, 1, 2, and 3 tons/acre) with four replications. Using drone-mounted multispectral imaging sensors, we collected NDVI/NDRE vegetation indices and compared these measurements with leaf-level hyperspectral data. Our goal is to determine if these technologies can effectively detect differences in plant response and potentially guide precision liming strategies in acidic soils. Moving forward, our research will focus on three key objectives: (1) Comparing drone-based vegetation indices with ground-level hyperspectral measurements to see which technology better captures plant responses to aluminum stress and liming treatments; (2) Correlating both the drone data and hyperspectral measurements with actual wheat performance metrics (like spike number and yield) to determine which sensing approach is more practical for farmers. (3) Developing methods to distinguish between wheat varieties and different liming treatments using these technologies, which could help farmers make more precise decisions about liming applications. What makes this research valuable for Palouse wheat growers is the potential to use remote sensing to quickly identify aluminum-tolerant varieties and optimize liming applications, saving both time and resources while improving wheat productivity in acidic soil conditions. From a grower's perspective, imagery throughout a whole field will be able to pinpoint areas of highest concern for soil adjustment, maximizing soil improvements in areas where large-scale lime applications are not feasible.

This research is supported by the Idaho Wheat Commission.

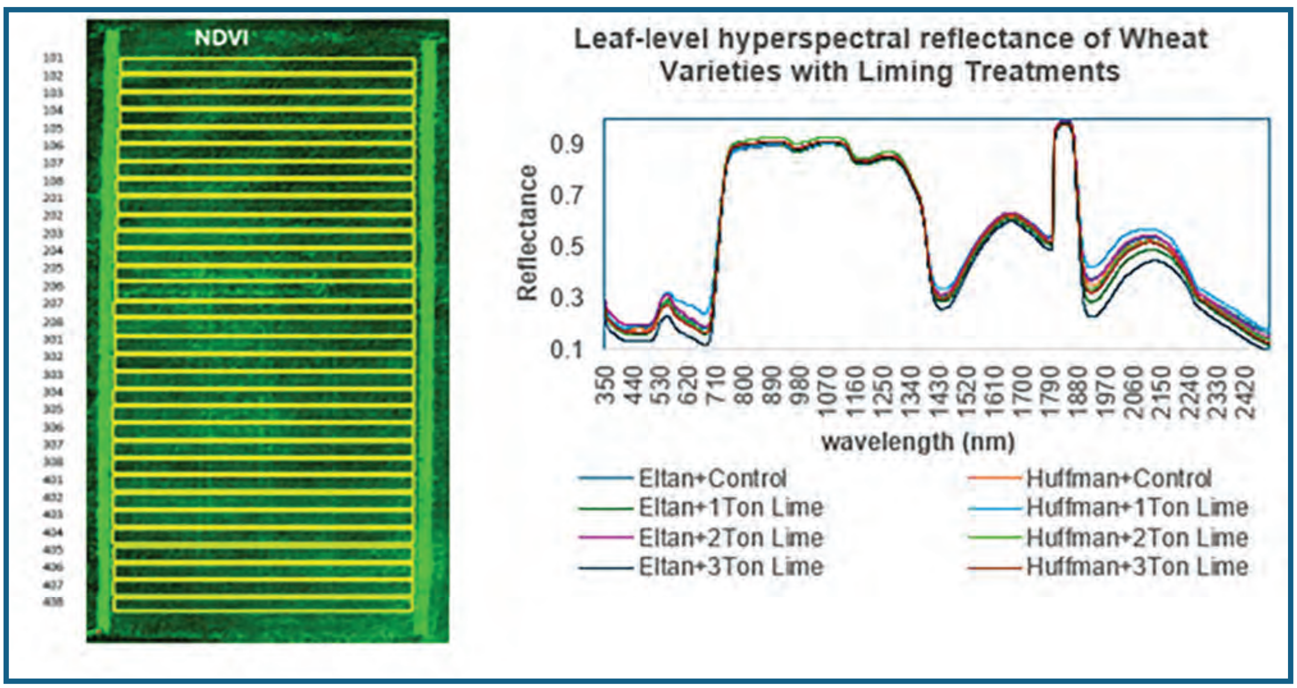


Figure 1. Aerial drone mapping (left) and hyperspectral response (right) of wheat liming.

Evaluating the Impact of the Seed Applied Biofertilizer MycoGold with Variable Fertilizer Rates on Winter Wheat in North Central Oregon

Jacob Powell
OSU Extension

Biological products are increasingly being marketed to the agricultural industry to improve crop nutrient efficiency. Biofertilizers usually do not contain fertilizers, but contain microbes that can increase nutrient cycling and nutrient availability for crops. One biofertilizer product, MycoGold, was examined in soft white winter wheat at the Sherman Experiment Station in Moro, OR in North Central Oregon during the 2023-2024 crop year under five different nitrogen fertilizer rates. MycoGold Wheat Blend is an endomycorrhizal fungi wheat seed treatment produced by MycoGold LLC out of Amelia, OH. It contains two strains of fungi and seven different bacteria strains. It also contains trace amounts of micro and macro nutrients. MycoGold was mixed in with seed packets prior to being seeded with a plot drill. Prior to planting total soil nitrogen averaged 82 lbs per acre. Fertilizer rates included a total of 6, 23, 40, 57, and 74 lbs of nitrogen per acre, including nitrogen from 110 lbs per acre of 16-20-0 (ammonium phosphate) starter fertilizer. Treatments were replicated four times with plots measuring 50 ft by 5 ft. Grain yield, grain quality, soil nutrients, wheat root size and weight, tissue nutrients, NDVI, and economic return on investment were examined. Neither MycoGold or fertilizer rate caused any significant response to grain yield and quality (Fig.1). MycoGold did have a significant impact on soil phosphorus levels, though this did not correlate with increased phosphorus levels in wheat tissue (Fig.2). Tissue nitrogen and nitrogen uptake were almost increased significantly by MycoGold ($p=0.09$ and $p=0.06$). NDVI was significantly correlated with fertilizer rate. Wheat roots were not significantly influenced by fertilizer rate or treatment. MycoGold did not provide a positive return on investment. The results of this research are similar to other research in Canada where most studies do not show a positive return on investment. If producers are interested in using these products they should be cautious and test first on small areas before wide spread use.

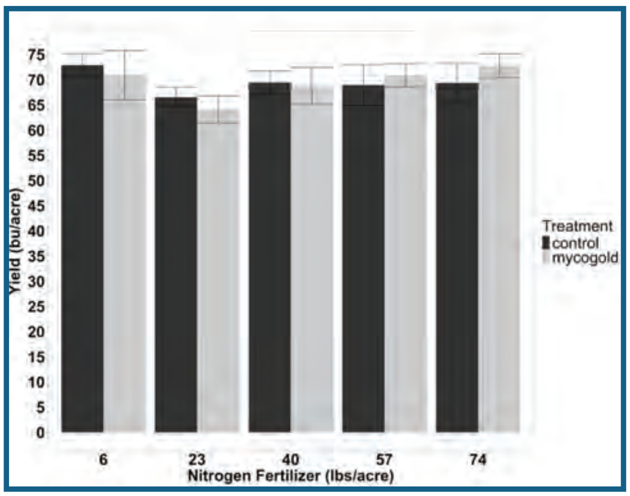


Figure 1. Grain yield for plots with five rates of nitrogen fertilizer with and without MycoGold with 91 lbs of soil nitrogen.

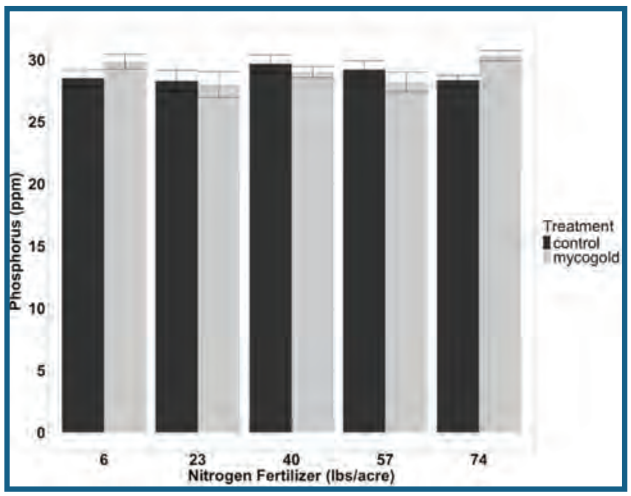


Figure 2. Soil phosphorus in the top foot in plots with five rates of nitrogen fertilizer with and without MycoGold with 91 lbs of soil nitrogen.

Evaluating the Impact of the Seed Applied Biofertilizer MycoGold with Variable Fertilizer Rates on Spring Wheat in Eastern Oregon

Jacob Powell
OSU Extension

Biological products are increasingly being marketed to the agricultural industry to improve crop nutrient efficiency. Biofertilizers usually do not contain fertilizers, but contain microbes that can increase nutrient cycling and nutrient availability for crops. One biofertilizer product, MycoGold, was examined in soft white spring wheat at the Pendleton Experiment Station in Pendleton, OR in Eastern Oregon during the 2023-2024 crop year under two different rates (labeled rate and doubled rate) and three different fertilizer rates. MycoGold Wheat Blend is an endomycorrhizal fungi wheat seed treatment produced by MycoGold LLC out of Amelia, OH. It contains two strains of fungi and seven different bacteria strains. It also contains trace amounts of micro and macro nutrients. MycoGold was mixed in with seed packets prior to being seeded with a plot drill. Prior to planting 69 lbs per acre of nitrogen was added. Starter fertilizer rates included 0, 40, and 80 lbs of 16-20-0 per acre (ammonium phosphate). Plots were 5 ft by 20 ft with each treatment replicated three times using a split plot design. Grain yield, grain quality, soil nutrients, tissue nutrients, and economic return on investment were examined. Yield was significantly increased with the 80 lb per acre rate of 16-20-0 in control treatments in the double rate split plots (Fig.1). Grain protein was significantly lowered by starter fertilizer rate. Soil phosphorus, soil potassium, and soil organic matter were all increased significantly by MycoGold applied at double the suggested rate. Phosphorus and potassium tissue levels were increased significantly by MycoGold at the labeled rate. Despite some significant impacts on soil nutrients and wheat tissue nutrients, MycoGold did not provide a positive return on investment. If producers are interested in using these products they should be cautious and test first on small areas before wide spread use.

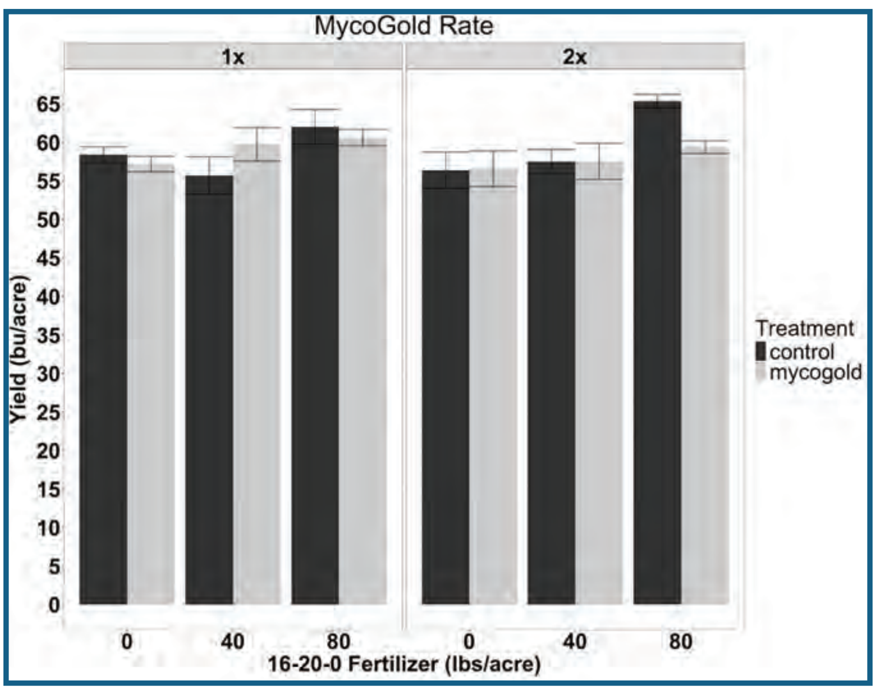


Figure 1. Spring wheat grain yield for plots with three rates of 16-20-0 starter fertilizer with and without MycoGold mixed in with seed at planting with 69 lbs of nitrogen fertilizer applied prior to seeding.

Evaluating the Impact of the Nitrogen Fixing Biofertilizer Utrisha-N Under Variable Fertilizer Rates

Jacob Powell
OSU Extension

Biological products are increasingly being marketed to the agricultural industry to improve crop nutrient efficiency. Biofertilizers typically do not contain any fertilizers, but contain microbes that can increase nutrient cycling and nutrient availability for crops. One biofertilizer product, Utrisha-N, was examined in soft white winter wheat at the Sherman Experiment Station in Moro, OR in North Central Oregon during the 2023-2024 crop year under five different nitrogen fertilizer rates. Utrisha-N is a foliar spring applied commercial product produced by Corteva Agriscience LLC containing a naturally occurring nitrogen fixing bacteria, *Methylobacterium symbioticum*. Prior to planting total soil nitrogen averaged 82 lbs per acre. Fertilizer rates included a total of 6, 23, 40, 57, and 74 lbs of nitrogen per acre, including nitrogen from 110 lbs per acre of 16-20-0 (ammonium phosphate) starter fertilizer. Treatments were replicated 3 times with plots measuring 50 ft by 5 ft. Grain yield, grain quality, soil nutrients, tissue nutrients, NDVI, and economic return on investment were examined to determine the effectiveness of using Utrisha in dryland wheat. Utrisha did not significantly increase yield (Fig. 1), protein (Fig. 2), or test weight, though fertilizer rate significantly increased grain yield and quality. The only soil variable that showed a significant response was potassium, which increased with fertilizer rate. The only nutrients in wheat tissue that showed a significant response was sulfur and calcium. Sulfur levels increased significantly with fertilizer rate and calcium was significantly lowered by Utrisha. NDVI was significantly correlated with fertilizer rate, but not biofertilizers, supporting the lack of response in nutrients in wheat tissue and other examined variables. The results of this research are similar to other research in Canada where most studies do not show a positive return on investment. If producers are interested in using these products they should do test strips first before using on large areas as crop impacts will likely not be economical or may be highly variable.

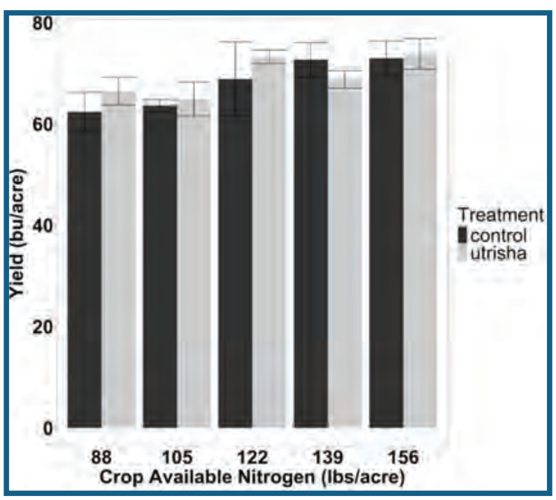


Figure 1. Grain yield for plots with five rates of nitrogen fertilizer with and without the biofertilizer Utrisha with 91 lbs of soil nitrogen.

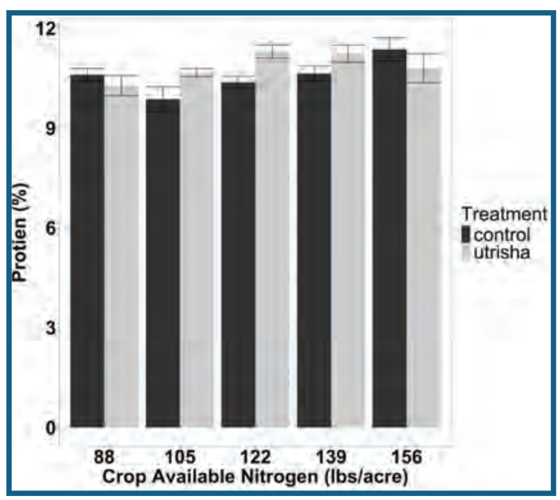


Figure 2. Grain protein for plots with five rates of nitrogen fertilizer with and without the biofertilizer Utrisha with 91 lbs of soil nitrogen.

Evaluating the Impact of the Nitrogen Fixing Biofertilizer Envita Under Variable Fertilizer Rates

Jacob Powell
OSU Extension

Biological products are increasingly being marketed to the agricultural industry to improve crop nutrient efficiency. Biofertilizers typically do not contain any fertilizers, but contain microbes that can increase nutrient cycling and nutrient availability for crops. Most biofertilizer products were initially developed for use in corn and soybeans and have not been investigated as intensively in wheat or in the arid growing regions of the inland Pacific Northwest. One biofertilizer product, Envita, was examined in soft white winter wheat at the Sherman Experiment Station in Moro, OR in North Central Oregon during the 2023-2024 crop year under five different nitrogen fertilizer rates. Envita is a foliar spring applied commercial product produced by Azotic North America LTD containing a naturally occurring nitrogen fixing bacteria, *Gluconacetobacter diazotrophicus*. Prior to planting total soil nitrogen averaged 91 lbs per acre. Fertilizer rates included a total of 0, 12, 29, 43, and 57 lbs of nitrogen per acre, including 75 lbs of 16-20-0 (ammonium phosphate) starter fertilizer. Treatments were replicated 6 times with plots measuring 50 ft by 12 ft. Grain yield, grain quality, soil nutrients, wheat roots, nitrogen tissue concentration, NDVI, and economic return on investment were examined to determine the effectiveness of using Envita in dryland wheat. Grain yield was significantly influenced by fertilizer rate, but not Envita (Fig.1). Both grain protein and test weight increased with fertilizer rate, while protein was significantly lowered with Envita (Fig.2). Envita significantly reduced soil organic matter, but did not impact any other soil nutrients. Envita and fertilizer rate did not impact wheat root size and weight or nitrogen tissue concentration. Drone imagery in early June found that NDVI increased significantly with higher fertilizer rates, but was not impacted by Envita. The best return on investment was the control treatment with 29 lbs of added nitrogen with a total of 120 lbs of crop available nitrogen. Envita failed to provide a positive return on investment. Findings during the 2024 crop year were similar to results from 2023. Farmers should be cautious to test new biofertilizer products on small areas before considering widespread adoption.

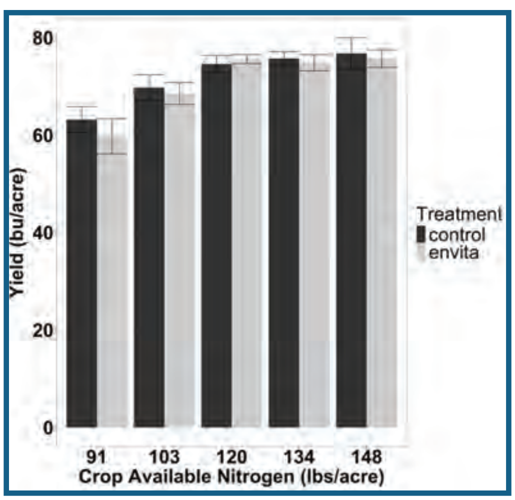


Figure 1. Grain yield for plots with five rates of nitrogen fertilizer with and without the biofertilizer Envita with 91 lbs of soil nitrogen.

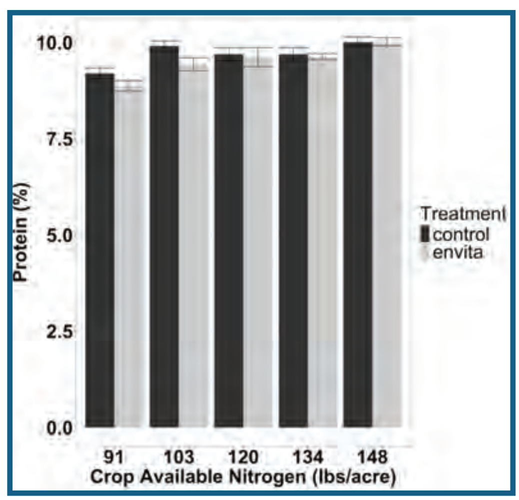


Figure 2. Grain protein for plots with five rates of nitrogen fertilizer with and without the biofertilizer Envita with 91 lbs of soil nitrogen.

Does Spring Wheat Yield Better After Winter Wheat or Winter Pea in the Drylands?

Solomon Amissah, Surendra Singh, Shikha Singh, and Bill Schillinger
Lind Dryland Research Station, WSU

Winter wheat (WW)-fallow (F) remains the predominant cropping system in the low precipitation zone (<12 inches annual precipitation) of the Pacific Northwest (PNW). Despite reliable yields, the lack of diversity makes the WW-F cropping system vulnerable to winter annual weeds, fungal diseases, and other pressures. Increasing crop diversity and implementing crop rotation can help break pest cycles and control weeds. Winter Pea (WP) is a viable alternative to WW in the PNW due to its excellent emergence from deep sowing depths, winter hardiness, and ability to reach physiological maturity before the onset of high temperatures. A 14-year field experiment investigated the performance of two 3-year rotations, WP-spring wheat (SW)-F versus WW-SW-F. The experiment was conducted at the Ron Jirava farm near Ritzville, WA, from 2011 to 2024. The WP and WW were sown in the last week of August or the first week of September. Spring wheat was sown in late March. Fertilizer application was based on the initial nutrient status of the soil. Data collected included grain yield and soil moisture content in early August and in mid-March.

Table 1. Yield of spring wheat following either winter pea or winter wheat.

	Grain yield bu/ac												
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Avg.
WP-SW- F	30	44	16	34	47	33	44	26	45	13	12	12	31
WW-SW-F	32	41	14	25	46	33	42	33	46	9	23	21	32
p-value	0.381	0.051	0.481	0.005	0.377	0.411	0.653	0.130	0.344	0.001	0.048	0.039	0.456

WP-SW-F: 3-year rotation of winter pea-spring wheat-fallow. WW-SW-F: 3-year rotation of winter wheat-spring wheat-fallow.
Within columns, means with different small letters are significantly different at $p < 0.05$.

Grain yields of the 3-year rotation of WP-SW-F and WW-SW-F both varied significantly across years. The yield of SW after WP was significantly higher than SW after WW in 2015 and 2021. Conversely, SW after WW produced the highest yield in 2022 and 2023 (Table 1). The yield of SW after WP ranged from 11.90 to 46.85 bu/ac, whereas the yield of SW after WW ranged from 8.77 to 46.13 bu/ac. When averaged over 12 years, the yield of SW was not significantly different with either WP or WW as the previous crop. The average soil water content in August after harvest was 0.51 inch higher for WP compared to WW ($p < 0.000$) (Table 2). However, there was no significant difference in soil moisture content in mid-March in WP versus WW stubble. The superior overwinter precipitation storage efficiency of WW stubble can be attributed to the reduced residue produced by WP compared to WW. The overwinter precipitation storage efficiency for WP was 47.1 %, while that of WW was 55.5 %.

Table 2. Soil water content after winter pea and winter wheat at time of harvest and in late March, soil overwinter gain and precipitation storage efficiency (PSE).

	Soil water content			
	August (inches)	March (inches)	Overwinter gain (inches)	PSE (%)
Winter pea	5.31 a	9.69 a	4.37 b	47.1
Winter wheat	4.80 b	9.92 a	5.16 a	55.5
p-value	<0.000	0.144	0.000	

PSE: precipitation storage efficiency. Within columns, means with different small letters are significantly different at $p < 0.05$.

The average yield of SW after WW was comparable to that of SW after WW. However, due to ample and upright stubble of WW, it had significantly greater overwinter precipitation storage compared to WP, which produces much less residue. Comparable yields of SW after WP and WW can be attributed to nitrogen fixation of WP leading to the elevated levels of nitrate-N on WP plots vs WW.

Overall, SW yield was slightly more stable after WW compared to SW yield after WP (Table 3). Additionally, results from the partial least squares regression indicate that SW after WW is more temperature-sensitive than SW yield after WP, which is more responsive to rainfall.

Table 3. Stability indices

	CV	Beta	PLS_Temperature	PLS_Precipitation
SW-WP	45.3	1.03	-0.382	0.978
SW-WW	41.2	0.966	-0.538	0.870

CV: Coefficient of Variation. Beta: The Finlay-Wilkinson model explains sensitivity to environmental variability. PLS: Partial Least Squares Regression.

Can Agronomic Biofortification Enhance Wheat Grain Micronutrient Concentration?

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Dept. of Crop and Soil Sciences, WSU

Micronutrients are an important constituent of the human diet and are vital for growth and development. Approximately two billion people in the world face micronutrient deficiency. Agricultural production has been majorly focused on increasing crop yields compromising grain nutritional quality. Agronomic biofortification is an approach to enhance nutrient concentration in crops using agronomic practices. The objective of this research trial was to increase winter wheat and spring field pea grain micronutrient concentration by altering the timing of micronutrient fertilizer application. The winter wheat trial was in Pullman, WA during the 2022-2023 and 2023-24 growing seasons and the spring field pea trial was conducted in Pullman, WA and Davenport, WA in 2024. The study design for both trials was a split plot design with four replicates and comprised three winter wheat varieties (LCS Shine, Purl, and Norwest Duet) and three spring field pea varieties (Hampton, Passion, and Banner). The four fertility treatments were no micronutrient fertilizer application, micronutrient fertilizer soil applied at planting, spring topdressing of micronutrient fertilizer near jointing, and foliar application of micronutrient fertilizer at heading stage. Grain micronutrient concentration was analyzed using Agilent MP-AES 4200 (Agilent Technologies, Santa Clara, CA, USA). The winter

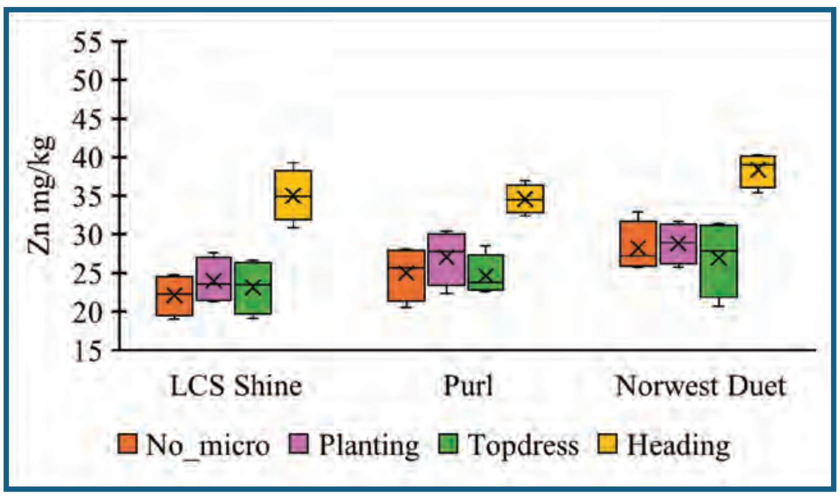


Figure 1. Graph showing grain Zn concentration of LCS Shine, Purl, and Norwest Duet soft white winter wheat varieties for four different micronutrient application timing treatments in 2023-24. The means followed by different uppercase letter are significantly different from each other (p<0.05).

wheat trial results indicated the micronutrient fertilizer application treatment had no significant impact on winter wheat grain yield, though variety was significant ($p=0.003$ in 2023, $p<0.0001$ in 2024). Soil application at planting and topdressing of micronutrient fertilizer did not translate into enhanced grain micronutrient concentration in both 2022-23 and 2023-24. However, micronutrient fertilizer application at heading stage resulted in higher grain micronutrient concentration. The grain zinc concentration was significantly impacted by micronutrient fertilizer application treatment ($p=0.036$ in 2023, $p<0.0001$ in 2024) and variety ($p=0.007$ in 2023, $p=0.0005$ in 2024) (Fig.1). In conclusion, foliar application of micronutrient fertilizer at heading stage can enhance winter wheat grain micronutrient concentration.

Compost Teas for Enhanced Nutrient Cycling

Lynne Carpenter-Boggs[1], Maren L. Friesen[2], Carol McFarland[1], Hanna Delgado[2], and Syed Hamid[1]
[1]Dept. of Crop and Soil Sciences, WSU; [2]Dept. of Plant Pathology, WSU

With increasing fertilizer and fuel costs, producers are increasingly keen to improve on-farm nutrient cycling through biologically intensive methods. Currently, poor plant-soil-microbe interactions do not support healthy nutrient flow, which limits crop yield and favors fertilizer-dependent farming. Slow residue breakdown also inhibits direct seeding adoption and adherence since heavy residue at seeding time impedes direct seeding and may inhibit seedling emergence. The use of compost teas might address all of these goals while increasing economic, environmental, and social sustainability.

Compost tea trials brewing in the Carpenter-Boggs lab at WSU.

Our team will conduct on-farm interviews of growers who use compost tea to document current practices and grower observations. We will collect samples of farm-brewed teas and previously researched lab-brewed teas and characterize their chemical makeup and microbial communities. Lab studies will determine effects of teas on residue breakdown rate and nutrient availability, two producer driven goals.

Anecdotal conversations support that growers appreciate the empowerment, and decreased dependence that comes along with producing more of their own inputs and that for many it would create feelings of pride in stewarding their land in alignment with their conservation goals. Decreasing the use of synthetic inputs and increasing conservation practices can result in increased marketing opportunities that have the potential to command a price premium resulting in more sustainable on-farm economics.

Cooperators: Clay Erskine, Brentley Uhlorn, Darrel Uhlorn (Uhlorn Family Farms), Sheryl Zakarison, Douglas Poole, Greg Friedstads, Lindsay Myron, and Jesse Bruner are producers who have used compost teas or are highly interested.

Straw ready for residue decomposition experiment.

Short-Term Effects of Cover Crops on Winter Wheat Yield and Protein Content in Dryland Cropping System

Gena Mahato[1], Curtis B. Adams[2], Rachael Plunkett[1], Surendra Singh[3], Judit Barroso[1], Stephen Machado[1], Grayson Namdar[1], Ryan Graebner[1], Nicole Durfee[2], Francisco Calderon[1], Catherine L. Reardon[2], and Christina Hagerty[1]
[1]Columbia Basin Agricultural Research Center, OSU; [2]USDA-ARS Columbia Plateau Conservation Research Center; [3]Lind Dryland Research Station, WSU

Dryland cropping systems of the Pacific Northwest (PNW) are challenged by limited precipitation, loss of soil organic matter, and weed and soilborne disease pressures. The Resilient Dryland Farming Alliance (RDFA) is a research collaboration aimed at providing viable solutions to the issues threatening the sustainability and profitability of dryland cropping system of the PNW. A current focus is integrating cover crops in winter wheat – fallow rotation to improve nutrient cycling, soil health, soil water infiltration, and weed suppression.

Cover crops offer several ecological benefits that may influence subsequent cash crop yield and quality, yet their effect on winter wheat yield and seed quality remain underexplored in the dryland cropping systems of the PWN. This study evaluated the impact of three fall-planted and six spring-planted cover crops and a fallow control on subsequent winter wheat yield and grain protein content, among other variables. The trial was set up at two locations in northeastern Oregon — Adams (16 inches annual precipitation) and Lexington (9 inches annual precipitation). Cover crops were planted in crop years 2021 and 2022, and winter wheat was planted in following crop years in 2022 and 2023.

Cover crops had significant effect on winter wheat yield with significant location × cover crop interactions, indicating variable cover crop effect across locations. Cover crops resulted in similar yield compared to fallow control at Adams (Fig. 1). On the other hand, winter pea and fall mix cover crops resulted in lower yield than fallow control at the drier Lexington site, though the remaining cover crops had no detectable effect (Fig. 1). Grain protein content was influenced by location × cover crop and year × cover crop interactions. In 2022, winter wheat grain protein was similar following all cover crops and the fallow control at both sites (Fig. 2). At Adams in 2023, winter wheat grain protein was higher following yellow mustard compared to fallow control. At Lexington in 2023, winter wheat grain protein was higher following winter pea than fallow, while grain protein was similar among all remaining cover crops and fallow. It is noteworthy that cover crop biomass production was low across all site-years except for winter pea and fall mix at Lexington in 2022.

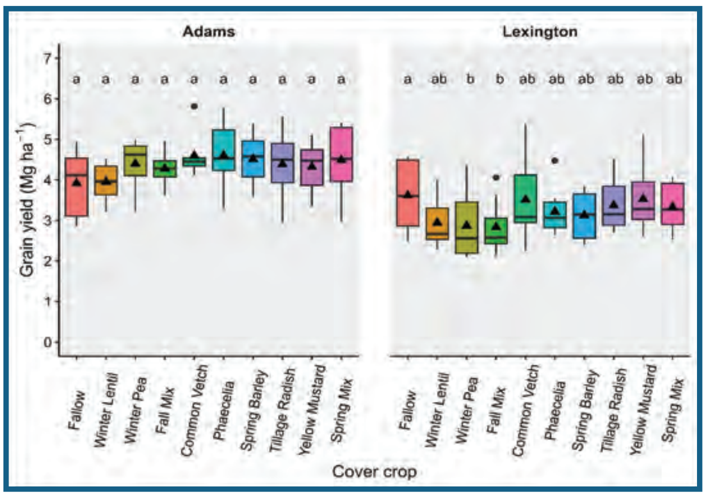


Figure 1. Yield of winter wheat following various cover crops and fallow at Adams and Lexington, OR. The data is averaged across two years (2022 and 2023). The horizontal line and triangle within the boxplot indicate the median and mean values, respectively. The lowercase letters above each box indicate statistical differences, with treatments given the same letter being statistically the same.

The effect of cover crops on subsequent wheat yield depends on precipitation, but any positive or negative effects we observed were subtle. The decision to integrate cover cropping into the fallow phase should be based on multiple factors, including various impacts on soil. More details about the research project can be found at following link: https://agsci-labs.oregonstate.edu/cerealpathology/resilient-dryland-farming-alliance/

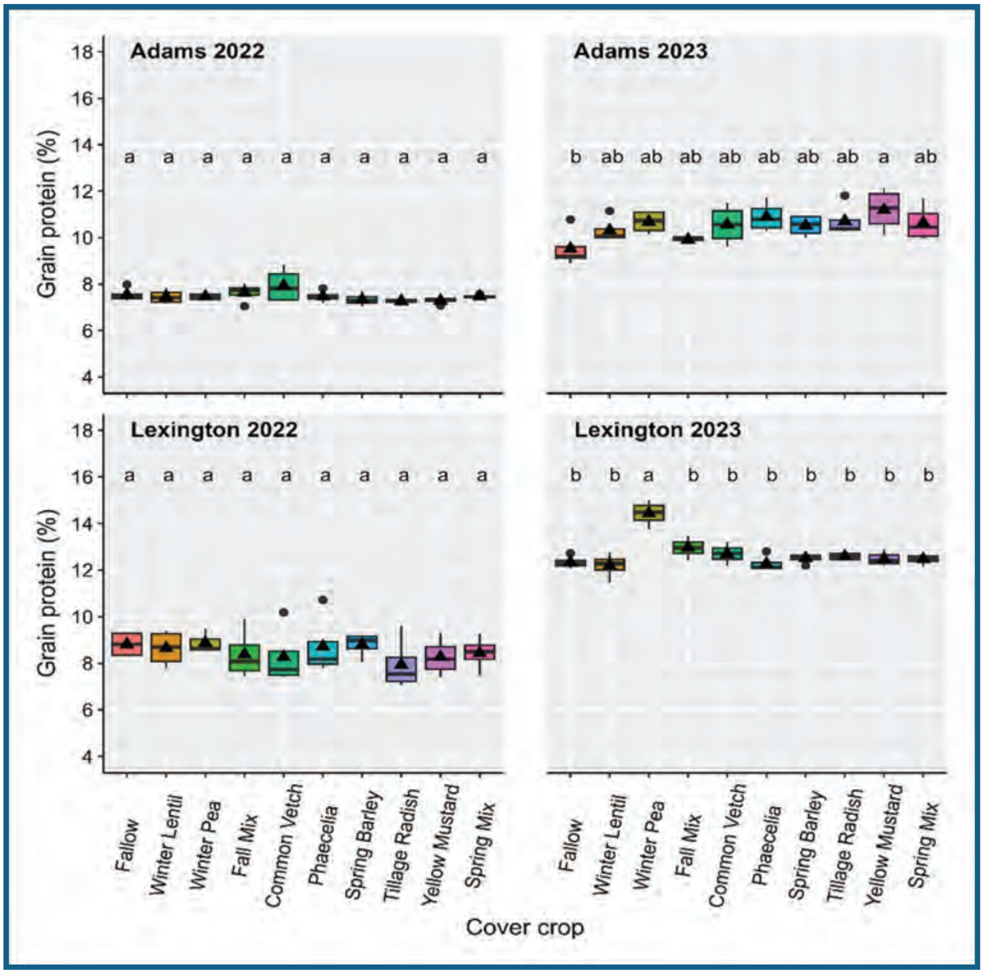


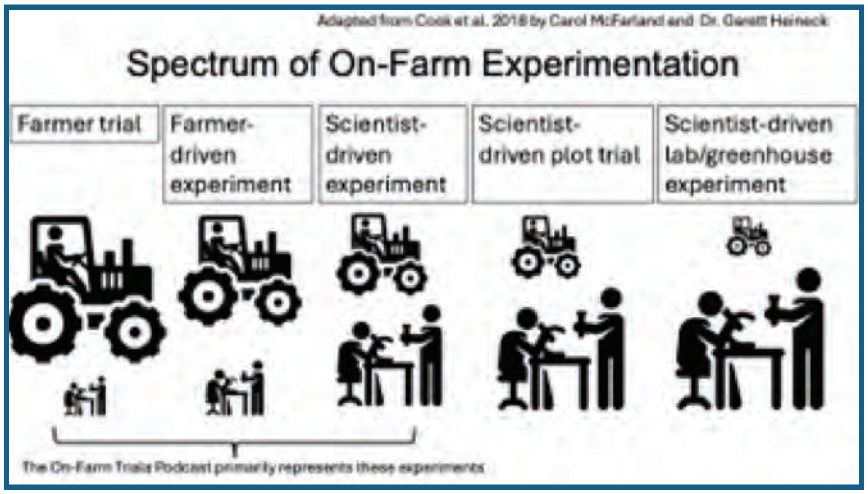
Figure 2. Grain protein concentration in wheat following various cover crops and fallow in 2022 and 2023 at Adams and Lexington following cover crops. The horizontal line and triangle within the boxplot indicate the median and mean values, respectively. The lowercase letters above each box indicate statistical differences, with treatments given the same letter being statistically the same.

Table 1. List of cover crops treatments used in the trial.

Seeding time	Cover crop
Fall-planted	Winter lentil
	Winter pea
	Fall mix (consisted of winter barley, Austrian pea, and yellow mustard)
Spring-planted	Common vetch
	Phacelia
	Spring barley
	Tillage radish
	Yellow mustard
	Spring mix (consisted of Austrian pea, yellow mustard, spring barley, phacelia, tillage radish, and common vetch)

Exploring On-Farm Experimentation in the iPNW with The On-Farm Trials Podcast

Carol McFarland[1], Carlos Flores[1], and Dave Huggins[2]
[1]Washington State University; [2]USDA-ARS



The On-Farm Trials Podcast is a collaborative effort being conducted by the PNW Farmers' Network to explore and highlight on-farm experimentation and cropping system innovation within the agricultural community of the inland Pacific Northwest(iPNW). The podcast highlights a compendium of case studies showcasing producers and the 'what, how, and why' of getting the most out of on-farm trials in rain-fed grain production. The featured interviews from this project cover a spectrum of on-farm experimentation from 'farmer-led trials' to those done in association with researchers or other partners. Emergent themes in this work include soil health and conservation, crop and market diversification, increasing the efficiency of inputs, and innovation as a tool in adapting to changing environmental, social, and economic conditions. The podcast is available through the PNW Farmers' Network website and on all podcasting platforms. The audience for this work is predominantly in eastern Washington, north Idaho, and northeastern Oregon, continues to grow, and is cross-cutting throughout sectors of the agricultural community.

Evaluation of Lime Requirement for Acidic Soil from Inland Pacific Northwest

Bishal Lamsal[1], Deepanjan Mridha[1], Cawayne B. Bryan[1], Joaquin Casanova[2], Richard T. Koenig[1], and Joao A. Antonangelo[1]
[1]Dept. of Crop and Soil Sciences, WSU; [2]USDA-ARS Northwest Agroecosystem Research Unit

Soil acidification affects nearly 40% of the global arable land and around 30% of farmlands in Washington (WA) state. While natural factors like high precipitation contribute to soil acidification, anthropogenic influences largely accelerate this process. The use of nitrogen (N) fertilizer is one of the major contributors. Hydrogen ions are released into the soil during nitrification of N fertilizers, causing soil acidification. One of the major impacts of low pH in the soil is that it solubilizes aluminum (Al). High Al concentration in soil negatively impacts root development and nutrient uptake, ultimately affecting plant growth and yield. However, the issue of soil acidification and Al toxicity can be alleviated with the help of lime ($CaCO_3$).

An incubation experiment was performed with soil collected at a 0-6 inch depth from Rockford, WA, a dryland agricultural area in eastern Washington. The experiment aimed to study the soil pH response to increasing lime rates. The collected soils were air-dried, passed through a 2 mm sieve, and treated with six lime rates (0, 0.5, 1, 2.5, 5, and 10 t/acre) with three replications per treatment. Each pot containing 200 g soil was maintained at 70% field capacity, which compares to typical winter-spring soil moisture, given that the annual precipitation of Rockford is 16.7 inches, with nearly 70% occurring in winter to spring. The lime used was ground very fine, and the pH was measured after 9 days of incubation. Despite its high solubility, in the farmlands, the original paletted lime should be applied a few months (4-6) before the crop cultivation to fully ameliorate the pH.

A regression model was used to analyze the response of soil pH to the lime application (Fig. 1). The model, with a strong R2 value, suggests that increasing the lime rate initially increases the soil pH, but the effect plateaus at a certain threshold lime rate (5.11 t/ha = 2.27 t/acre) with a pH value of 6.37. The model also demonstrates that to get the desired soil pH, farmers need to apply only a certain amount of $CaCO_3$, and applying beyond that point might yield diminishing results since lime is costly. Beyond pH adjustment, the lime application significantly reduced the Al concentration while increasing sulfur (S) availability (Fig. 2). The results are particularly beneficial for canola cultivation, as it almost always requires S. In our study, the S came from the lime coating itself.

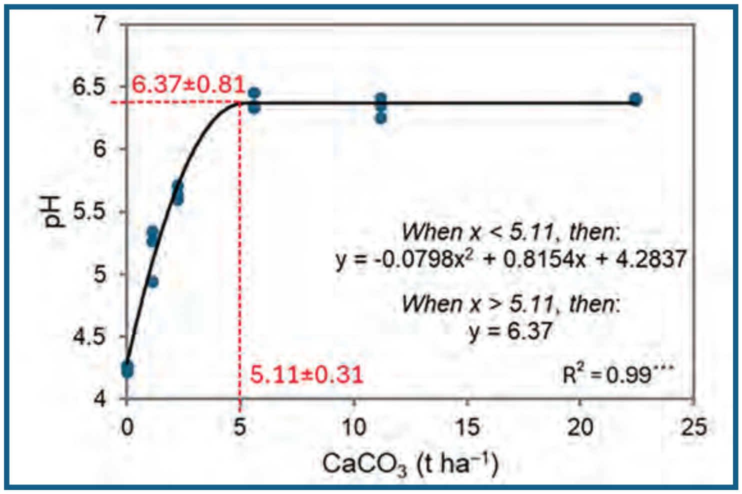


Figure 1. Segmented quadratic-with-plateau regression model (1 t/ha ≈ 0.446 tons/acre).

Since lime requires water to react with the soil effectively and given the dryland agricultural area, incorporating the lime is the best idea. Our incubation experiment showed a rapid lime response (within 9 days) in thorough mixing, mirroring the field scale incorporation in tilled agricultural systems. However, fall application can leverage the winter precipitation and allow for a longer soil-to-lime contact, facilitating lime movement and effective interaction with the soil, even at no-till systems.

The authors are thankful for the financial support provided by the Washington Oilseed Cropping System to conduct this project.

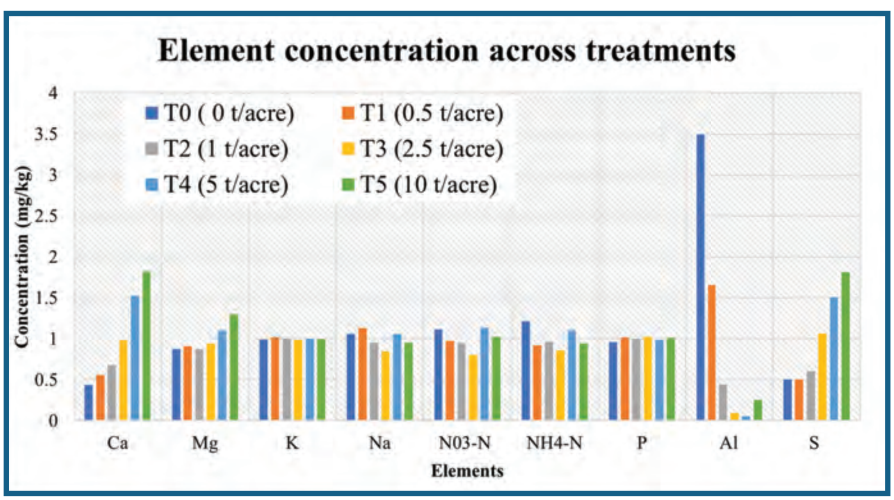


Figure 2. Soil nutrients and Al response to increasing lime rates treatment. Each measurement was normalized by dividing it by the average value of the entire dataset to illustrate trends in soil chemical attributes.

Building Resilient Soils: Insights from Long-Term Field Data and Climate Scenario Modeling in Eastern Oregon

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The potential for enhancing carbon (C) storage in dryland croplands remains an active research focus, with limited data on long-term retention under conservation practices. This study assesses soil C sequestration and stabilization following legume integration in the traditional wheat systems in Eastern Oregon. Using long-term experiments at CBARC, we compared conventional tillage (CT) winter wheat–summer fallow (WW–SF) with winter wheat–spring pea (WW–SP) rotations under CT and no-till (NT). Total C and mineral-associated organic matter (MAOM) were measured in samples from the WW-SF system collected in 1976-1977 and 2015-2016, while those from the WW-SP system were collected in 1985 and 2021. Simulations using the DayCent model under moderate (RCP 4.5) and high-emissions (RCP 8.5) climate scenarios projected long-term soil C dynamics. Results showed annual soil carbon gains of 0.15 t C ha^{-1} yr^{-1} under CT WW-SP and 0.16 t C ha^{-1} yr^{-1} under NT WW–SP cropping systems and soil carbon loss of -0.11 t C ha^{-1} yr^{-1} under CT WW-SF in the 0-30 cm bulk soil fraction. MAOM followed a similar trend with gains of 0.03 and 0.07 t C ha–1 yr–1 under CT and NT WW-SP, respectively, in the 0-30 cm soil depth profile. Under CT WW-SF, MAOM showed a loss of -0.28 t C ha^{-1} yr^{-1}. These findings demonstrate the susceptibility of WW–SF systems to carbon losses while demonstrating that legume-based rotations not only enhance overall soil carbon levels but also promote the accumulation of stable, long-lasting carbon (MAOM). In addition, there are few differences between CT WW-SP and NT WW-SP in terms of bulk SOC and MAOM. This indicates that cropping intensity has a more significant impact on soil organic carbon (SOC) accumulation than tillage. CT and NT influence SOC distribution, but the total in the 30 cm soil depth profile is almost the same.

Table 1. Annual soil C sequestration rates (t C ha^{-1} yr^{-1}) in bulk soil and MAOM (0–30 cm) under CT WW–SF, CT WW–SP, and NT WW–SP systems.

	CT WW–SF		CT WW–SP		NT WW–SP	
Depth	Bulk soil	MAOM	Bulk soil	MAOM	Bulk soil	MAOM
cm	t C ha^{-1} yr^{-1}	t C ha^{-1} y^{r} 1	t ha^{-1} yr^{-1}	t C ha^{-1} yr^{-1}	t ha^{-1} yr^{-1}	t C ha^{-1} yr^{-1}
0–10	-0.13 ±0.03	-0.17±0.03	0.02±0.04	-0.05±0.03	0.11±0.04	0.00±0.03
10–20	0.00±0.03	-0.06±0.03	0.08±0.04	0.04±0.05	0.01±0.02	0.02±0.02
20–30	0.02±0.02	-0.02±0.02	0.05±0.06	0.05±0.04	0.04±0.05	0.04±0.01
0–30	-0.11	-0.28	0.15	0.03	0.16	0.07

To further examine long-term impacts under changing climate conditions, we used the DayCent model to simulate soil carbon dynamics across contrasting scenarios. Results indicate that NT WW–SP systems demonstrated greater resilience and a more substantial capacity to mitigate carbon losses under the moderate RCP 4.5 scenario compared to WW–SF systems (Fig. 1). Under the high-emissions RCP 8.5 scenario, however, the effectiveness of NT practices declined due to increased climate variability—such as erratic rainfall, temperature extremes, and drought—which can accelerate decomposition and reduce biological inputs. These findings emphasize the need to investigate alternative adaptive strategies, including cover crops, organic amendments, and drought-resilient rotations, especially under heightened climate stress. While long-term field data and simulations affirm the benefits of NT WW–SP for soil resilience and carbon storage, maintaining these gains under extreme scenarios will require more comprehensive conservation approaches.

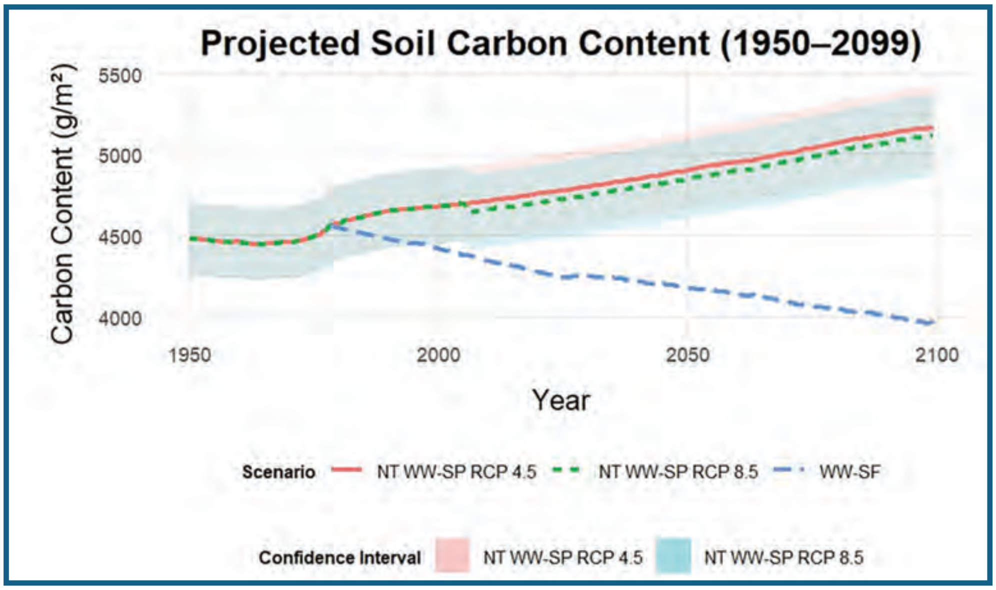

Figure 1. Projected soil carbon content (g/m²) from 1950 to 2100 under two climate scenarios—RCP 4.5 and RCP 8.5—for NT WW–SP and CT WW–SF cropping systems. This figure illustrates how future climate trajectories may shape soil C dynamics, emphasizing the critical need for proactive and adaptive management strategies in dryland agricultural regions.

Employing 'Soil to Society' Approach for Sustainable Agriculture in the Palouse

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The Palouse is a unique geographical region located in the northwest part of the United States. It is characterized by rolling hills, highly productive soils, and one of the most productive dryland wheat growing areas in the world. However, agricultural production in the Palouse is challenged by several soil conservation and agronomic challenges such as soil acidification, limited water availability, decreasing soil organic matter content, soil erosion, and runoff. Soil to Society is a unique approach designed to track the flow of nutrients from soil to the human diet to develop a sustainable food production system. It is an interdisciplinary pipeline that aims to prioritize both soil and human health. To achieve agronomic sustainability, it is crucial to optimize crop production and soil management to produce nutritionally dense crops. The objective of this research project is to understand how cropping system and soil management practices affect crop nutritional quality and soil health metrics. A field trial started in fall 2021 at the Palouse Conservation Field Station (PCFS) in Pullman, WA. Pullman has a mediterranean climate with a mean annual precipitation of 533 mm and soil pH of 5.3. The trial consists of a winter wheat (Triticum aestivum) - spring barley (Hordeum vulgare) - spring field pea (Pisum sativum) crop rotation and comprised of a strip plot randomized complete block design (RCBD) with four replicates. The treatments include 1) Conventional till + no lime + no residue (CT-

NL-NR), 2) No-till + lime + no residue (NT-L-NR), 3) No-till + lime + residue (NT-L-R), 4) No-till + no lime + no residue (NT-NL-NR), and 5) No-till + no lime + residue (NT-NL-R). The soil samples are analyzed for physical, chemical, and biological parameters including macronutrients, micronutrients, soil pH, soil bulk density, soil organic matter, wet aggregate stability, saturated hydraulic conductivity, mineralizable carbon, permanganate oxidizable carbon, phospholipid fatty acids, and soil enzymes. Crops are analyzed for grain and biomass yield, grain test weight, grain protein content, and grain nutrient concentration. The results indicated an increase in soil pH from <5 to 6.1 in 0-7 cm soil depth in lime application treatments and the pH was highly stratified in 0-7 cm soil depth (Fig.1). Soil organic matter content showed a consistent trend downward in the top 0-7 cm across all treatments, though differences were only significant for CT-NL-NR and NT-NL-NR (7 g/kg decline for both). The percentage of Arbuscular Mycorrhizal Fungi and gram-positive bacteria were significantly impacted by treatment (p-values 0.004 and 0.0001, respectively) and crops (p-values <0.0001 and 0.024, respectively (Fig.2)). No significant difference was observed between treatments for crop yields and grain protein content, so the growers in the Palouse may be able to transition to conservation agricultural practices without inflicting a yield penalty.

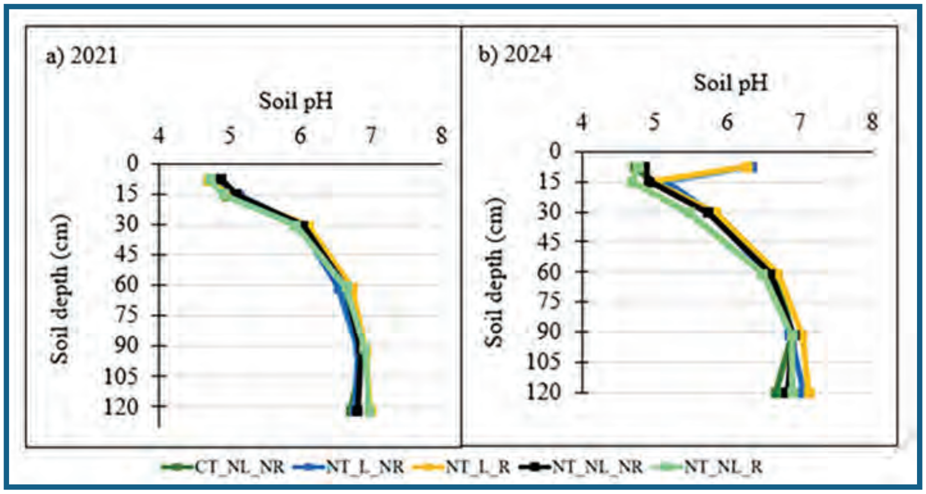

Figure 1. Graphs showing the variation of soil pH for a) 2021 and b) 2024 with soil depth (0-120 cm) for Conventional till + no lime + no residue (CT-NL-NR), No-till + lime + no residue (NT-L-NR), No-till + lime + residue (NT-L-R), No-till + no lime + no residue (NT-NL-NR), and No-till + no lime + residue (NT-NL-R) treatments.

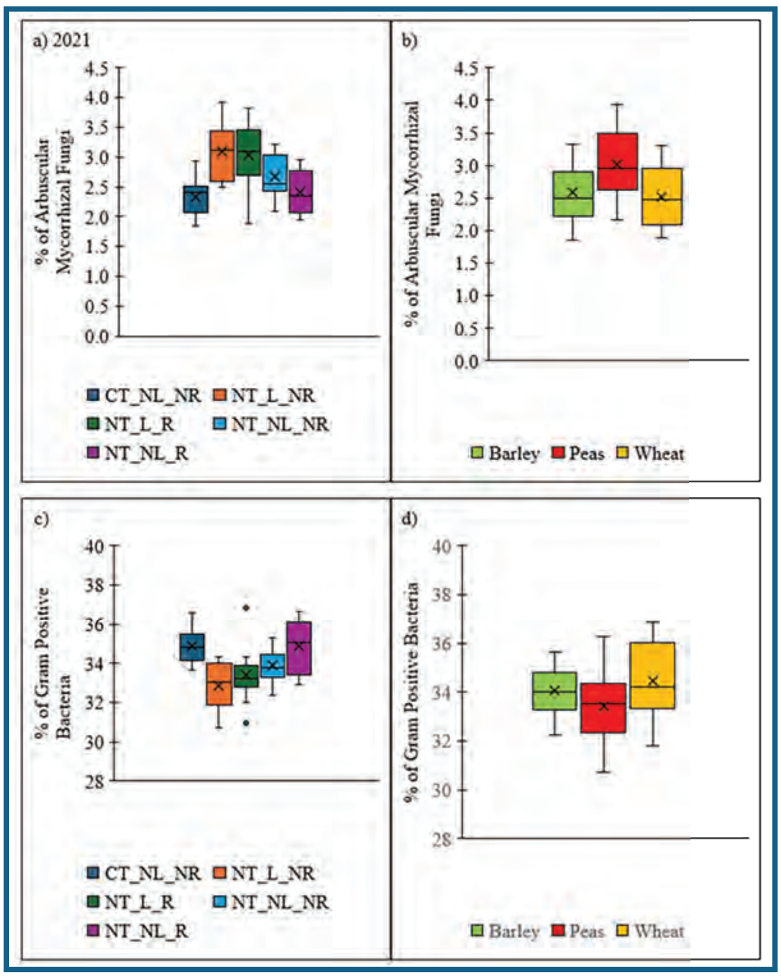

Figure 2. Graphs showing variation in the a) percentage (%) of Arbuscular mycorrhizal fungi with treatments, b) percentage (%) of Arbuscular mycorrhizal fungi with crops, c)) percentage (%) of Gram-positive bacteria with treatments, and d) percentage (%) of Gram-positive bacteria with crops.

Advancing Dryland Spring Wheat Yield Prediction using High-Resolution Satellite and Weather Data using Long-Term Trial

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Crop rotations and environmental factors significantly influence wheat productivity, yet their combined effects on yield prediction using satellite-based vegetation indices remain understudied, especially for the dryland region of eastern WA. This research investigates how different crop rotations affect spring wheat yield and evaluates the accuracy of satellite-based vegetation indices in predicting yields across growing seasons (2017–2024) and rotations. The study was conducted by leveraging an ongoing long-term crop rotations trial at Ron Jirava Farm Near Ritzville, WA. This trial was initiated in 1997 and consisted of six different crop rotations: (i) Tilled fallow-winter wheat-spring wheat (TF-WW-SW), (ii) Winter canola-spring wheat-chemical fallow (Canola-SW-CF), (iii) Chemical fallow-winter triticale-spring wheat (CF-WT-SW), (iv) Continuous spring wheat (Cont. SW), (v) Tilled fallow-winter wheat (TF-WW), and (vi) Spring barley-spring wheat (SB-SW). The analysis integrated vegetation indices with weather parameters (precipitation, temperature, solar radiation, and humidity) collected at ten time points from March to August each year. Results showed that spring wheat in CF-WT-SW rotation produced the highest yields throughout the years of study, while Canola-SW-CF yielded the lowest, highlighting the importance of rotation selection in spring wheat production systems. Vegetation indices measured from early June (heading stage) through late July (maturity stage) demonstrated the strongest correlations with yield, with predictive accuracy improving as more years of data accumulated, capturing more significant variability in both yields and vegetation indices. Predictive modeling using linear regression and machine learning algorithms, such as the random forest and the extreme gradient boosting, demonstrated that integrating vegetation indices with weather variables outperformed models based on vegetation indices alone. The machine learning approaches provided superior yield predictions compared to linear regression, particularly when using vegetation indices alone. Vegetation indices have a complex, nonlinear relationship with yield that machine learning models can capture effectively. In contrast, weather variables like rainfall usually have a direct linear relationship with yield. Integrating vegetation indices with weather data enables machine learning to leverage both nonlinear relationships and direct patterns. Although the advantage of machine learning is slightly reduced with weather data included, the integration still yields strong predictions. This difference may occur from the uniformity of weather data across plots, while vegetation indices provide plot-specific variability, which provides more accurate predictions at the plot level. This research underscores the value of integrating remote sensing technology with environmental data to enhance yield prediction accuracy across diverse growing seasons and farming practices. These findings give growers practical insights into

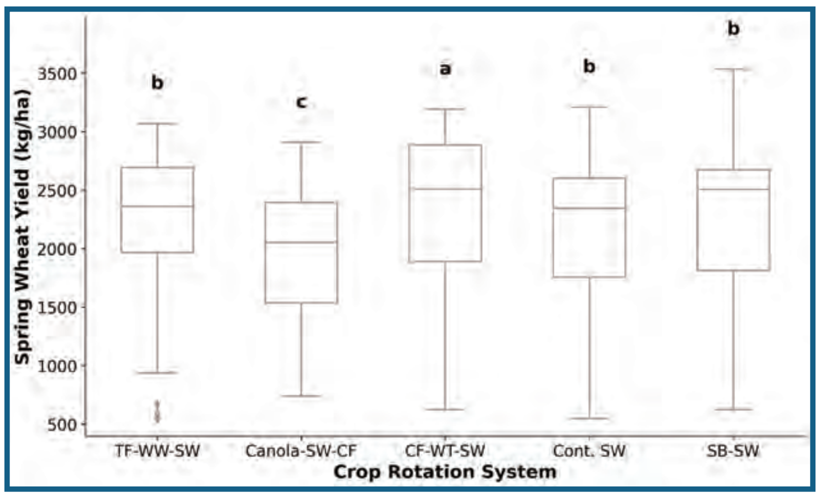

Figure 1. Mean differences in spring wheat yield compared among crop rotation systems across years.

implementing optimal rotation systems and help researchers develop more robust predictive tools. Future work will refine feature selection, optimize models, and conduct temporal validation to improve prediction reliability across variable growing conditions.

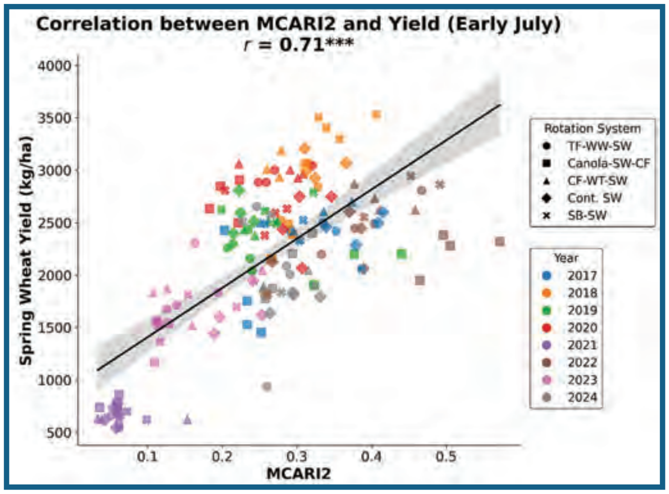

Figure 2. A sample of a strong relationship between the vegetation index and spring wheat yield, with the MCARI2 showing the highest correlation to yield in early July.

Table 1. Predictions of spring wheat yields present the top five best features and time points for each model.

Model	Time Point	Feature	Training Dataset			Testing Dataset		
			Single VI	Weather Variables	VI + Weather	Single VI	Weather Variables	VI + Weather
Linear Regression	Late June	GNDVI	0.37	0.80	0.80	0.46	0.84	0.84
	Late June	MCARI2	0.34		0.81	0.46		0.85
	Late June	NDVI	0.33		0.80	0.45		0.84
	Late June	NDWI	0.37		0.80	0.46		0.84
	Early July	MCARI2	0.51	0.66	0.75	0.49	0.68	0.77
Random Forest	Early July	CIGreen	0.61	0.81	0.90	0.66	0.88	0.85
	Early July	EVI	0.69		0.90	0.66		0.86
	Early July	LAI	0.69		0.90	0.66		0.86
	Early July	MCARI2	0.71		0.87	0.69		0.87
	Early July	WDRVI	0.61		0.90	0.65		0.85
Extreme Gradient Boosting	Early July	EVI	0.70	0.81	0.88	0.64	0.87	0.86
	Early July	EVI2	0.76		0.89	0.62		0.85
	Early July	LAI	0.70		0.88	0.64		0.86
	Early July	MCARI2	0.77		0.89	0.69		0.87
	Early July	SR	0.71		0.88	0.63		0.85

Role of Nitrogen-Fixing Bacteria in Wheat-Based Cropping Systems: Implications for Plant and Soil Health

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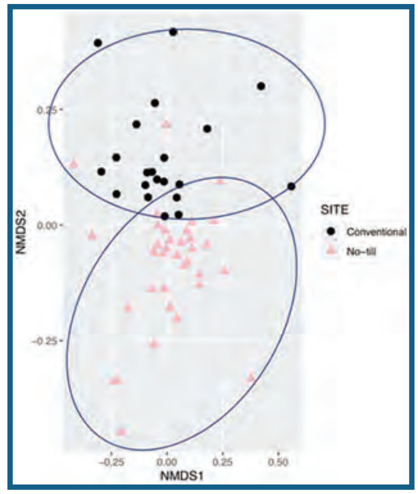
Biological nitrogen fixation (BNF) is a natural process whereby nitrogen-fixing bacteria convert atmospheric dinitrogen (N_2) into a usable form for plants. The efficiency and distribution of nitrogen-fixing bacteria can be influenced by various management practices. This study investigates the effects of two contrasting tillage systems–conventional tillage vs no-till–on the nitrogen-fixing bacterial communities within a wheat-based cropping system at the Cook Farm LTAR (Long-Term Agroecosystem Research). We find that no-till and conventional tillage systems each harbor distinct diazotrophic communities, with the relative abundance of nitrogen-fixing bacteria differing significantly between these systems. Bradyrhizobiaceae and Rhodocyclaceae were more abundant in no-till soils, while Spirochaetaceae and Methylocystaceae dominated conventional tillage soils. Interestingly, conventional tillage soils exhibited significantly higher species richness. We also saw a positive correlation between certain bacterial families and soil health indicators, such as organic matter content, plant available nitrogen, and the Haney Soil Health Score. These findings emphasize the need to consider soil microbial communities, particularly nitrogen-fixing bacteria, when evaluating agricultural management practices. Understanding these relationships can help guide more sustainable farming practices that promote plant and soil health and optimize nitrogen cycling.



Diazotroph communities differ between conventional and no-till fields at the Cook Farm LTAR.

Living Mulch and Grazing Techniques to Improve Soil Health and Weed Control for Farmers Transitioning to Organic Farming Across Climatic Zones

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Lind Dryland Research Station, WSU

The demand for organic food and areas under organic production have exponentially grown in the last few years. While organic products fetch premium prices, conversion of conventional farms to an organic system also helps prevent soil degradation and enhance soil health. However, the rate of this conversion is lower among growers due to yield gaps, economic and sustainable nitrogen sources, and weed management strategies. In the inland Pacific Northwest (iPNW), where winter wheat is the major crop, the suitability of its organic production is less explored, especially during the transition phase from conventional to organic systems. A four-year study was initiated in 2024 in Adams, Oregon to determine the feasibility of organic production of winter wheat using leguminous living mulch and grazing strategies to provide N and better weed control. However, the utilization of perennial cover crops as living mulch remains a challenge, owing to the lack of sufficient information on the intercropping ability of different cover crop species and establishment methods for wide geographical regions in the U.S. Therefore, similar studies were also initiated in Southeastern and Northeastern United States to investigate the same in different climatic zones The trial in Adams, Oregon is led by researchers from WSU and OSU in which we are looking at the impacts of living mulch and integrated livestock grazing on crop and livestock performance along with soil health and carbon sequestration. The treatments include (i) Aberlasting clover (perennial) with grazing/no grazing (ii) Red clover (annual) with grazing/no grazing (iii) cover crop mix (75% pea, 12.5% oats and 12.5% triticale) with grazing/no grazing, and (iv) no living mulch, no grazing (control). In this study, we are looking at crop and livestock performance, soil health and carbon sequestration, and weed management. We will be creating educational materials and disseminate the findings to growers and stakeholders. Soil health will be analyzed through a suite of soil physical, chemical and biological attributes including soil organic carbon (SOC), wet aggregate stability (size distribution and stability), potential of C mineralization and microbial community structure, and soil nutrient status. The total carbon fluxes from the soil surface will always be recorded throughout the summer. Additionally, we will be monitoring weed population and management, due to the increased difficulty managing weeds in organic cropping systems. This experiment was initiated in 2024 and is currently in progress. We anticipate a beneficial increase in the soil health indicators above with these organic practices being implemented.

Figure 1. Plots on date of fall soil sample (2024/09/26).

Predicting Soil Available Nutrients Using Portable XRF (pXRF) Technology in Dryland Soils from the Inland Pacific Northwest

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Conventional soil testing protocols are widely accepted worldwide and considered generally accurate. Precision agriculture provides detailed information on the spatial variability of soil properties, including nutrient content, allowing for local-specific decision making. Portable X-ray fluorescence (pXRF) spectrometry can quantify several elements of the periodic table in seconds. Elements determined by pXRF have been used to predict exchangeable/available nutrient contents and other soil properties. Thus, pXRF elemental results and the development of prediction models can reduce the cost and time required for traditional wet chemistry laboratory analyses of nutrient contents. The objective of this study is to assess the viability of utilizing X-ray Fluorescence (XRF) as a predictive tool for plant-available nutrient estimation. A total of 30 soil samples were collected from a depth of 0-30 cm in canola fields across eastern Washington, USA (Fig. 1). Prior to analyzing the collected field samples, an incubation experiment was conducted using increasing lime application rates (0, 0.5, 1.0, 2.5, 5, and 10 t/ac) on soil from Rockford, WA (pH = 4.5) to create a calcium (Ca) and magnesium (Mg) gradient for calibrating the pXRF instrument for subsequent analysis of the 30 field samples collected in the eastern Washington. Both the incubated soils and field samples were analyzed using wet chemistry for available nutrient fractions and pXRF for total elemental concentrations. The incubation experiment showed that Ca ($R^2 = 0.84$) has a better correlation than Mg ($R^2 = 0.27$). Further, the results from the incubation data served as the 'training' dataset for model calibration. The calibration provided valuable insights into predicting available nutrient concentration from total elemental data obtained via pXRF. The data analysis showed the predictive accuracy for Ca ($R^2 = 0.36$, $p<0.0001$) was more reliable than the Mg ($R^2 = 0.18$, $p<0.01$) (Fig. 1). Therefore, further optimization and exploration of alternative models are warranted to improve prediction accuracy.

The authors are thankful for the financial support provided by the Washington Oilseed Cropping System, Washington Oilseed Commission, and Washington Grain Commission to conduct this project.

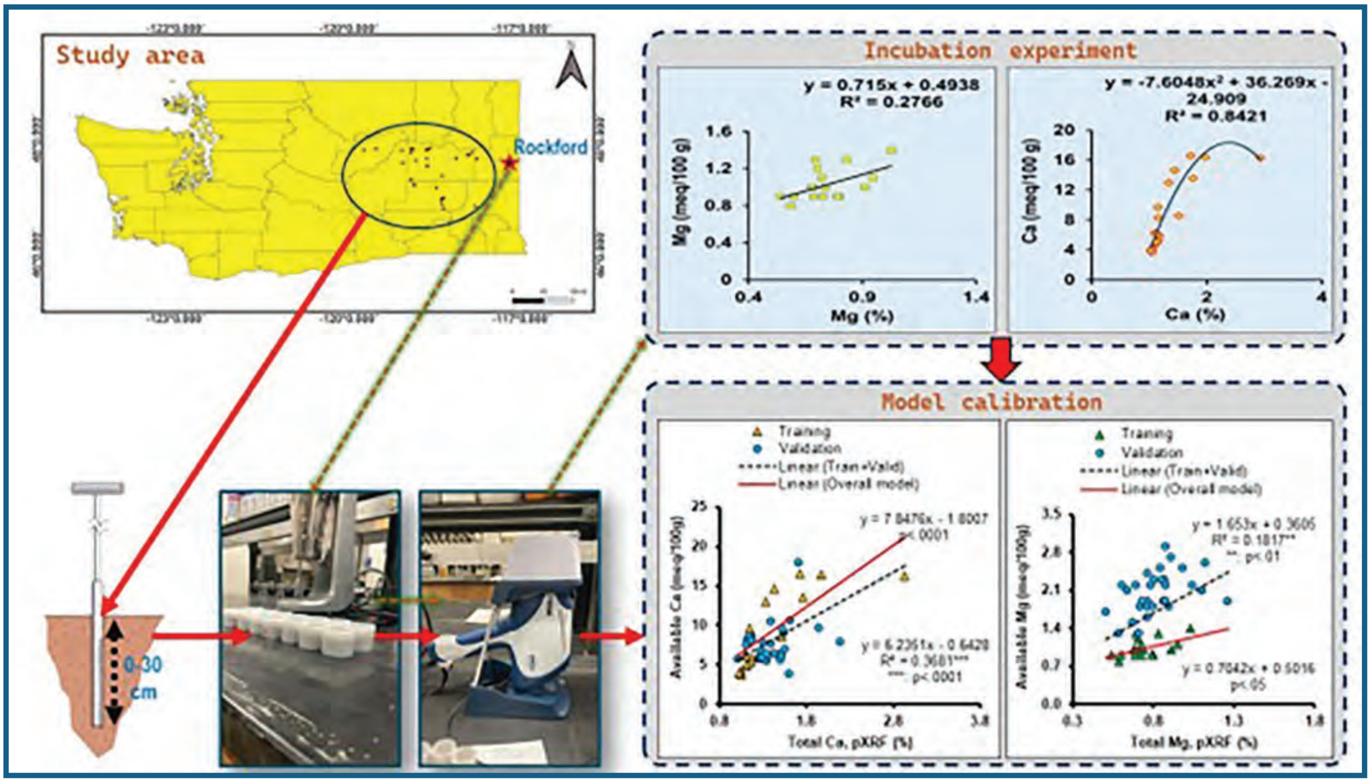

Figure 1. The graphical representation of this study.

Nitrogen Stabilizer Impacts on Nitrous Oxide Emissions

Claire Phillips[1], Fabio Scarpare[2], Robert Meadows[2], Ian Leslie[1], Leah Amazing Brown Chidziwe[2], and Dave Huggins[1]

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A field trial was initiated in Pullman, Washington in September 2023 to evaluate the impact of a nitrification inhibitor (pronitridine, TMC LockdowN) on winter wheat growth, nitrogen use efficiency, and nitrous oxide emissions. Pronitridine is a nitrification inhibitor that prevents microbial transformation of ammonia to nitrate. We hypothesized that pronitridine would reduce soil N losses and reduce nitrous oxide emissions. Here we report findings from harvest year (HY) 2024 and early HY 2025. Treatments consisted of a no-N control to estimate soil mineralization, a standard fall application of 140 lbs/acre N (liquid urea) subsurface banded at planting, the standard fall application with pronitridine (1.85 gal/ton fertilizer), and a split application with 70% of N banded in fall and 30% surface-applied in early March as dry urea. Each treatment was replicated 4 times in a randomized block design on ground previously planted in garbanzos. Plots were 50 ft long × 7 ft wide, and were sited on a footslope where soil moisture, and therefore nitrous oxide emissions, were expected to be high.

Crop Response and N Performance

In HY2024 we found no benefit of the N stabilizer in terms of grain yield or protein concentration (Fig. 1). Nitrogen performance, expressed as N balance index (N in grain / N applied in fertilizer) was unexpectedly lower in plots with stabilizer than without (Fig. 1C). However, these results may be influenced by higher amounts of pre-plant N in the non-stabilized plots (average 60 lbs N/acre higher than in stabilized plots, measured to 5 ft depth). This bias was inadvertent, and was due to high spatial variability in soil N over small distances.

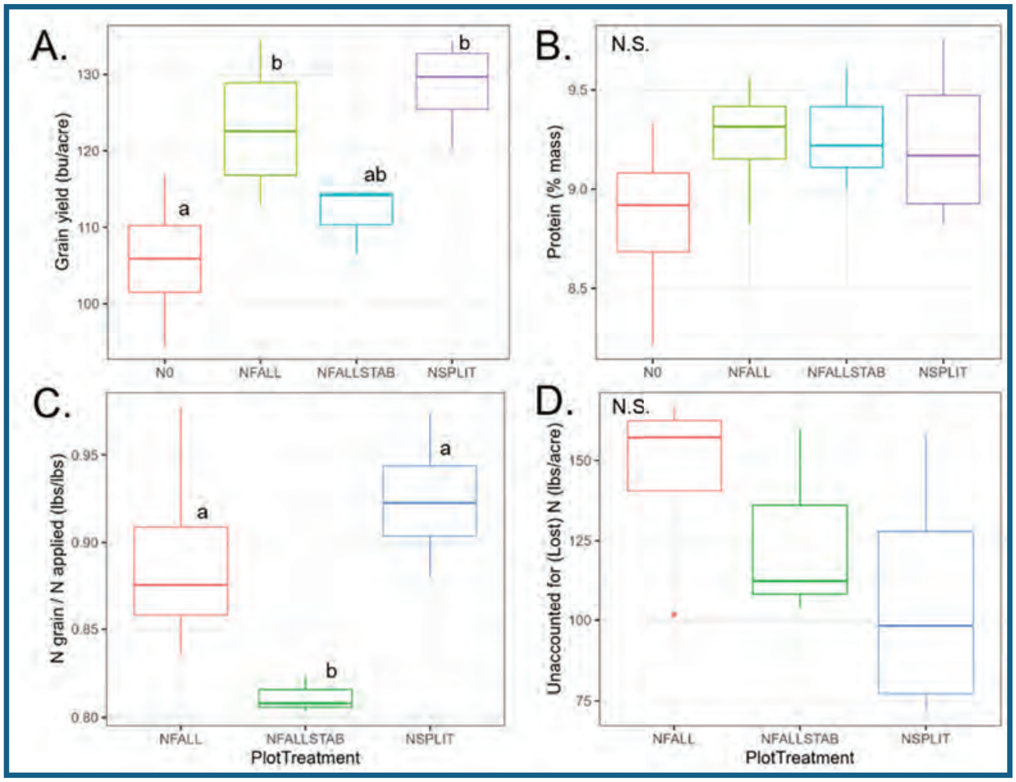

Figure 1. Crop response and N performance in winter wheat under alternative N management. (A) Grain yield, (B) grain protein, (C) N balance index, and (D) unaccounted (lost) N, estimated using a N budget approach. Treatments not sharing the same letter were statistically different (p > 0.05). N.S. = not statistically significant. N0 = no N fertilizer, NFALL = 140 lbs N/acre at fall planting, NFALLSTAB = 140 lbs N/acre in fall plus pronitridine, NSPLIT = 100 lbs N at fall planting, 40 lbs N in early March..

We constructed an N budget by summing N sources supplied over the growing season (i.e. pre-plant soil profile N + fertilizer N + N mineralized in the no-N plots) and subtracting N remaining in the crop and soil at harvest (N in grain + N in residue + post-harvest soil profile N). N supply consistently exceeded N remaining at harvest, and showed an average of 93 lbs N/acre was lost to the environment. While the treatments were not statistically different, there was a trend towards smaller losses in the stabilized and split-N treatments relative to standard non-stabilized fall application (Fig. 1D).

Nitrous oxide emissions

Nitrous oxide (N2O), which is a potent greenhouse gas, had highest emissions in the standard practice in HY24, and considerably lower emissions in the stabilized and split-N treatments. In HY25 we ensured there were no treatment biases in pre-plant soil profile N. We found no treatment differences in N2O emissions in the fall, but found that the stabilized treatment had the highest N2O emissions following winter snowmelt.

Conclusions

This trial has so far not shown a benefit of pronitridine for N performance in winter wheat in the high rainfall zone. Impacts on N2O emissions were inconclusive due to inconsistent levels of pre-plant soil N in HY24. We expect shoulder and summit positions of hillslopes that are more prone to N loss may be a better target for N stabilizers than the footslope position studied here.

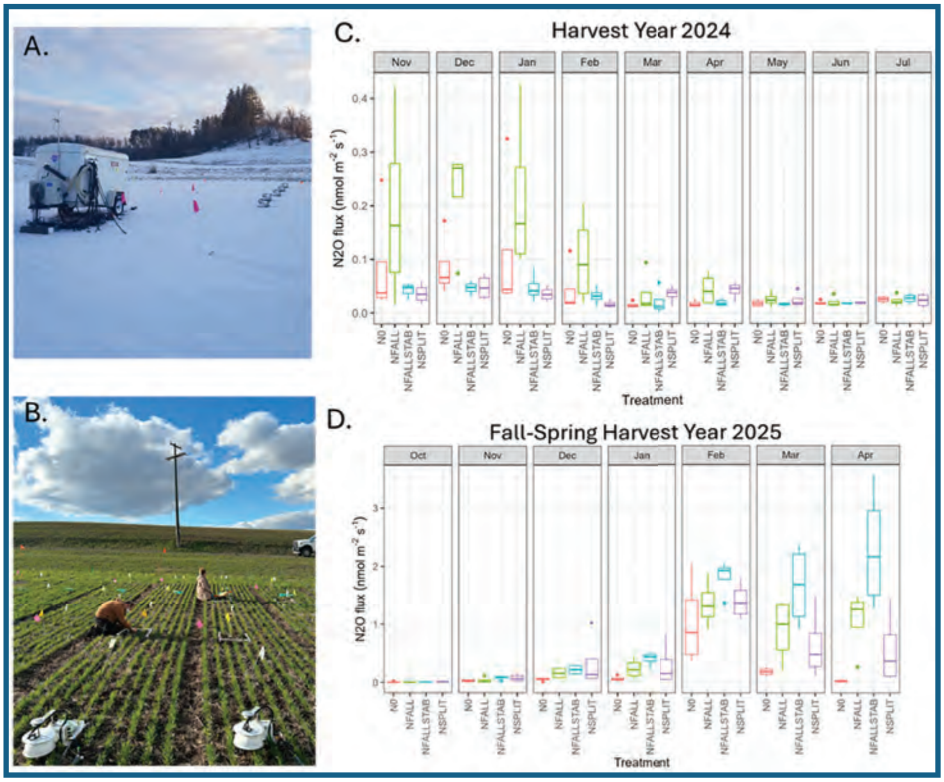

Figure 2. Nitrous oxide flux chambers in (A) winter and (B) spring. Monthly average nitrous oxide emissions for (C) harvest year 2024, and (D) fall through spring of harvest year 2025. The first year had a relatively wet fall and the 2nd year was comparatively dry. Note the difference in scales for C and D, and the very high fluxes on thaw days in in Mar-April 2025.

Inter-Specific Interactions and Crop Productivity in Cereal-Pea Intercropping Systems

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Intercropping is an agricultural practice of growing two or more crop species together, improving resource use efficiencies and productivity. However, how species interactions enhance resource use efficiencies is not well understood. We thus examined how barley and wheat interact with neighboring peas in cereal-pea intercropping systems under drought-stressed conditions, pertaining to dryland areas. A field experiment was conducted at the University of Idaho's Aberdeen Research & Extension Center. We established experimental plots of monoculture and intercropping of spring barley, spring wheat, and spring pea under drought-stressed (50% crop evapotranspiration (ET)) and well-watered conditions (100% ET). The intercropping treatments included barley or wheat at 75% of their monocropping seeding rates intercropped with peas at 25%, 50%, and 75% of their monocropping seeding rate, as well as 50% of cereals intercropped with 50% peas (Fig. 1).

Aboveground biomass significantly differed in barley-pea and wheat-pea cropping systems ($p < 0.0001$ for both), but was not significantly affected by water availability ($p > 0.05$). Grain yield differed between water regimes only in barley-pea systems ($p = 0.04$).

At physiological maturity, biomass-based relative interaction index (RII) revealed different patterns between cereals and peas (Fig. 2). Both barley and wheat maintained positive RII values when intercropped with 75% pea under drought stress, however, these values were near zero or negative under well-watered conditions. Pea RII values were near zero in systems with 25% pea seeding rate, but consistently negative at higher seeding rates (50% and 75%), regardless of water regime.

Figure 1. A barley-pea intercropping plot at the University of Idaho Aberdeen Research & Extension Center.

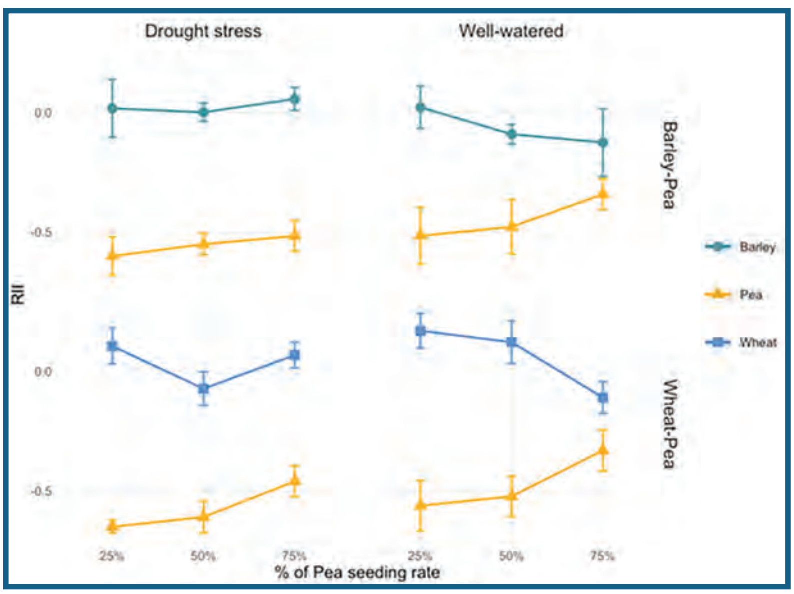

Figure 2. Relative interaction index (RII) on biomass of barley-pea and wheat-pea intercropping systems by pea ratios (75% cereal intercropped with 25%, 50%, and 75% pea) at physiological maturity. The RII quantifies interaction intensity between plant species, ranging from -1 (strong competitive inhibition) to 1 (strong facilitation), indicating whether each plant experiences negative or positive effects from neighboring plants.

Land equivalent ratio (LER) analysis revealed yield advantages in specific combinations (Figure 3). In barley-pea systems, only the 75% barley + 75% pea treatment under drought stress achieved a total LER significantly greater than 1 ($p = 0.04$). Wheat-pea intercropping showed LERs exceeding 1 in 75% wheat + 25% pea under well-watered conditions, 75% wheat + 75% pea under drought stress, and 50% wheat + 50% pea under both water conditions ($p < 0.05$). No cereal partial LERs exceeded 1, and all pea partial LERs were significantly below 1.

These findings suggest that cereal-pea intercropping, particularly at higher seeding rates under drought conditions, can provide yield advantages over monoculture systems. The positive RII values for cereals coupled with negative RII values for peas indicate asymmetric competitive interactions that benefit cereal productivity at the expense of pea performance. This competitive dynamic appears to drive the observed yield advantages in intercropping systems. Despite the competitive suppression of peas, the overall productivity benefits demonstrated by total LER values exceeding 1 suggest that strategic cereal-legume intercropping could improve resource use efficiency and cropping system resilience in water-limited environments.

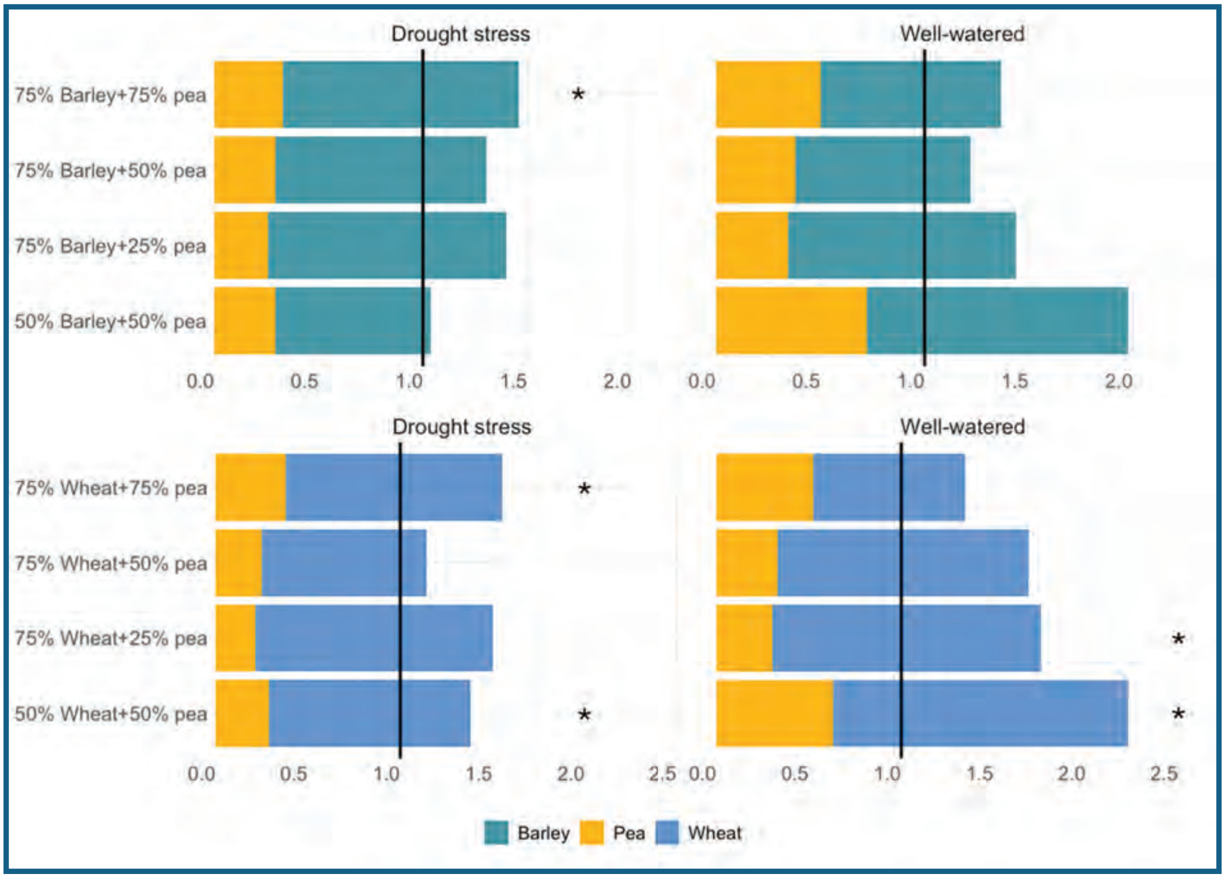

Figure 3. Grain-based land equivalent ratio (LER) of cereal-pea intercropping systems. LER compares the land area required under monocropping to the land area under intercropping needed to produce equivalent yields under the same management conditions. Values are calculated as the sum of component crops' partial LERs (the fraction of each intercrop yield relative to its monoculture yield). LER > 1 indicates intercropping yield advantage over monoculture. Asterisks (*) indicate LER significantly higher than 1 ($p < 0.05$).

Part 2. Oilseeds and Other Alternative Crops

Response of Winter Canola Cultivars to Cabbage Seed Weevils

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Canola (*Brassica napus* L.) is an oilseed crop commonly used as an edible oil (canola), biofuel (industrial rapeseed), and livestock feed. Both spring (i.e., spring-seeded) and winter (i.e., fall-seeded) canola are vulnerable to a wide range of insect pests including cabbage seedpod weevil (*Ceutorhynchus obstrictus*). Cabbage seedpod weevil moves into the canola crops to feed on their buds, flowers, and developing pods resulting in significant reduction in crop yield. While management of this pest using chemical, mechanical or biological methods are recommended, having cultivars resistant to cabbage seedpod weevil can help minimize crop losses and contribute to integrated pest management. Therefore, in this study, we assessed five winter canola cultivars for their response against cabbage seedpod weevil.

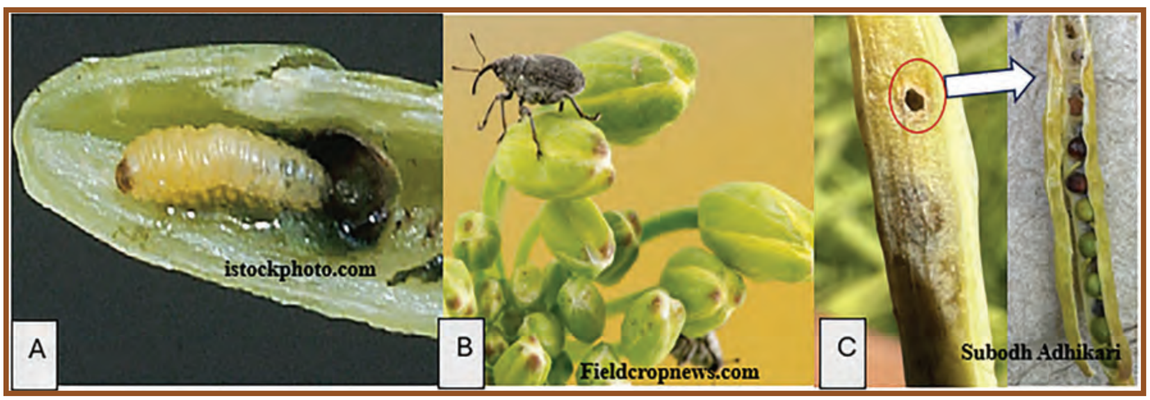

Figure 1. (A) Cabbage seedpod weevil larva, (B) Cabbage seedpod weevil adult, (C) Cabbage seedpod weevil exit hole and seed damage.

The study was conducted using the "Pacific Northwest Winter Canola Variety Trials" managed by "Canola, Rapeseed and Mustard Breeding Program" of University of Idaho. The trials were in three locations: Parker Research Farm, Moscow, ID; Kambitsch Research Farm, Genesee, ID and a grower's farm at Craigmont, ID. The trials were conducted using a randomized complete block design (RCBD) with four replications. Out of 40 cultivars tested in the variety trials, five cultivars including Durola, Erica, CP320W RR, Surfire, and Messi, were selected to estimate the response to cabbage seedpod weevil damage. When the crop was ready for harvest, the primary racemes were collected from five randomly selected canola plants in each plot for all five selected cultivars. All pods in each raceme were carefully examined for the cabbage seedpod weevil exit holes in the laboratory. Each raceme was threshed individually after examining and counting the cabbage seedpod weevil exit holes. The seeds were weighed to determine the seed yield per raceme.

Our results showed that in Craigmont farm trials that Durola had the highest exit hole numbers while Erica had the lowest, but the cultivars did not differ from each other (Fig.2). In the Kambitsch Farm trial, CP320W.RR had the highest numbers of exit holes whereas Messi had the lowest, yet again the cultivar response was not significantly different. At Parker Farm, the highest numbers of exit holes were observed in CP320W.RR while Erica had the lowest and was significantly different among the cultivars. Preliminary results showed variations in winter canola cultivar response to cabbage seedpod weevil infestation across the sites. Cultivars that showed little to no impact from the damage could be due to the cultivar being tolerant to the cabbage seedpod weevil damage. Other factors like farming history or landscape composition may have influenced the weevil impacts. We are repeating the same experiment for the 2024-2025 season in the same three locations, and we expect results that will help us explain the variations observed across the experimental sites.

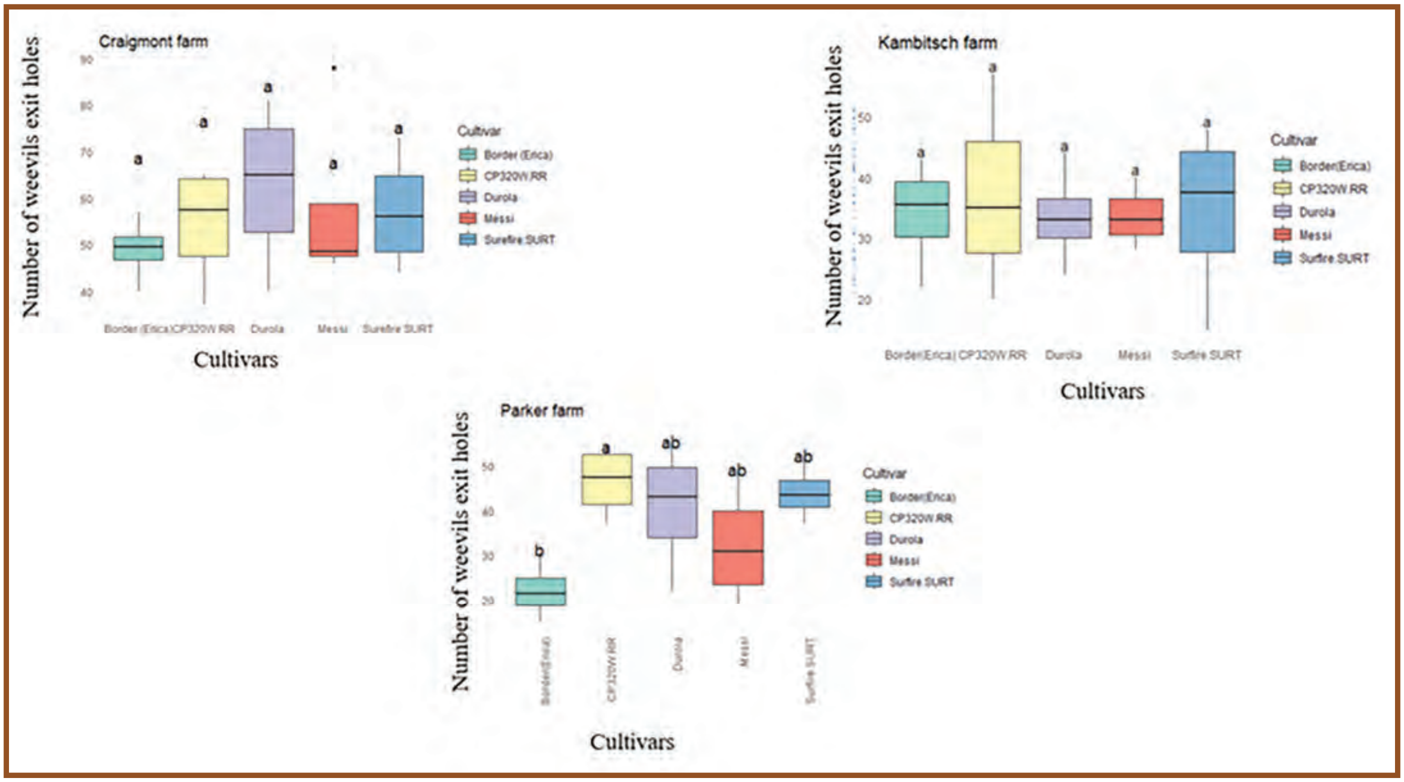

Figure 2. Preliminary results of winter canola cultivar response to cabbage seedpod weevil across three sites. Bars indicate the means and whiskers indicate the standard errors. Bars with the same letters indicate that means are not significantly different between the number of weevils exit holes and cultivars according to Tukey's multiple comparison test ($p < 0.05$).

Automated Detection and Quantification of Flea Beetle Damage in Canola

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The canola growers in the Pacific Northwest encounter considerable challenges associated with flea beetle management. Among different species, Phyllotreta cruciferae ranks as the most stubborn and harmful insect pests affecting canola production. The feeding behavior of flea beetles is unique: they chew and damage the stems, cotyledons, and young true leaves. The harm manifests as indentations, depressions, and perforated patterns, all of which obstruct proper seedling growth. The extent of damage differs, yet in many instances, it results in hindered plant growth, diminished defenses, and reduced crop production. On average, loss in seed yield due to flea beetle damage can be up to 35%. During severe outbreaks, the damage potentially results in the loss of millions of dollars throughout North America.

Acknowledging the immediate need for improved and efficient management techniques to tackle flea beetle infestations, this study presents an innovative solution: a computer vision-driven method for the automated identification and measurement of flea beetle damage on canola leaves. In this research, the proportion of flea beetle damage was assessed by using deep learning models, particularly YOLOv10 with a customized dataset. We have used 180 high-resolution images of plants with beetles and beetle damage. 70% of the images from the dataset are used in training and 25% of the images are used in testing, and the rest of the images are used for validation purposes. The primary innovation of this method is the capability to delineate and compute the damaged leaf area on a pixel-by-pixel basis. The deep learning models were trained to identify and categorize three main components: flea beetle damage, healthy leaf tissue, and the occurrence of crucifer flea beetles. This segmentation approach provides a more accurate and thorough assessment of the damage in comparison to conventional scouting techniques. The YOLOv10 model's test results showcased remarkable performance, attaining 99% overall accuracy, with 98% accuracy in detecting beetle damage, 100% accuracy in leaf detection, and 100% accuracy in recognizing the presence of crucifer flea beetles.

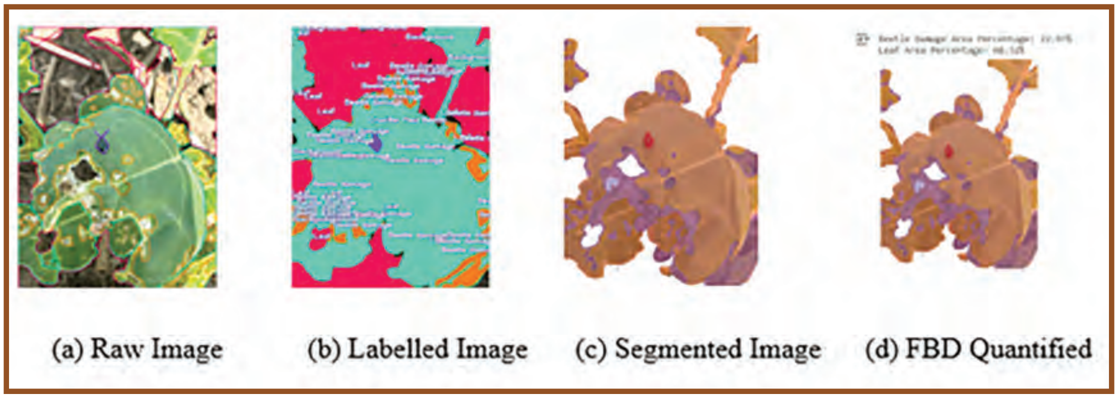

Figure 1. Smart phone and AI-enabled flea beetle damage (FBD) detection and quantification.

The timing for assessing crop damage is particularly critical since the action threshold for applying insecticides is usually established at 25% damage to the total surface area of cotyledons and young leaves. After this stage, the damage can quickly worsen, with defoliation rates passing economic injury levels in just a day or two during intense infestations. The current visual scouting techniques are labor-intensive yet not precise, which may differ based on the observer, site conditions, and environmental factors. This inconsistency can result in a delay in recognizing infestations and executing prompt spray interventions. The automated system created in this study could provide major benefits to PNW canola growers by minimizing these issues. This study shows a huge potential of using AI in significantly improving flea beetle management efficiency by offering growers more precise information.

Evaluating the Response of Canola and Mustard Cultivars to Flea Beetle Damage

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Canola (*Brassica napus* L.) and mustard (e.g., *Sinapis alba,* and *B. juncea*) are economically important crops in North America. Flea beetles (Coleoptera: Chrysomelidae) are the major insects in canola and mustards in the Pacific Northwest. Flea beetles chew leaves and tender stems, making potholes (Fig.1). Reports show that if unmanaged, up to 35% yield loss could occur due to flea beetle damage, although crop cultivar responses could highly vary. Hence, our research aim was to evaluate the response of canola and mustard cultivars to flea beetle damage.

Figure 1. Damage caused by flea beetles to mustard and canola at different growth stages. Leaf defoliation and unique shot-hole feeding patterns are caused by flea beetle feeding (photos by Subodh Adhikari).

The experiment was conducted in the summer of 2024 at UI-Parker Research Farm, Moscow Idaho, using a split-plot design with four replications. Among the six cultivars tested, four of them were canola [CP9978TF, CS2600.CR-T, DynaGro280CL, Industrious (industrial rapeseed)], and two were mustard cultivars (IdaGold: *Sinapus alba* and Pacific Gold: *B. juncea*). The Industrious cultivar was tested with (i.e., IndustriousT) and without seed treatment (i.e., IndustriousN), while all the other cultivar seeds were treated with Helix Vibrance at 23 fl oz per 100 lbs of seed. The main plots included foliar spray (SP) and no spray (NS) for flea beetles. Spraying was done with Grizzly Too (ai: lambda-cyhalothrin). The individual plot sizes were: 5 ft x 16.5 ft. Planting was done on April 24, 2024, and foliar spray treatments were applied on May 14 and June 08, 2024. The variables measured included percentage damage and crop yield. Damage was recorded by proportion of leaf damage to total leaf area (i.e., 0 - 100%) based on the protocol developed by Canola Council of Canada. Randomly selected seedlings from each experimental plot (20 per plot) were observed for flea beetle damage weekly for four weeks. The statistical test used was a mixed effects model in R using *lmer* and *glmer* functions.

The first flea beetle damage data was assessed on May 13 before applying the foliar spray treatment on May 14. The second damage assessment was done on May 21. The results showed that CS2600-CR-T had the lowest damage among cultivars, but no significant difference between control and treated plants across cultivars before spray treatments (Fig.2; left panel). However, spray treatment had signigicant effects on percentage damage across all cultivars (Fig.2; right panel), with a stronger effects on some cultivars such as IndustriousT, IndustriousN, and Pacific Gold. Compared to other cultivars, IdaGold had the lowest flea beetle damage in both control and treated plants (Fig.2; right panel).

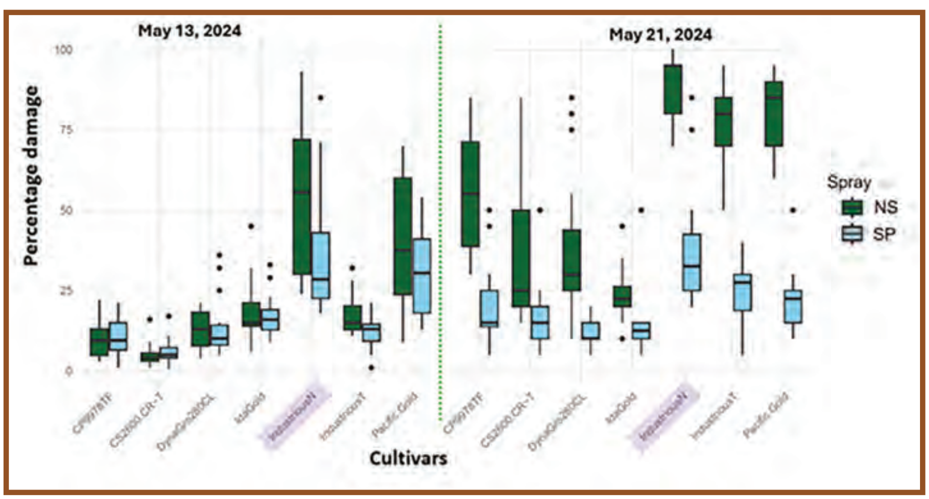

Figure 2. Percentage damage of leaves by flea beetles. The bars in green represents cultivars that were not sprayed (NS) and the bars in blue represent cultivars that were sprayed (SP) with Grizzly Too. The vertical green dotted line indicates foliar spray date on May 14. We found a strong cultivar, spray, and spray by cultivar differences (P=<0.0001 for all).

Overall, we found a cultivar-specific responses to flea beetle damage. For example, CS2600-CR-T cultivar showed the highest yield with or without foliar spray for flea beetles (Fig.3). IdaGold had a higher yield compared to Pacific Gold under control conditions. The result indicated that CS2600-CR-T and IdaGold are relatively resistant to flea beetles compared to other cultivars. Pacific Gold was preferred by flea beetles, but spraying was effective in managing beetles and maintaining similar yield to canola cultivars such as CP9978TF and DynaGro280CL. Industrious with treated seeds had a higher yield compared to non-treated Industrious, but a combination of a seed treatment and foliar spray reduced flea beetle damage and increased yield most effectively, indicating the significance of these treatments in flea beetle management.

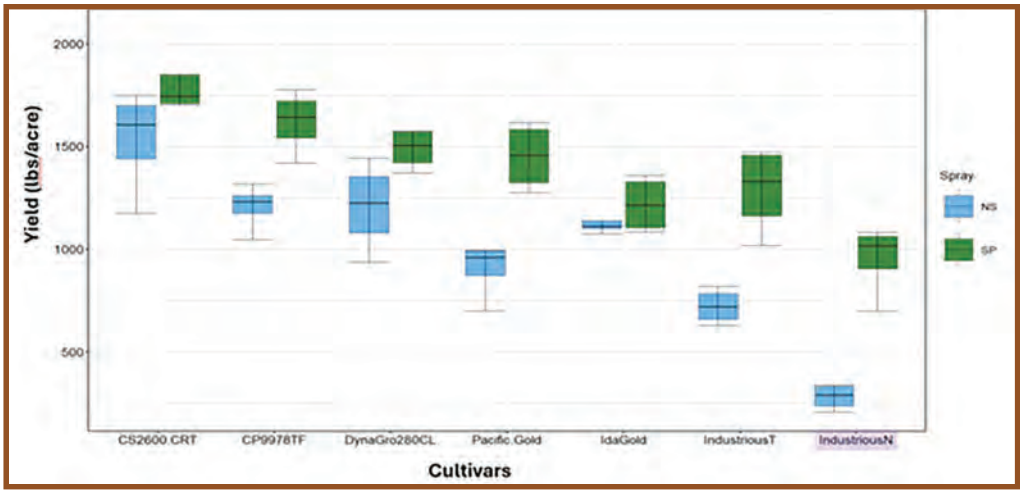

Figure 3. Brassica cultivar yield. The blue bars represents cultivars that were not sprayed (NS) and the green bars represents cultivars that were sprayed (SP) with Grizzly Too. The first three cultivars are canola, followed by IdaGold (Sinapus alba) and Pacific Gold (Brassica juncea) which are mustards, whereas Industrious is a rapeseed.

Pealina: Investigating the Intercrop Potential of Camelina and Pea

Wilson Craine[1] and Surendra Singh[2]
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Intercropping is an agricultural practice where two or more different crops are grown simultaneously in the same field, and can lead to higher overall yields, increased crop resilience, improved soil health, and more sustainable farming practices by optimizing space, reducing input costs, and minimizing environmental impact. Intercropping legumes and oilseeds creates a synergistic partnership due to their different growth habits and plant architecture. The nitrogen-fixing ability of legumes enriches the soil, while reducing reliance on synthetic fertilizers normally required for the nutrient-demanding oilseed crops. This partnership can improve water and nutrient efficiency, suppress weeds, minimize pest and disease risks, and stabilize yields.

This "PeaLina" research project investigates the potential of intercropping fall-seeded peas and camelina in the dryland wheat-fallow zone. The goal is to explore different agronomic protocols to optimize this intercrop system and guide future research efforts. Specifically, this project utilizes different seeding rates, methods, and depths in addition to variable nitrogen application rates to better understand agronomic practices critical to establishing this intercrop and how these practices can impact seed yield. The protocols established by this research project will facilitate future PeaLina intercrop rotation studies.

The ultimate vision of this project is to determine if a PeaLina intercrop is able sustainably intensify the wheat-fallow rotation by transitioning a 3-year Winter Wheat – PeaLina – Fallow rotation. Consequently, all PeaLina plots were seeded with a "no-till" plot drill, into wheat stubble from the previous year.

The winter pea used for this trial was "Vail". There are both winter and spring camelina biotypes that exhibit different growth habits, so a check variety for both spring and winter camelina was used to determine which performed better and best matched the maturity timing of the peas. The table below describes the various types of treatments being investigated. There are 3 replicate plots for each treatment combination.

PeaLina on 4/16/25.

Treatment	Details
Camelina Biotype	Winter = "Joelle"; Spring = "Calena"
Seeding Method	Camelina and Pea seeded together, "dusted-in" ¼in deep Camelina and Pea seeded separately, Pea first 1in deep, Camelina after ¼ in deep
Nitrogen applied	0lbs/acre; 40lbs/acre; 80lbs/acre; 120lbs/acre
Seeding Rate*	100% Camelina; 2/3 Camelina+1/3 Pea; 1/2 Camelina+ 1/2 Pea; 1/3 Camelina+ 2/3 Pea; 100% Pea

*Seeding rate = % of full seeding rate**
**100% camelina = 6.5lbs/acre
**100% pea = 132lbs/acre (352,000 seeds/acre)

Optimizing Canola Production through Depth-Specific Lime Application in the Dryland Palouse Region

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Canola (*Brassica napus* L.) is one of the most important crops grown in the Pacific Northwest due to its economic significance and importance in rotational farming systems. The acidic soil conditions common to this region often pose limitations on canola productivity due to aluminum toxicity and nutrient imbalances. Soil acidity has become stratified, with a highly acidified layer at the depth of fertilizer application. Stratification becomes worse over time in no-till systems, since residues are not reincorporated. This research aims to address the problem of pH stratification, which may affect canola root growth and nutrient absorption. A depth-specific approach is ideal for correcting soil pH and subsequently improving soil-available nutrients and root growth. This will be achieved by testing the effectiveness of depth-specific lime application versus conventional techniques, where lime is applied to the surface and incorporated into the soil. This integrated study utilizes two primary methodologies: a controlled greenhouse study at the WSU wheat research greenhouse facility, and a field study at the Palouse Conservation Field Station (PCFS), Pullman.

A preliminary incubation study was conducted on soil (pH = 4.5) collected from a depth of 0-6 inches in Rockford, WA (the same source as the greenhouse experiment soil), a dryland farming area in Eastern Washington, to derive the optimal lime dosages for the subsequent experiments. This investigation focused on the pH response of soil to six levels of finely ground lime (the equivalent of 0, 0.5, 1, 2.5, 5, and 10 t/acre). The observations obtained from the experiments suggested that while lime application increased soil pH it plateaued at approximately 6.37 with a rate of 2.28 t/acre (Fig. 1). In addition, the incubation showed that lime application reasonably reduced aluminum concentration and increased the amount of plant-available sulfur which is a primary component of the lignin coating/binder which encapsulated the lime that was applied to the soil. which is especially advantageous for canola as it tends to require this nutrient. Such results formed the rationale for the lime treatments in the primary greenhouse experiment conducted afterwards.

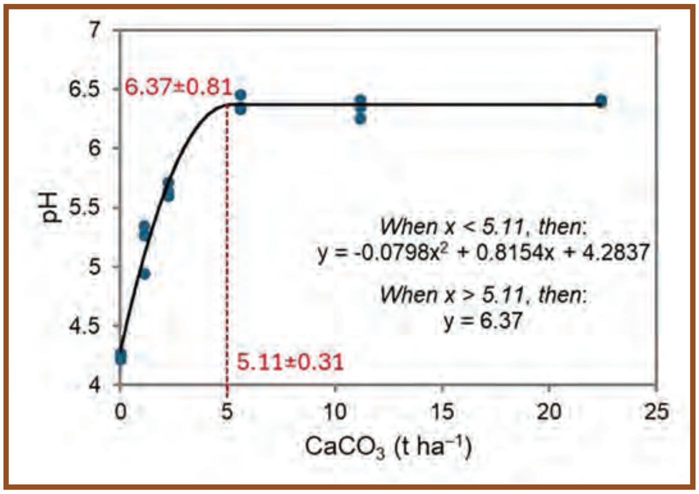

Figure 1. Presents the segmented quadratic-with-plateau regression model employed to assess the relationship between lime application rate (1 t/ha = 0.446 t/acre) and soil pH.

The authors are thankful for the financial support provided by the Washington Oilseed Commission to conduct this project.

Yield Performance and Stability of Spring Canola Cultivars under Acidic Soil Conditions

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Soil acidification is a significant global issue that negatively affects crop productivity. It has emerged as a potential threat to growers in the Pacific Northwest, particularly in the Palouse regions of Washington and Idaho. Over the past 25 years, soil in Northern Idaho and Eastern Washington has experienced rapid acidification due to high ammonium fertilizer inputs. Canola, which has become an integral part of the rotation in the cereal-based cropping systems of the region, is sensitive to soil acidity. Aluminum and manganese toxicity associated with acidic soil reduces root development and root density, ultimately affecting canola yield. Unfortunately, there have been limited efforts in the past to breed acid-tolerant canola cultivars. Therefore, we evaluated a set of 38 spring canola cultivars to identify stable and high-yielding cultivars under different acidic soil environments to provide the growers with options to select the best genetics suitable for their farm soil.

We evaluated the cultivars in randomized complete block design studies at three different locations: Moscow (pH = 4.4, Al = 426 ppm), Rockford, WA (pH = 4.36, Al = 189ppm), and Pullman, WA (pH = 4.76, Al = 40 ppm). Additive Main Effects and Multiplicative Interaction (AMMI), Genotype and Genotype by Environment Interaction (GGE) biplots, and stability parameters were computed to identify stable and high-yielding cultivars.

An AMMI analysis of seed yield variance revealed a significant effect of genotype, environment, and genotype by environment interaction, accounting for 14.3%, 66.7%, and 7.0% of the total variation, respectively. Based on AMMI1 biplot (Fig. 1), Pullman, WA was the highest yielding location, which has a slightly higher pH and lowest Al concentration compared to Rockford, WA, and Moscow, ID. The which -won- where view of the GGE biplot analysis showed three distinct mega-environments with different winning cultivars: V22 (Colette.CL) in Pullman, WA; V32 (21. SC.28A.2), V36 (Goldrush), and V37 (Gem) in Moscow, ID; and V25 (StarFlex.TF) in Rockford, WA. In addition, based on the AMMI stability value (ASV) and Yield Stability Index (YSI), the top yielding and stable cultivars across locations were V1 (InVigor.LR344PC), V18 (NC527CR.TF), V26 (CP9978TF), V29 (CP7250LL), and V6 (InVigor.L350PC). These cultivars will be further evaluated for one more season to confirm these results.

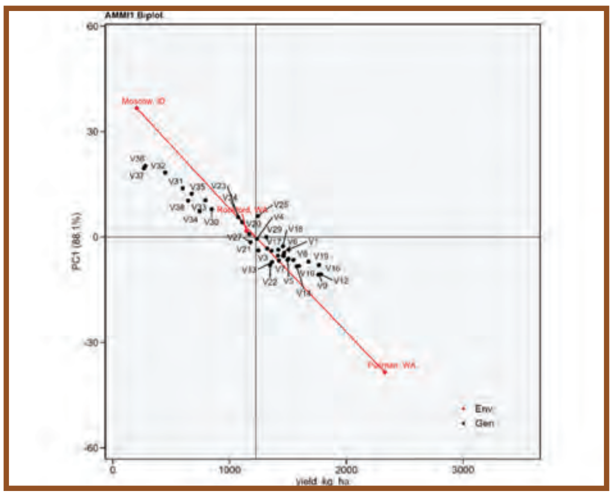

Figure 1. AMMI1 biplot based on PC1 and mean yield showing genotype by environment interaction of 38 spring canola cultivars across three test environments

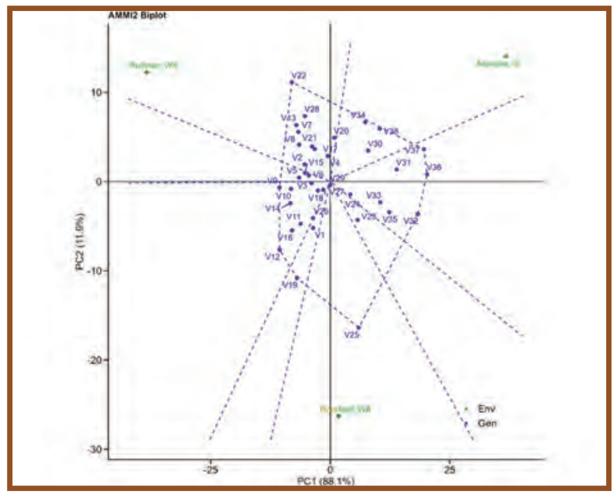

Figure 2. The "which-won-where" view of the GGE biplot showing which cultivars performed best in which mega-environment.

Elucidating the Effect of Metal Lactate, a Potential Plant Bio-Stimulant on Different Canola Varieties

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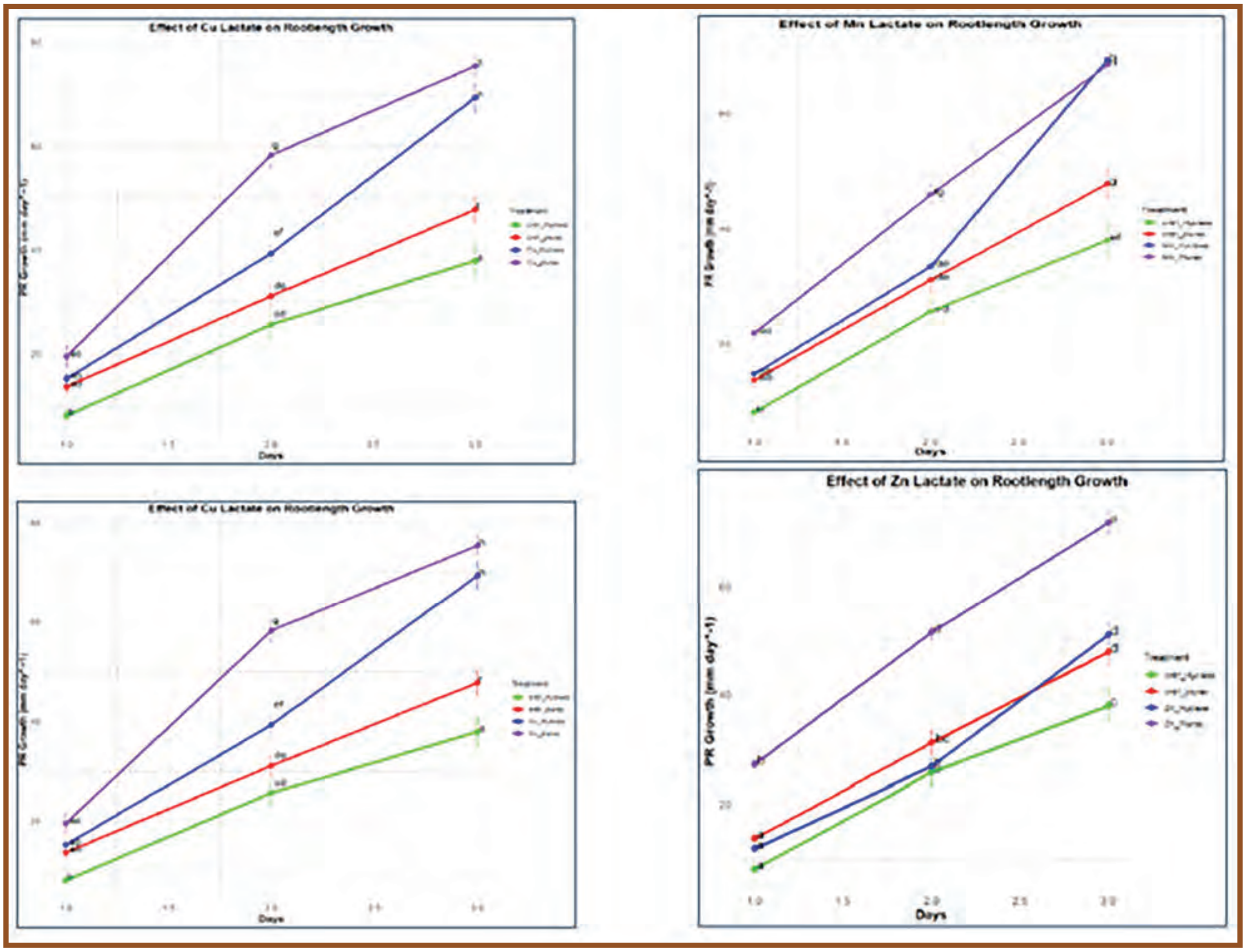
Dept. of Crop and Soil Sciences, WSU

The global agricultural landscape faces pressure from the demands of escalating food production, which has sparked a surge to find ways to boost crop yield and enhance growth. Metal lactates have emerged as candidate plant bio-stimulants that offer a sustainable alternative to inorganic micronutrients required for optimal crop growth, they provide both a labile carbon source and mineral nutrition for plant and microbial growth. To gain knowledge about how canola responses to metal lactate, we investigated the impact of metal lactate treatment on the primary root length growth of two canola (Brassica napus) varieties, Hyclass and Plurax, by comparing treated seedlings to untreated controls using quantitative root length measurement. Also, to test if the two varieties will utilize metal lactates differently, reflecting varietal differences in metal uptake and utilization efficiency. Our results showed that a lower concentration (0.5µM and 1µM) of metal lactate enhances the root length and overall biomass of canola, and the root length of the Plurax variety was enhanced than the Hyclass variety. This finding provides evidence to support metal lactate as a crop bio-stimulant due to its ability to provide nutrients and enhance growth.



Optimizing Seed and Nitrogen Rates for Pea and Canola Intercropping in the Inland Pacific Northwest

Lauren R. Stubbs[1,4], Shikha Singh[1,4], Surendra Singh[1,4], Don Wysocki[2], Garett Heineck[3], and Haly Neely[4]
[1]Lind Dryland Research Station, WSU; [2]OSU Extension; [3]Prosser Irrigated Agriculture Research and Extension Center, WSU; [4]Dept. of Crop and Soil Sciences, WSU

The purpose of this study is to evaluate the effect of varied seeding rates and nitrogen fertility regimes in an intercropped spring pea-canola (peaola) system. The first iteration of this trial was established on April 15th, 2024, at WSU's Wilke Research Farm in Davenport, WA. To assess the suitability of the system under intermediate rainfall conditions, yield and seed quality attributes, land equivalency ratios, soil moisture and nutrient availability, microbial biomass and arbuscular mycorrhizal fungi colonization, biological N fixation, and soil carbon fractions will be studied. The winter pea cultivar Vail (2,700 seeds/lb.) and spring canola cultivar NCC101S (86,000 seeds/lb.) were used in this study, with pea and canola planted in each row. Experimental treatments consist of 1/3 pea + 2/3 canola, 1/2 pea + 1/2 canola, 2/3 pea + 1/3 canola, pea monoculture, and canola monoculture seeding rates, in addition to N applications that range from 0, 50%, and 100% of the recommended lb./ac. rate for canola (Table 1). Based on regional data, the canola N rate requirement (100% N) was determined to be 67 lb./ac (Table 1).

Table 1. Experimental treatments, listed numerically by treatment ID, ratio of pea-to-canola seeded, seeding rate in lb./ac., N fertilizer input, and rate of N applied in lb./ac.

Treatment ID	Seed Ratio	Seeding Rate (Pea + Canola, lb./ac.)	N Fertilizer Input	N Fertilizer Rate (lb./ac.)
Treatment 1	Canola monoculture check	0 + 5	100% N	67
Treatment 2	1/3 pea + 2/3 canola	50 + 3.5	0% N	0
Treatment 3	1/2 pea + 1/2 canola	75 + 2.5	0% N	0
Treatment 4	2/3 pea + 1/3 canola	100 + 1.75	0% N	0
Treatment 5	1/3 pea + 2/3 canola	50 + 3.5	50% N	22
Treatment 6	1/2 pea + 1/2 canola	75 + 2.5	50% N	17
Treatment 7	2/3 pea + 1/3 canola	100 + 1.75	50% N	11
Treatment 8	1/3 pea + 2/3 canola	50 + 3.5	100% N	45
Treatment 9	1/2 pea + 1/2 canola	75 + 2.5	100% N	33.5
Treatment 10	2/3 pea + 1/3 canola	100 + 1.75	100% N	22.3
Treatment 11	Pea monoculture check	150 + 0	0% N	0

From grain yield data collected in 2024, we observed that generally, canola-dominant treatments outyielded pea-dominant treatments, with Treatment 1 as the highest-yielding treatment, and Treatment 11 yielding the least (Fig. 1). Additionally, treatments that received at least half the required N rate outyielded treatments that received no additional N (checks excluded), with Treatments 3 and 10 as the only exceptions (Fig. 1). Similarly, the highest yielding intercropped treatment was Treatment 8, which received the full N application and was canola-dominant, while the lowest yielding intercropped treatment was Treatment 10, which also received the full N application, but was pea-dominant (Figure 1). While none of the intercropped treatments outyielded the canola monoculture check, there is no significant difference between the yields of Treatment 1 and Treatments 8, 5, and 9. Conversely, there is a significant difference between the lowest-yielding intercropped treatment and the pea monoculture (Fig. 1). Therefore, preliminary data indicates there is some yield advantage to intercropping, at least in regard to pea production. The data collection and analyses of soil health attributes is still ongoing—we plan to report full results in 2026.

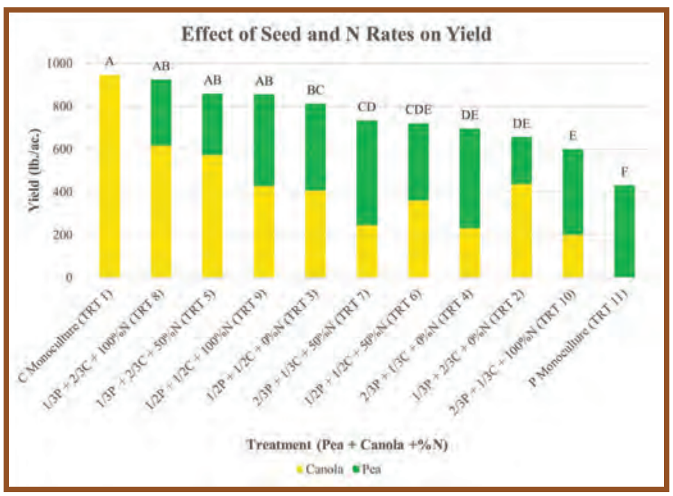


Figure 1. Total yields of each treatment in lb./ac., with the highest-yielding treatment on the far left, and the lowest-yielding treatment on the far right. Letters shared between treatments indicate that yields are not considered to be significantly different.

Part 3. Pathology, Weeds, and Insects

Weed Infestation in a Winter Wheat-Spring Pea Rotation: Insights from a Three-Year Study of Tillage Regimes in the Pacific Northwest

Vhuthu Ndou[1], Fernando Oreja[2], Jennifer Gourlie[1], Stephen Machado[1], Larry Pritchett[1], Francisco Calderón[1], and Judit Barroso[1]
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Compared to conventional tillage, no-till reduces soil and water erosion and appears more sustainable under dryland conditions of the Pacific Northwest. However, weed control in this system relies heavily on herbicides, leading to an increase in herbicide-resistant weeds. Using an established winter wheat–spring pea rotation initiated in 1964 at the Columbia Basin Agricultural Research Center near Adams, Oregon, this study investigated the effect of the different tillage treatments included in that long-term experiment on weed infestation in 2021, 2023, and 2024.

The experimental design was a split-plot in a randomized complete block arrangement with four replications. The tillage treatments were (a) fall moldboard plow, (b) spring moldboard plow, (c) maximum tillage (disk + chisel), and (d) no-tillage. Fall plowing treatment is characterized by moldboard plowing in the fall after each crop harvest. Spring plowing differentiates from fall plowing in that the moldboard plowing after winter wheat is conducted in the spring (before the pea seeding) instead of in the fall. Maximum tillage treatment is similar in timing to the fall plowing but substitutes the moldboard plow with a disk and a chisel plow. Under the no-till treatment, weeds are controlled only using herbicides. All tillage treatments have herbicides applied at seeding in both the wheat and pea phase and in-crop for the wheat phase. Weed percentage cover was evaluated before weed control in the wheat phase each year using ten random sampling frames (1 x 4 ft) per plot (24 x 120 ft).

Weed percentage cover was affected by the year and the tillage treatment ($P < 0.001$). Downy brome, the predominant weed species, was higher in 2021 (31%) and 2024 (23%) than in 2023 (6%). A similar trend was observed in total weeds. However, regardless of the year, weed cover was always higher in the no-till treatment compared to the other tillage treatments. For example, in 2024, the total weed cover in no-till was 33% compared to 9%, 13%, and 15% in treatments a, b, and c, respectively (Fig. 1). Winter wheat yield was not significantly different with the year, but it was with the tillage treatment ($P < 0.001$). The highest wheat yield was observed in the spring plow treatment (63 bu/A), although it was not significantly

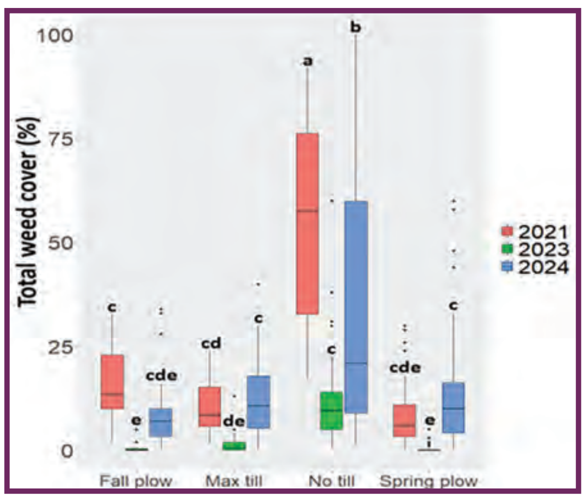

Figure 1. Total weed cover (%) under different tillage treatments (fall moldboard plow, maximum tillage (disk + chisel), no tillage and spring moldboard plow) during in the 2021, 2023 and 2024 growing seasons. Boxes indicate the distribution of 50% of the data. The solid black line indicates the median. Bars with different letters indicate significant differences between years based on Tukey's HSD ($p < 0.05$).

different from the fall plow treatment (57 bu/A) or the maximum tillage treatment (54 bu/A). Yield in the no-till treatment (47 bu/A) was the lowest but only statistically different from the spring plow treatment (Fig. 2).

The reduced wheat yield in the no-till treatment might have been caused by the higher downy brome infestation in this treatment. Furthermore, it is possible that the high downy brome cover was due to resistance of this weed to imazamox, which has been used to control grassy weed species like downy brome for the past decade in this long-term winter wheat-pea rotation. However, a dose-response study will be necessary to confirm resistance in downy brome in this experiment. In summary, the use of herbicides alone may not control downy brome in the long-term and can increase herbicide resistance in weeds. This study also indicates that tillage timing may be important in effective weed control. Further studies have been initiated to evaluate conservation tillage systems in controlling herbicide-resistant weeds.

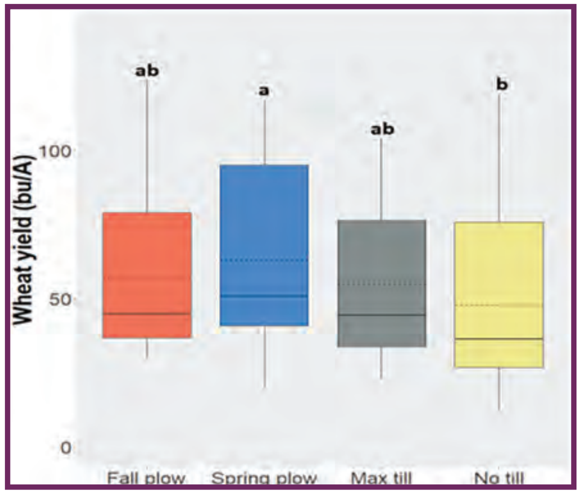

Figure 2. Wheat yield (bu/A) under different tillage treatments (fall and spring moldboard plow, maximum tillage (disk +chisel) and no tillage in 2021, 2023, and 2024 seasons. Boxes indicate the distribution of 50% of the data. The dashed line inside the boxes indicates the mean and the solid line is the median. Different letters on top of the boxes indicate significant differences between treatments according to Tukey's HSD ($p < 0.05$).

Fungicide Application at Herbicide Timing in Dryland Winter Wheat

A.D. Esser
WSU Extension

The application of fungicides with herbicide timing is a common practice for winter wheat (*Triticum aestivum*) farmers across eastern Washington for stripe rust and Strawbreaker foot rot (commonly called eyespot) control. They commonly cite 'free ride', 'cheap insurance', and 'plant health' as justification for this approach. However, this approach increases costs, potentially antagonizes grassy weed control, and research is needed on the impact fungicide application on soil health. Washington State University and USDA/ARS scientists devote resources into assessing and rating wheat cultivars for susceptibility to both these diseases, so growers can make more informed decisions about fungicide application. This data is widely available via print, web, and verbal communication. In 2020, an on-farm trial was established at the WSU Wilke Research and Extension Farm to examine the feasibility of fungicide application, and this study has been repeated each year through the 2024 crop (5 years and 7 site years). Plots are 200 ft long and 30 ft wide with 4 replications and a randomized complete block design. Three treatments were established: 1) 10 gal/ac water (check), 2) 14 oz/ac Quilt Xcel fungicide, and 3) 18 g/ac PiKSi dust (potassium silicate). Quilt Xcel has both stripe rust and Strawbreaker foot rot on its label at the 14 oz/ac application rate. Variety selection is very important and has varied from year to year. In 2020 and 2021 Resilience CL+ was grown, in 2022 and 2023 Piranha CL+ was grown, and in 2024 both Sockeye CL+ and Kraken AX were grown. There were no agronomic differences within all three treatments over the 5 years the study was completed despite multiple growing seasons and varieties planted. Winter wheat yielded 88.4 bu/acre over the duration of the study.

Post-harvest Russian Thistle Control in Spring Wheat Stubble

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Dept. of Crop and Soil Sciences, WSU

Russian thistle is a warm season introduced annual forb and is a major weed problem in both winter and spring wheat and will flourish in wheat stubble following harvest if left uncontrolled (Fig. 1). Previous research has found that post-harvest late-season Russian thistle root growth can remove as much as 26 gallons of water per plant and deplete most all the available soil water to a depth of at least 6 feet. Paraquat, a contact herbicide, can provide effective control of Russian thistle after wheat harvest but it is very toxic and can pose health risks to applicators. Glyphosate, a systemic herbicide, can provide effective control of actively growing Russian thistle after wheat harvest but can be less effective if applied at too low of a rate for the size of the plants being treated, to plants that are stressed and not growing rapidly, or to plants that are glyphosate-resistant. Group 14 herbicides (Inhibitors of PPO) have burndown activity and can be tank mixed with glyphosate for increased efficacy.

Figure 1. Russian thistle in spring wheat stubble one week after harvest at the WSU Lind Dryland Research Station, Lind, WA.

We compared BAS 85101H, an experimental Group 14 herbicide, with and without PowerMax® (glyphosate) for post-harvest Russian thistle control. We also compared tank mixes with Sharpen® (saflufenacil, Group 14), Distinct® (diflufenzopyr, Group 19 + dicamba, Group 4), and Weedone® 638 (2,4-D, Group 4). See Table 1 for application rates.

Table 1. Herbicide treatments and rates.

Treatments*	Rates**
	(oz/A)
PowerMax	64
BAS 85101H	1.4
BAS 85101H + PowerMax	1.4 + 32
Sharpen + PowerMax	2.0 + 32
Distinct + Weedone 638 + PowerMax	2.5 + 22 + 32
Distinct + Sharpen + PowerMax	4.0 + 1.0 + 32

*All treatments included ammonium sulfate (AMS) at 17 lb/100 gal and methylated seed oil (MSO) at 1.0% v/v.

**Rates in fluid ounces except Distinct, which is a dry granular product.

The study location was on the WSU Lind Dryland Research Station near Lind, WA, and all treatments were applied on August 1, 2024, a week after the spring wheat had been harvested. The wheat stubble height was 10 inches at the time of application and the Russian thistle plant heights were up to 15 inches.

Treatments were applied with a CO_2-pressurized backpack sprayer and 10-ft hand-held spray boom with six TT110015 TeeJet® nozzles. Spray output was 15 gpa with 45 psi nozzle pressure and 3 mph ground speed. The experimental design was a randomized complete block with four replicates per treatment and 10- by 30-ft plots. All treatments included ammonium sulfate (AMS) at 17 lb/100 gal and methylated seed oil (MSO) at 1% v/v. Treatments were visually evaluated at 1, 2, and 4 weeks after treatment (WAT) and compared as a percentage of control compared to the nontreated check.

By 1 WAT, Russian thistle burndown and control with BAS 85101H and BAS 85101H + PowerMax was 100% and was greater than all other treatments. PowerMax by itself had only resulted in 12% control but then increased to 70% by 4 WAT (Fig. 2). Some regrowth occurred after application and by 2 WAT, BAS 85101H control had declined to 93% and then 80% by 4 WAT; however, at 4 WAT BAS 85101H + PowerMax resulted in 87% control, which was the best control observed at 4 WAT. Control at 4 WAT averaged between 70-75% with all other treatments that did not include BAS 85101H.

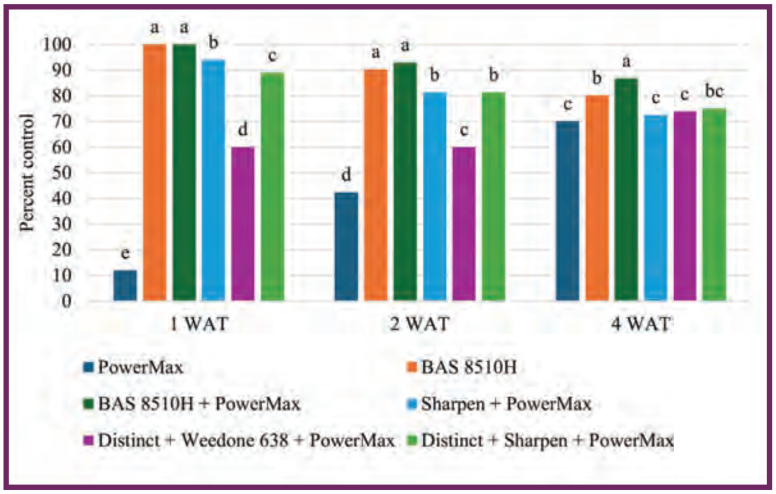

Figure 2.

Off-Label or Experimental-Use Disclaimer

Some of the pesticides discussed in this presentation were tested under an experimental use permit granted by WSDA. Application of a pesticide to a crop or site that is not on the label is a violation of pesticide law and may subject the applicator to civil penalties up to $7,500. In addition, such an application may also result in illegal residues that could subject the crop to seizure or embargo action by WSDA and/or the U.S. Food and Drug Administration. It is your responsibility to check the label before using the product to ensure lawful use and obtain all necessary permits in advance.

Comparing Root-Lesion Nematode Abundance in Long-Term Cropping Regimes in the Dryland Pacific Northwest's Rainfed Cereal Crops

Rachael Plunkett, Paulina B. Ramirez, Richard W. Smiley, and Francisco Calderon
Columbia Basin Agricultural Research Center (CBARC), OSU

Root-lesion (RL) nematodes (*Pratylenchus spp.*) are persistent pests of the dryland Pacific Northwest's rainfed cereal crops. *Pratylenchus* feed on and damage the root structures of crops, making them more susceptible to diseases and reducing the efficiency of nutrient and water uptake, leading to plant stress and decreased crop yields. We quantified RL nematodes in three long-term experiments (LTE's; since

1930) located at the Columbia Basin Agricultural Research Center (CBARC) to determine the effects of conventional crop management on plant-parasitic nematodes in rainfed cereal crops. Given that nematodes are well-established indicators of soil health, we hypothesize that the observed differences are primarily driven by the effects of crop management practices on soil health. We considered three fertilizer treatments (nitrogen (N; 40-80 lbs.), manure, peavine), two burn treatments (spring burn, fall burn), three tillage treatments (minimum tillage, fall tillage, conventional tillage), and three controls (no additions, no burn, no-till) in three winter wheat experiments. Nematodes were collected via soil sampling and quantified pre-harvest in 2022 and 2024. In 2022, more RL's were observed in the spring burn compared to the no burn control, the non-fertilized control compared to the 80 lbs. N addition, and no-till compared to conventional tillage. There were no observed differences between organic vs. inorganic N amendments, minimum tillage vs. fall tillage, and fall burn vs. spring burn or no burn control. In 2024, there were no observed differences between fertilizer and burn treatments, but more RL's were again observed in the no-till vs. the conventional tillage control. As hypothesized, we expect that management effects on soil health are driving these differences but varied rainfall between our two study years may be causing inconsistent results. Thus, more research is needed to determine if the inconsistencies between years of data collection persist. With additional field samples, we aim to gain a deeper understanding of how agricultural management practices in wheat-based cropping systems influence *Pratylenchus spp.* populations. This knowledge will help growers make informed, data-driven decisions to better manage soil health and crop productivity.

Image 1. Soil core samples from which nematodes were extracted. Cores were taken with a slide hammer using a 2x6 in plastic sleeve.

Image 2. A live Pratylenchus spp. nematode collected from CBARC observed under a light microscope. The mouth and stylet are clearly visible.

Integrated Weed Control for Cereal Grain Cropping Systems

A.D. Esser
WSU Extension

Weeds and herbicide resistant weeds are the single greatest barrier farmers in the dryland cereal grain cropping region of the Inland Pacific Northwest face in today's agriculture and is a large threat to conservation tillage moving forward. I have dedicated a large portion of my time to providing and facilitating research and outreach to this significant challenge farmers face. In my region, downy brome

(*Bromus tectorum*) resistant to Group 2 and Group 9 herbicides is the biggest issue; however, my program is focused on the larger problem across eastern Washington. My efforts include using the WSU Wilke Research and Extension Farm and large-scale research to 'show-and tell' farms how they can economically use a long-term cropping plan to get multiple effective herbicides onto the ground, and how to use targeted tillage to enhance winter annual weed control for an integrated approach. My program is also looking at biological weed control for enhanced long-term control in a series of large-scale demonstrations across the dryland wheat producing region of Adams County. This barrier farmers face will truly take a combination of chemical, physical and potentially biological methods to maintain economically viable winter wheat production. Over the last two winter grower meeting seasons I have presented trial results and WSU Wilke Farm experiences at 37 meetings to over 2,200 participants and have started to see adoption of these practices.

Stripe Rust Management and Research in 2024

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[1]USDA-ARS Wheat Health, Genetics, and Quality Research Unit; [2]Dept of Plant Pathology, WSU

Stripe rust was accurately forecasted in early January and March based on the 2023-24 winter weather data and monitored in the Pacific Northwest throughout the crop season. Rust updates and recommendations were provided to growers throughout the crop season. Stripe rust of wheat was severe on winter wheat in the eastern Pacific Northwest due to the early start of the disease. Based on the forecasts, rust updates, and recommendations, the application of fungicides in the early growth season prevented epidemics and unnecessary use of fungicides, saving growers multimillion dollars in 2024. We tested 15 fungicide treatments in a randomized complete block design experiment with four replications on a susceptible winter wheat variety (PS 279) near Pullman, Washington (WA) under natural infection of the stripe rust pathogen. The first fungicide application timing at the early jointing stage (Feekes 5) was made on May 15 when stripe rust was 1 to 4% severity in all plots. The second application at the boot stage (Feekes 10) was conducted on May 30 when stripe rust was 30 to 55% severity in unsprayed plots. Rust severity was assessed four times for each plot during the rust season. The plots were harvested individually on August 1, and rain yield and test weight were measured for each plot. Area under disease progress curve (AUDPC) was calculated for each plot using the five sets of severity data. Relative AUDPC (rAUDPC) was calculated as percent of the non-treated check. Rust severity, rAUDPC, grain test weight, and yield data were subjected to analysis of variance, and means were separated by Fisher's protected LSD test. The results are summarized in Table 1.

Table 1. Summary of fungicide tests on susceptible winter wheat (PS 279) near Pullman, WA in 2024

Treatment[a] Fungicide, rate (fl oz/A)	Growth stage (Feekes)[b]	Stripe rust severity (%)[c] May 14 E. jointing	May 29 Boot	June 12 Flowering	June 21 Milk	Relative AUDPC	Test weight[c] (lb/bu)	Yield Mean[c] (bu/A)	Increase %
No fungicide	...	2.25 AB	32.5 B	70.0 A	97.8 A	100.0 A	54.2 EF	49.8 J	0.0
Quadris, 6.0	5	2.25 AB	5.0 CD	51.3 B	99.0 A	64.9 CD	52.2 G	61.8 I	24.1
Tilt, 4.0	5	1.75 B	6.5 CD	63.8 A	98.5 A	74.1 BC	53.5 FG	65.4 HI	31.2
Tilt, 4.0	10	2.50 AB	36.3 AB	48.8 BC	65.0 B	80.7 B	58.0 A-C	69.5 G-I	39.5
Quilt Xcel, 14.0	5	2.25 AB	5.0 CD	48.8 BC	97.3 A	62.8 D	53.8 FG	71.1 F-H	42.8
Quadris, 6.0	10	2.00 AB	38.8 AB	41.3 C	66.3 B	77.9 B	57.4 B-D	73.9 FG	48.3
Trivapro, 13.7	10	2.00 AB	40.0 A	42.5 BC	60.0 B	78.2 B	58.3 AB	74.6 FG	49.8
Quilt Xcel, 14.0	10	3.00 A	38.8 AB	41.3 C	50.0 C	74.1 BC	58.6 AB	77.3 E-G	55.3
Quadris, 6.0; Quadris, 6.0	5; 10	2.25 AB	7.5 CD	15.0 D	35.0 D	26.3 E	56.4 CD	77.6 E-G	55.9
Trivapro, 9.4	5	2.50 AB	3.8 D	42.5 BC	97.3 A	57.7 D	55.9 DE	79.1 D-F	58.8
Tilt, 4.0; Tilt, 4.0	5; 10	2.25 AB	6.3 CD	13.5 DE	20.0 E	20.4 EF	59.0 AB	83.6 B-E	67.9
Tilt, 4.0; Quilt Xcel, 14.0	5; 10	2.50 AB	11.3 C	12.5 DE	17.5 EF	23.4 EF	58.3 AB	86.8 BC	74.3
Quilt Xcel, 7.5; Quilt Xcel, 7.5	5; 10	3.00 A	7.5 CD	7.5 DE	10.0 G	15.2 FG	59.2 AB	89.0 BC	78.7
Tilt, 4.0 + Quadris, 6.0; Tilt, 4.0 + Quadris, 6.0	5; 10	2.00 AB	7.0 CD	7.0 DE	8.8 G	13.7 FG	59.2 AB	93.7 B	88.2
Trivapro, 9.4; Trivapro, 13.7	5; 10	2.00 AB	4.5 CD	5.0 E	7.5 G	9.9 G	59.7 A	93.9 B	88.6
Tilt, 4.0; Trivapro, 13.7	5; 10	2.50 AB	7.5 CD	10.0 DE	11.8 FG	17.1 EF	59.8 A	104.4 A	109.5
LSD ($P \leq 0.05$)		1.17	6.93	9.43	6.45	10.62	1.78	8.47	

[a] 0.25% v/v NIS was included in each application of all treatments.
[b] The application at Feekes 5 (early jointing) was done on May 15 and at Feekes 10 (boot) on May 30, 2024.
[c] Means sharing one or more letters are not significantly different at $P = 0.05$.

We tested 23 commercially grown winter wheat varieties, plus susceptible check PS 279 near Pullman under natural infection of the stripe rust pathogen. The 24 entries were arranged in a randomized split-block design with four replications. Quilt Xcel was sprayed at the rate of 14.0 fl oz/A at the early jointing stage (Feekes 5) on May 15 when stripe rust was just appearing (0-0.1% severity) and sprayed again at the same rate on May 30 when plants were at the boot stage (Feekes 10) and stripe rust in the non-sprayed PS 279 plots was 25-40% severity. Stripe rust severity was assessed four times from each plot during the rust season. The plots were harvested on August 2, and grain yield and test weight were measured for each plot. The data analyses were done in similar ways as described above. The results are summarized in Table 2.

Table 2. Summary of winter wheat yield losses and fungicide responses in the experimental field near Pullman, WA in 2024

	rAUDPC (%)			Test weight (lb/bu)			Yield (bu/A)			Yield loss (%)	Yield inc. (%)	Relative	Fungicide
Variety	No spray	Spray[a]	Reduction	No spray	Spray[a]	Increase	No spray	Spray[a]	Difference	by stripe rust	by fungicide	yield loss (%)	rating[b]
PS279	100.0	9.6	90.4 *	52.4	57.6	5.2 *[c]	47.9	109.0	61.2 *	56.1	127.8	100.0	2
UI Magic	36.9	3.9	33.0 *	54.5	59.6	5.1 *	77.6	130.2	52.6 *	40.4	67.8	72.0	2
Curiosity CL+	21.1	6.7	14.4 *	52.5	52.4	-0.2	112.4	138.4	26.1 *	18.8	23.2	33.5	1
LCS Jet	19.2	5.1	14.1 *	58.7	60.0	1.3	114.0	139.2	25.1 *	18.1	22.0	32.2	1
Otto	12.3	4.5	7.8 *	53.6	52.9	-0.6	119.7	144.2	24.5 *	17.0	20.4	30.2	1
Keldin	17.0	4.0	13.0 *	60.3	61.2	0.9	103.9	119.1	15.2	12.8	14.7	22.8	1
Mela CL+	15.7	6.9	8.8 *	56.1	57.4	1.3	118.7	134.8	16.0	11.9	13.5	21.2	1
LCS Helix	20.9	6.2	14.7 *	61.8	62.7	0.9	105.1	117.7	12.6	10.7	11.9	19.0	1
Northwest Duet	3.4	3.2	0.2	57.8	58.2	0.5	145.0	159.0	14.0	8.8	9.7	15.7	1
ARS-Crescent	13.8	2.8	11.0 *	55.8	55.9	0.1	116.1	125.2	9.1	7.3	7.8	13.0	0
Stingray CL+	6.8	6.3	0.5	54.9	55.1	0.2	112.8	121.0	8.1	6.7	7.2	12.0	0
LCS Shine	1.7	1.6	0.1	59.3	60.0	0.7	138.1	147.9	9.8	6.6	7.1	11.8	0
Castella	14.2	4.5	9.7 *	58.1	59.1	1.0	116.7	121.9	5.1	4.2	4.4	7.5	0
Northwest Tandem	2.3	2.8	-0.6	58.4	58.6	0.1	133.8	138.5	4.8	3.4	3.6	6.1	0
AP Iliad	2.4	2.2	0.3	60.1	59.9	-0.3	137.6	141.5	3.9	2.8	2.8	4.9	0
Pritchett	5.5	2.0	3.5	56.2	56.8	0.7	141.6	145.4	3.8	2.6	2.7	4.7	0
LCS Blackjack	3.7	3.4	0.3	55.3	56.4	1.1	142.0	145.0	3.1	2.1	2.1	3.7	0
LCS Artdeco	8.5	3.8	4.7 *	56.3	57.2	1.0	126.4	129.1	2.7	2.1	2.1	3.7	0
Piranha CL+	2.2	1.5	0.7	56.3	57.3	1.0	135.8	137.3	1.5	1.1	1.1	2.0	0
SY Assure	2.4	2.3	0.2	61.5	61.5	0.0	130.8	131.5	0.6	0.5	0.5	0.8	0
M-Press	4.5	4.3	0.3	58.6	58.7	0.1	131.6	131.2	-0.4	-0.3	-0.3	-0.5	0
Resilience CL+	6.1	6.1	0.0	57.9	58.4	0.5	131.6	130.2	-1.4	-1.1	-1.1	-1.9	0
LCS Hulk	8.3	9.8	-1.5	58.8	59.8	1.0	137.1	135.6	-1.5	-1.1	-1.1	-2.0	0
SY Dayton	5.1	4.0	1.1	58.0	57.5	-0.6	125.4	122.4	-2.9	-2.4	-2.4	-4.3	0
Mean (excl. PS279)	10.2	4.3	5.9 *	57.4	58.1	0.7	124.1	134.2	10.1	7.5	8.1	13.4	0
LSD (P = 0.05)			4.8			2.7			25.0				

[a] Quilt Xcel at 14.0 fl oz/A was sprayed first time at early jointing stage (Feekes 5) on May 15 when stripe rust was just appearing (0-0.1%) in the field, and second time on May 30 when plants were at boot stage (Feekes 10) and the non-first spray PS 279 plots had 25-40% stripe rust severity.

[b] Rating = the single digit number of yield difference/LSD. Varieties with rating 0 does not need fungicide application, those with rating 1 may or may not need fungicide application, and those with rating 2 need application.

[c] * The difference between the non-sprayed check and fungicide spray plots is significant at $P \leq 0.05$.

In 2024, we evaluated more than 16,000 wheat and barley entries for resistance to stripe rust. Through these tests, susceptible breeding lines can be eliminated, which should prevent risk of releasing susceptible varieties and assisted breeding programs to release new varieties of high yield and quality, good adaptation, and effective disease resistance. We collaborated with public breeding programs in releasing and registered seven wheat varieties. Varieties developed by private breeding programs were also tested for stripe rust resistance in our program. we identified a new gene for high-temperature adult-plant (HTAP) resistance to stripe rust in a wheat line carrying all-stage resistance Yr8. Using the GWAS (genome-wide association study) and marker-assisted detection approaches, we identified 39 stripe rust resistance loci in a HTAP resistance panel of 465 winter wheat entries and developed Kompetitive allele specific PCR (KASP) markers for eight loci conferring strong HTAP resistance. We completed a study of GWAS mapping of 44 loci associated to stripe rust resistance in a spring barley panel of 318 accessions and developed KASP markers for eight broad spectrum resistance loci. These markers can be used in marker-assisted selection for developing new wheat and barley varieties with stripe rust resistance.

Effects of Climate-Smart Agriculture on Pest and Beneficial Soil Arthropod Communities

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Climate change has presented a significant challenge to agricultural systems, particularly in dryland regions. Reported impacts on soil biodiversity and health have directly affected crop production. As major components of soil biodiversity, soil arthropods serve as crucial indicators of soil health. They contribute to the decomposition of organic matter, nutrient cycling, and enhancing the resilience of soil ecosystems. While adopting climate-smart practices to mitigate and adapt to climate change is essential, the effects of these agricultural strategies on soil arthropods remain under-researched. Therefore, this study aims to investigate the effects of eight different climate-smart agriculture practices on soil arthropod biodiversity, crop performance, and soil health within the Pacific Northwest dryland farming system.

The research is being carried out at the University of Idaho (UI) Moscow benchmark farm as part of the Innovative Agriculture and Marketing Partnership (IAMP), Idaho's climate-smart agriculture project. Eight climate-smart treatments are: (i) Business as Usual (BAU: Typical rotation with winter wheat and tillage), (ii) compost treatment in which 15% of nitrogen is sourced from compost, (iii) BAU with no fertilizer, (iv) inter-seed with pea and canola, (v) reduced nitrogen levels by 15% for winter wheat and spring barley, (vi) spring cover crop, (vii) BAU canola, and (viii) BAU peas. These treatments are implemented using a randomized complete block design (Fig. 1).

Figure 1. Research Site-UI Moscow benchmark farm with eight climate-smart agricultural practices and 43 plots (15 plots of 30 m x 80 m length and 28 of 10 m x 80 m length). Chickpeas were planted on all plots in 2024 and soil arthropod samples for baseline data were collected after harvest. Soil arthropod samples will be collected in 2025 after implementing climate-smart agricultural practices.

We hypothesized that after implementing climate-smart agricultural practices, the soil arthropod composition would show divergence due to the creation of different microhabitats that influence the diversity of soil arthropod communities. Therefore, in the fall of 2024 ten soil cores from each of the 43 plots were collected to extract the soil arthropod communities using Berlese-Tullgren funnels to obtain baseline data before applying climate-smart agricultural practices (Fig. 2). Arthropods were identified to assess community composition.

The baseline results indicate that the soil arthropod community structure was similar across the experimental plots, with considerable overlap in composition. Mites (Oribatida: 28%, Mesostigmata: 26%, and Prostigmata: 8%) and springtails (Collembola: 30%) dominated the arthropod specimens (Fig. 3).

Data will be collected after implementing climate-smart practices in the summer of 2025 to assess the differences from the 2024 baseline results. Based on field data, soil arthropod sampling, and soil parameter measurements will be conducted. Soil health will be evaluated using soil arthropods as biological indicators through the QBS-ar index (Soil Biological Quality Arthropods), which is based on the ecological-morphological adaptive features of soil arthropods.

The research findings will benefit farmers and the scientific community by facilitating informed decisions regarding management practices that can enhance soil arthropod communities, thereby improving soil health and crop performance.

Figure 2. Berlese-Tullgren Funnel, where soil is placed with a bulb at top for the arthropod extraction.

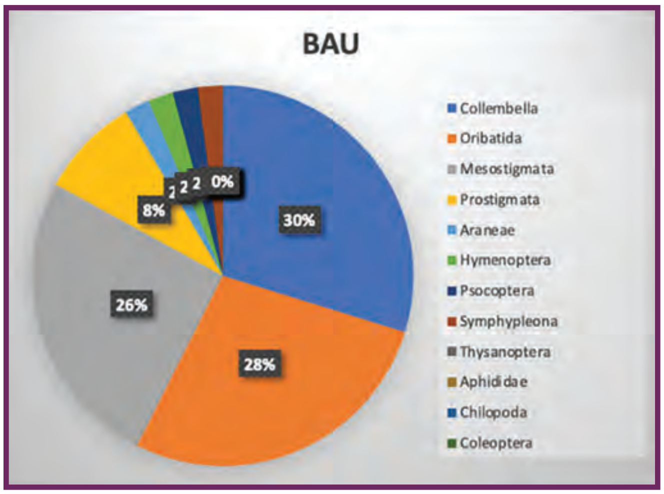

Figure 3 Baseline result before the application of treatments/climate-smart practices. This is the representative figure of the arthropod community composition where the Acari and Collembola groups are in highest number.

Influence of Soil pH on Weed Growth and Crop Competition in Northern Idaho

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Continual use of ammonium-based nitrogen fertilizers has led to the acidification of arable land in northern Idaho. In some of these acidified soils, concentrations of soluble aluminum have increased resulting in plant toxicity and reductions in crop yield. Application of calcium carbonate (lime) has long been shown to ameliorate low soil pH, reducing and reversing the harmful effects of soil acidification. The aim of this project is to understand how problematic weeds of the area respond to changes in soil pH, and how soil pH impacts the competition between crops and weeds. Two separate trials were established in fields with a pH below 5.0 in northern Idaho to determine whether amending soil with lime has any impact on weed density and crop competition. These field trials, located at Potlatch and Lenville, were established in 2016 and 2023, respectively, and were both subject to variable rates of ground limestone (No lime, 1, 2, and 3 tons/A). Both locations were planted with winter wheat in the fall of 2023. Soils were sampled at four depths (0-3, 3-6, 6-9, and 9-12 inches) in the spring to determine soil pH and soluble aluminum concentrations. The two locations shared similar results, with soil pH increasing incrementally and aluminum concentrations decreasing substantially as the lime rate increased, especially in the upper 6 inches.

Weed seedling density surveys were conducted in late April and utilized a 2.8 ft2 quadrant three times in each plot to count and identify weed seedlings present. Weeds appeared to be relatively uniformly distributed throughout plots of similar liming treatments. Mayweed chamomile was the dominant weed present at both locations and was significantly reduced with the application of lime at both locations (Fig. 1). Prior to harvest, weed biomass measurements were made, separating the biomass into grassy weed or broadleaf weed (Fig. 2). The dry weight of grassy and broadleaf weeds at the Potlatch site was significantly reduced with increasing lime rates, particularly the grassy weeds at the 3 ton/A rate and broadleaf weeds, namely mayweed chamomile. Weed biomass at Lenville was quite low and not influenced by lime treatment.

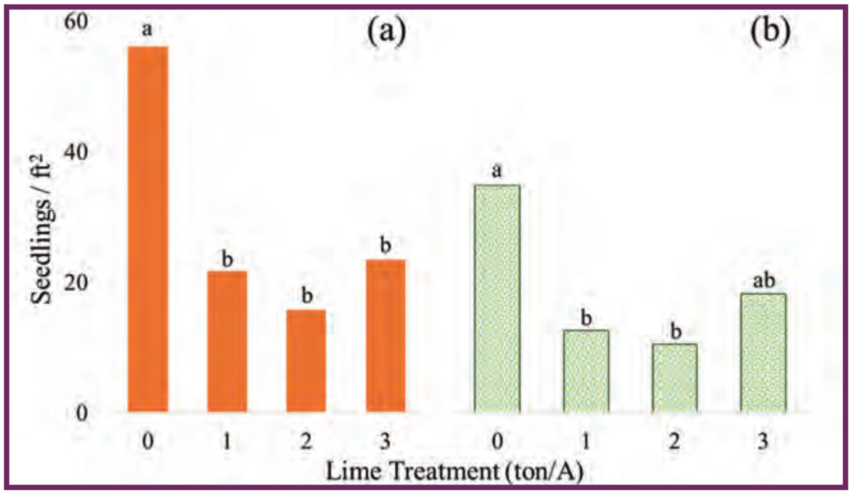

Figure 1. Mayweed chamomile seedling counts at (a) Lenville and (b) Potlatch. Treatments with the same letter are not significantly different using Tukey's HSD (a =0.05).

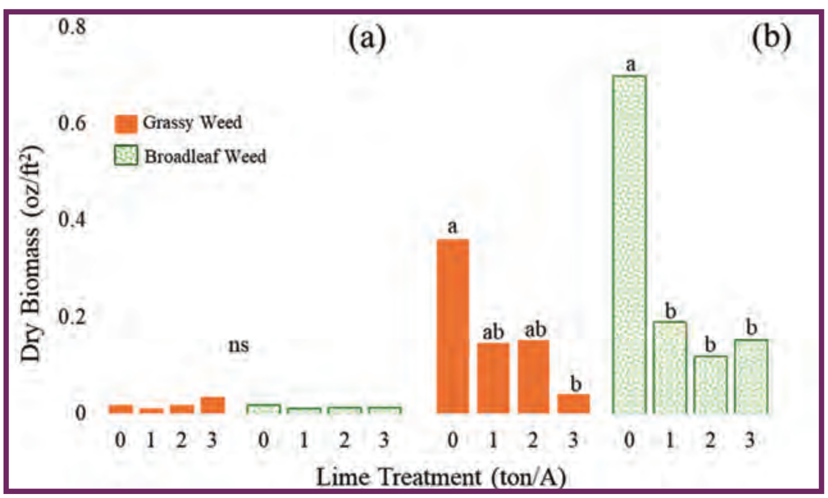

Figure 2. Biomass of grassy and broadleaf weeds at (a) Lenville and (b) Potlatch. Treatments with the same letter are not significantly different using Tukey's HSD (a=0.05).

To assess crop health and competitiveness with weeds, tiller counts, mature biomass and yield were assessed (Table 1). Although there was no significant difference in any of the measurements at the Lenville site, tiller number, dry wheat biomass and yield all significantly increased with higher lime rates at Potlatch. While weed seedling densities differed between treatments at Lenville, canopy closure occurred relatively uniformly across the entire site, driving increased crop competition, uniform yields, and the reduction in the pre-harvest weed biomass. At the Potlatch site, mayweed chamomile, Italian ryegrass, and wild oat were abundant and competed strongly with the winter wheat in the "no lime" treatments, likely contributing to or resulting from the poor plant growth and ability to compete. The weed seedbank from each of these locations is currently being assessed to determine the additional contribution of increased crop competition on reducing weed seed populations. Preliminary results from the first season of this study indicate that liming to increase soil pH suppresses weed growth and improves crop competition through improved plant health. Growers can use this information as another piece of evidence supporting the benefits of lime application. In addition to improved crop yield, there may be an improvement in the effectiveness of herbicide applications, slowing the spread of herbicide-resistant weeds. The continuation of this research will provide insight into optimizing soil pH for wheat production and weed management.

Table 1. Number of tillers, dry biomass and seed yield for winter wheat at Potlatch and Lenville.

Location	Treatment	Tillers (tillers/ft²)	Dry Biomass (oz/ft²)	Yield (bu/A)
Potlatch	No Lime	13 a[z]	1.7 a	19 a
	1-Ton	19 b	3.0 b	35 b
	2-Ton	18 ab	3.5 bc	43 c
	3-Ton	22 b	4.4 c	46 c
Lenville	No Lime	37	6.2	74
	1-Ton	43	7.1	73
	2-Ton	41	7.2	78
	3-Ton	39	6.9	75

[z]Means within a column followed by the same letter are not significantly different using Tukey's HSD (a=0.05). The two locations were analyzed separately.

Herbicide Resistant Wild Oat Survey in Northern Idaho and Eastern Washington

Traci Rauch and Joan Campbell
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The Pacific Northwest of the United States is a productive wheat growing region with significant yield loss from annual grass weeds. Persistent use of herbicides with the same modes of action has resulted in the selection of many herbicide-resistant weeds. Resistance to herbicides used for annual grass control is a problem for farmers in the region. A survey in 2023 of 59 fields in northern Idaho and eastern Washington was conducted to determine the extent of wild oat resistance to grass herbicides commonly used in winter wheat-cropping systems. Plants were grown from collected seed samples in a greenhouse and were tested for resistance to Osprey, Aggressor, Tacoma, Axial XL, Shadow, FarGo, Sonalan and Roundup Power Max 3. Osprey is an ALS-inhibiting herbicide used in wheat and resistance was observed at 34% of the populations tested. Aggressor, an ACCase-inhibiting non-selective herbicide in grass crops, is used in CoAXium® wheat. CoAXium wheat has been selected for tolerance to Aggressor. Resistance occurred in 17% of the tested populations. Tacoma and Axial XL are ACCase-inhibiting herbicides used in wheat and barley and resistance was observed at 22 and 15%, respectively. FarGo, a pre-emergent lipid synthesis inhibiting herbicide used in wheat and legume crops, had 4% resistant populations. All populations tested were susceptible to Shadow and Sonalan, both herbicides are used in wheat-cropping system rotational crops. Populations susceptible to all four ACCase inhibiting herbicides occurred at 63%. Populations are still being screened with Roundup Power Max 3. Currently, 41% of populations tested are susceptible to all eight herbicides tested.

Plant Derived Herbicides to Combat Problem Weeds in Dryland Cropping Systems

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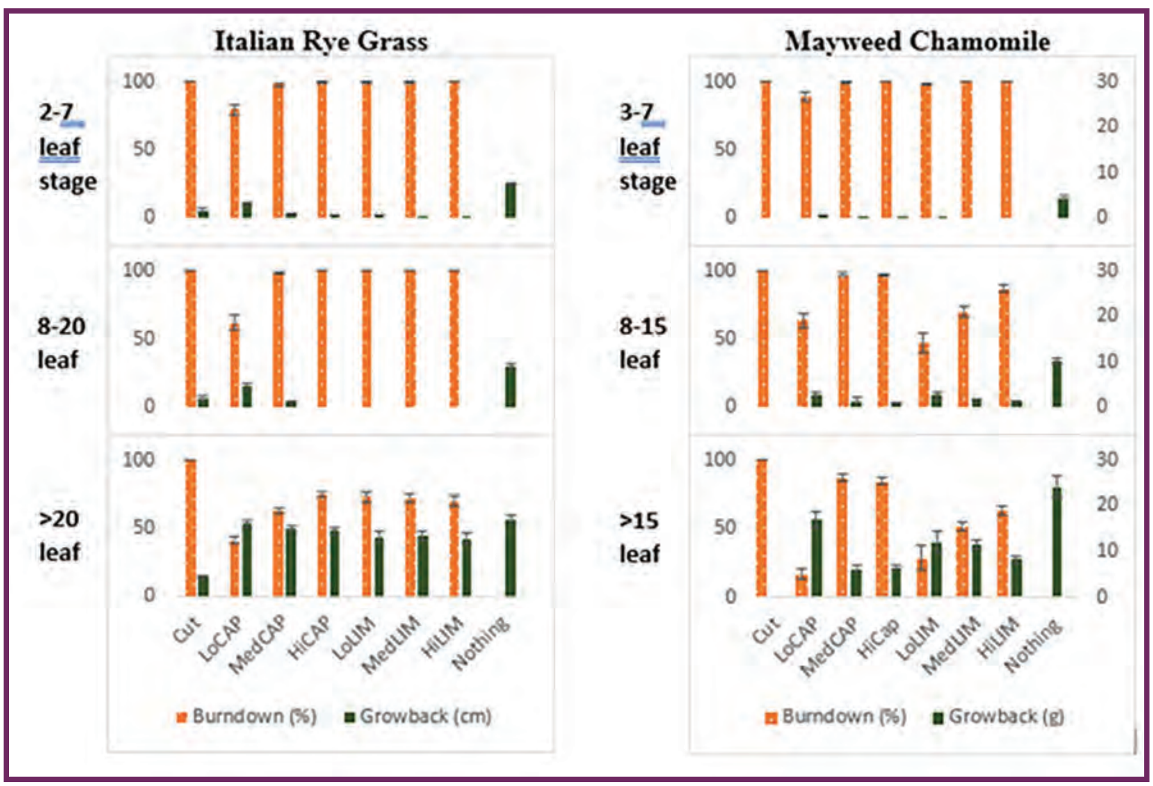
The dryland cropping systems of the inland Pacific Northwest (PNW) are good candidates for the adoption of effective plant derived herbicides. Especially those practicing conservation tillage and relying on herbicides for weed management. This reliance on herbicides has resulted in several herbicide resistant weeds in the region. There are very few options for combating resistant weeds other than tillage; however, tillage could result in increased soil erosion due to the region's unique topography and weather patterns. The lack of viable weed management options, facilitates plant derived herbicides to more seamlessly integrate into existing weed management compared to other technology. Two herbicides registered for use in certified organic production utilizing plant derived active ingredients, capric + caprylic acid (CAP) and d-limonene (LIM), have unique modes of action not targeted by commercial synthetic herbicides.

In a greenhouse study, different life stages (small, medium, large) of problem weeds, including Italian rye grass (*Lolium multiflorum*) and Mayweed chamomile (*Anthemis cotula*), were treated with CAP and LIM herbicides at different labeled concentrations (lo, med, hi) to evaluate burndown and weed growth after treatment. Herbicides were compared to cutting weeds at the soil surface and a do-nothing control. Both herbicides were comparable to cutting when weeds were small, but less effective at controlling very large weeds. Each herbicide's unique mode of action affected grass and broadleaf weeds differently. LIM performed better on grass weeds with less growback, while CAP performed better on broadleaf weeds reducing weed biomass. These herbicides give farmers more options for controlling difficult weeds in dryland cropping systems.



Part 4. Breeding, Genetic Improvement, and Variety Evaluation

From Plot to Composite: Evaluating a New Test for Low Falling Number at Different Levels in the 'Grain Chain'

Anna J. Carroll[1], John H. Kelly[1], Adam Johnson[2], Cat Salois[3], Kirk Freeman[4], Liman Liu[5], Jayne Bock[5], Alison L. Thompson[6], and Amber L. Hauvermale[1]
[1]Dept. of Crop and Soil Sciences, WSU; [2]Envirologix Inc.; [3]The McGregor Company; [4] HighLine Grain Growers; [5]Wheat Marketing Center; [6]USDA-ARS – Wheat Health, Genetics and Quality Research

The Hagberg-Perten Falling Number (FN) is a critical quality parameter in the wheat industry, traditionally assessed using an expensive and slow laboratory-based method. To address the need for a more rapid and mobile test, a novel lateral flow immunoassay (LFI) was developed to predict FN (immuno-FN) by quantifying alpha-amylase activity, the enzyme responsible for low FN due to preharvest sprouting or late-maturity alpha-amylase. To validate the performance of the rapid test across the grain supply chain, a large-scale beta-testing effort was conducted in 2024 across different levels of whet production. Test performance for soft white wheat (SW) is reported here. Plot-level samples (n=240), sourced from the McGregor Co. variety trials in the Pacific Northwest (PNW), were tested at Washington State University. Elevator samples (n=107; HighLine Grain Growers) and PNW composite samples (n=456; Wheat Marketing Center) were evaluated on-site to assess performance in broader industry pipelines. All samples were analyzed for immuno-FN, traditional FN, protein, and moisture content.

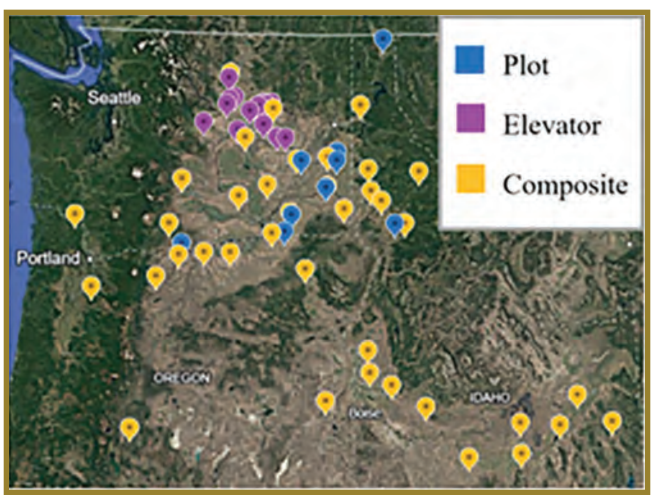


Figure 1. Map of PNW showing sample source locations.

LFI test performance was evaluated by comparing the LFI result with the FN. Immuno-FN results that fell within the manufacturer's parameters were classified as a "pass" and outside of parameters as a "fail" (Fig. 2). Overall accuracy of the LFI test was >83% across all sample types, with the highest accuracy observed at the composite level (93.42%) and more variability at the elevator (88.79%) and plot (83.75%) levels. Factors that may have influenced test reliability include protein content (outside of normal ranges) and starch properties. We hypothesize that environmental factors are likely causes of these variables; ongoing work is being done to validate this. Test performance will continue to be evaluated across different wheat market classes and testing environments to assess the potential of the new LFI assay as a valuable tool for early and on-site grain quality assessment throughout the wheat industry.

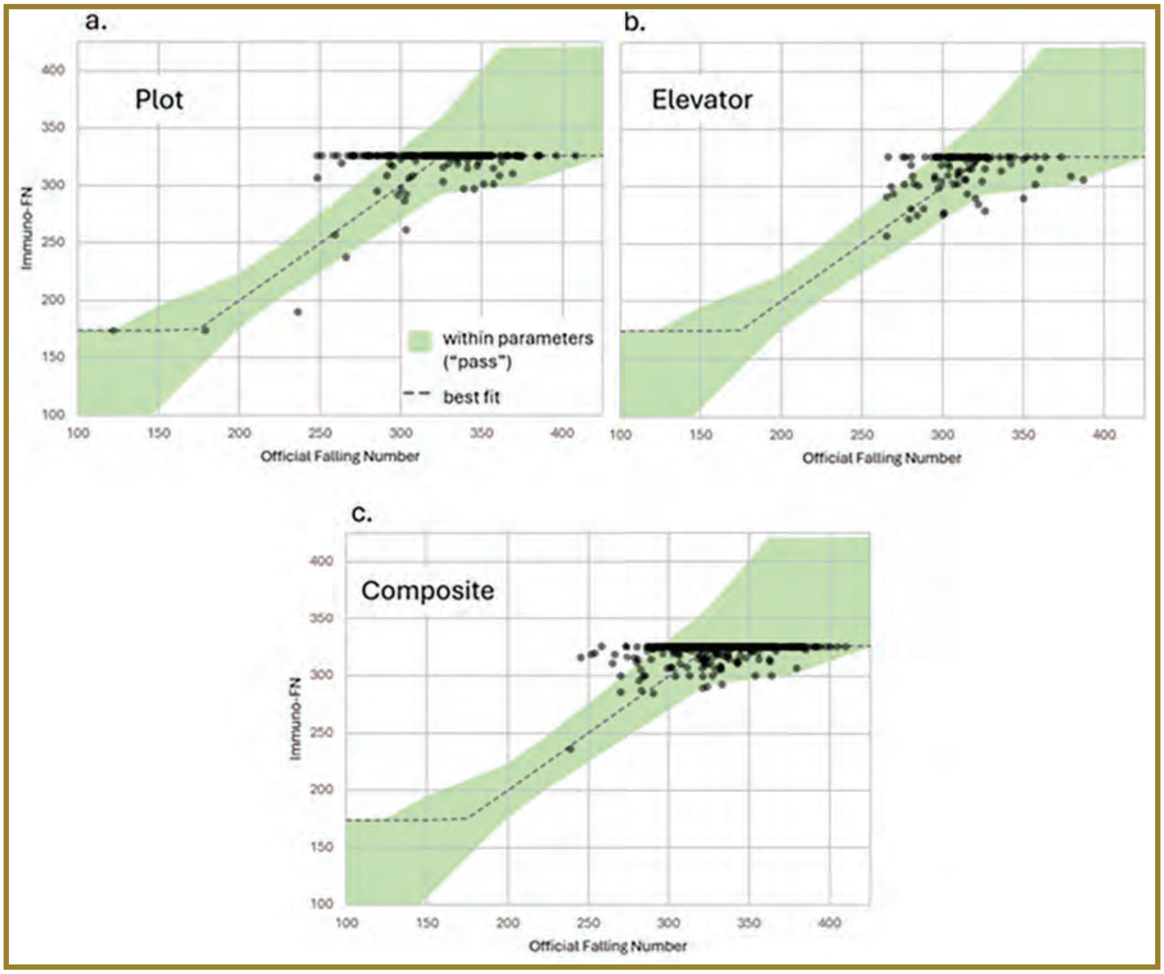


Figure 2. Graphs showing official falling number vs. immuno-FN at plot (2a), elevator (2b), and composite (2c) levels. Green shaded area indicates a "passing" result and the dotted line indicates a 1:1 match between the immuno-FN and falling number.

Field Year 2024 At a Glance with Falling Number

Alison L. Thompson[1,2], Amber L. Hauvermale[2], Clark Neely[2], Cat Salois[3], Ryan Greabner[4], Kim Garland-Campbell[1,2], Michael O. Pumphrey[2], Arron H. Carter[2], Max B. Wood[2], Brady Conway[2], Anna Carroll[2], John Kelly[2]
[1]USDA-ARS Pullman; [2]Dept. of Crop and Soil Sciences, WSU; [3]The McGregor Company; [4]CBARC, OSU

In 2024, several locations in the Pacific Northwest (PNW) experienced one or more, mid to late spring freezing temperatures, prompting a question: what will be the ramifications on end-use quality? To help answer that question, soft white winter and spring wheat samples were collected from 29 locations in Washington (22), Oregon (5), and Idaho (2) representing 35 varieties for a total of 164 samples. Each sample was measured for protein content (%), falling number (seconds)*, alpha-amylase activity (Au), and a starch pasting property called setback (cP). The resulting dataset was examined for location and variety impact on the measured traits, and showed all traits were influenced by location and variety. Further analysis identified five categories that explained differences in the collected samples. Most samples fell into the 'Acceptable FN' category where the average FN was above the 300 second threshold and within acceptable protein ranges. In the remaining four categories, one had protein content above the preferred 8-10% range, two had low FN (<300 sec), and the final category had acceptable FN and protein, but had increased alpha-amylase activity (Fig. 1).

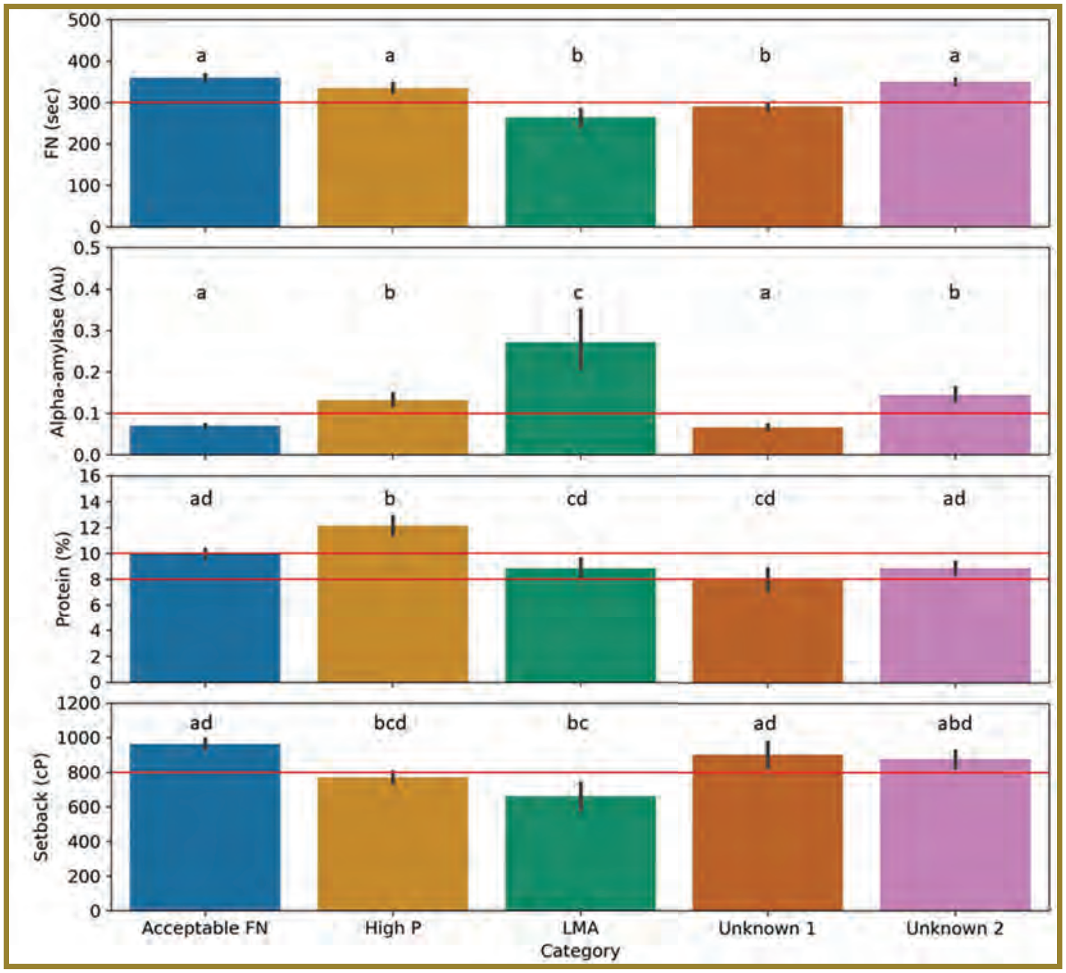


Figure 1 shows the average value, and deviation from the average, for each measured trait within the five identified categories. The letters above each bar represent significant differences between the categories within each measurement. Categories that have the same letter were not significantly different from each other. The red line indicates the minimum acceptable falling number (300 sec), the alpha-amylase activity associated with a falling number of 300 seconds, the preferred protein range for soft white wheat (8-10%), and the starch pasting setback associated with a falling number of 300 seconds when alpha-amylase and protein are within 'normal' range.

Further examination of the two categories with low FN found that one was due to late-maturity alpha-amylase (LMA), the result of untimely production of the alpha-amylase enzyme in developing grain*. The second category with low FN, 'Unknown 1', did not have elevated alpha-amylase activity excluding LMA and preharvest sprouting*, another source of low FN in the PNW. Furthermore, samples in 'Unknown 1' had, on average low protein, less than 8%, and increased setback compared to the LMA category, providing evidence that 'Unknown 1' results from a new cause of low FN (Fig. 1). While a new cause of low FN is discouraging, the low alpha-amylase activity and increased setback indicate that intentional blending with 'Unknown 1' grain lots should not reduce FN, nor should it significantly impact end-product quality (cakes, cookies etc.). Research is already underway to evaluate these hypotheses and determine the cause of 'Unknown 1'. The results of this research will be used to understand genetic factors for variety improvement, and post-harvest grain management strategies to reduce the financial impact to growers.

The category with grain above the preferred protein range ('High P') presents two major concerns, first soft white wheat over 10% protein may receive discounts*, as much as $0.50 per bushel. Second, even though the FN in this category was acceptable, the average alpha-amylase activity was high. Protein is known to 'buffer' a FN because the gluten protein complex will increase viscosity. However, the presence of alpha-amylase activity means grain from the 'High P' category, when blended, may increase the risk of low FN in otherwise acceptable grain. Extra care is needed for intentional blending with 'High P' grain. The final category, 'Unknown 2', presents similar concerns with those of 'High P' in that increased alpha-amylase activity was detected yet samples had an acceptable FN. As the protein content for 'Unknown 2' was within the preferred range, it is unclear at this time what is causing the FN to remain high in the presence of elevated alpha-amylase. One possibility, given the high setback results, is that these samples contain amylase resistant starch, however more work is needed to test this hypothesis. Overall, the 2024 soft white wheat quality for the PNW met preferred market specification with only a few isolated events of low falling number or high protein. A more in-depth look at the quality of PNW grain can be found in the U.S. Wheat Associates Crop Quality Report*. The possible identification of a new low falling number cause and amylase resistant starch shows more work is needed to understand the complexities of falling number and provide improved testing solutions to identify problems.

* Learn more about these topics:
Falling number: https://wheatlife.org/wp-content/uploads/2023/10/10_WLNov23web.pdf
Late-maturity alpha-amylase: https://acsess.onlinelibrary.wiley.com/doi/full/10.1002/crso.20359
Preharvest sprouting: https://acsess.onlinelibrary.wiley.com/doi/full/10.1002/agj2.21701
Protein discounts: https://www.fsa.usda.gov/sites/default/files/documents/2024-Discounts-for-Wheat-Barley-and-Oats.pdf
Crop quality report: https://uswheat.org/crop-quality/2024-soft-white-regional-report-2/

The USDA-ARS Western Wheat Quality Laboratory

Dr. Sean M. Finnie
USDA-ARS Western Wheat Quality Laboratory

Sean M. Finnie, Alecia Kiszonas, Gail Peden, William J. Kelley, Shelle Lenssen, Janet Luna, Stacey Sykes, Robin Saam, Kelly Leonard, Judene Mclane, Megan Russo, Daniel Zborowski, Gabriely Alfaro, Galina Mikhaylenko, Julie Jenkins, Emily Klarquist, Shauna Flores, Michaela Schulz, and Sean Larsen.

The mission of the USDA-ARS Western Wheat Quality Lab is two-fold: conduct milling, baking, and end-use quality evaluations on wheat breeding lines, and conduct research on wheat grain quality and utilization. Our web site: http://wwql.wsu.edu/ provides great access to our research and publications.

Our current research projects include super soft kernel texture, grain hardness, lipids, starch in field peas, and high-amylose noodles. Our recent publications include characterization of starch fraction from wet protein isolation process in pea (*Pisum sativum* L.) published in Legume Science. Research on the effects of pea flour substitution and sodium metabisulfite on physical and sensory properties of pancake formulations was published in Cereal Chemistry. Research on how protein functionality is critical for the texturization process during high moisture extrusion cooking was published in ACS Food Science and Technology. A genome-wide association study on chickpea (*Cicer arietinum* L.) yield and nutritional components was published in Euphytica. Research on the proteomics analysis of round and wrinkled pea (*Pisum sativum* L.) seeds during different development periods was published in Proteomics

Journal. A study on the development of a novel pressure vessel system for the simulation of starch expansion—methylated and regular waxy corn behave significantly different with and without cellulose inclusion was published in Starch – Starke. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA ARS scientists include Piranha CL+ and Sockeye CL+.

USDA-ARS Club Wheat Breeding

Kim Garland-Campbell[1], Olufunke Ayegbidun[2], Brian Bellinger[1], Patricia DeMacon[2], Ron Sloot[2], Nuan Wen[2], Marita White[2], and Aicha Djibo Waziri[2]
[1]USDA-ARS; [2]Washington State University

The focus of the USDA breeding program is to develop high quality club wheat and soft white cultivars, and to incorporate germplasm for disease resistance into adapted wheat germplasm. The breeding program has yield trials in 13 locations across Eastern Washington, Idaho, and Oregon that allow us to test our promising new lines in a variety of different climates and endemic diseases, so we can release high-performing varieties adapted to specific PNW conditions. Several of these trials are conducted in collaboration with the WSU Winter Wheat and WSU Cereal Grain Variety Testing Programs.


ARS14X1114RS-3CBW a potential new club wheat release, grown at Spillman Farm 2024.

The top goals for 2025 are to 1) develop earlier maturing club wheat varieties with improved emergence and snow mold tolerance; 2) select club wheat cultivars that meet the quality specifications of our export customers; 3) reduce our breeding cycle time using 'mini-bulk' generation advance; 4) develop herbicide resistant club wheat cultivars in collaboration with the WSU Winter Wheat Breeding Program; 5) screen germplasm for footrot, aluminum, stripe rust, and falling numbers resistance; 6) assess and improve current concentrations of Iron and Zinc and other essential nutrients in club wheat grain and flour.


Summer crew taping single head selections for stripe rust resistance at Spillman Farm in 2024.

We evaluate cultivars and breeding lines for cold tolerance using freezing trials conducted at the WSU Plant Growth Facility. Data are provided to the WSU Cereal Variety Testing Program and regional winter wheat breeders. The mini-bulk rapid breeding technique allows us to rapidly advance early generation nurseries and get them to the field sooner. We are evaluating breeding lines with two-gene resistance to Beyond® herbicide in the field in all our 13 locations. We also have two Clearfield clubs in the Variety Testing CLOAX trials. Additionally, we are evaluating breeding lines with CO-AX resistance at five locations. Several of these populations are also segregating for snow mold resistance. We screen for resistance to stripe rust and stem rust in collaboration with Xianming Chen's and Bob Bruggeman's groups. We evaluate breeding lines and regional nurseries for foot rot resistance at

Spillman Farm. We evaluate breeding lines for Aluminum tolerance at toxic locations at Rockford, WA, in collaboration with the WSU Spring Wheat Program, at Moscow, ID with University of Idaho, and at Enid, OK with the Oklahoma State University breeding program.

We have six breeding lines being evaluated in the Washington Cereal Variety Trials in 2025. Four are in the soft white winter trials and two with the two-gene IMI resistance trait are in the CLOAX trials. We have one breeding line in both the North Idaho and the Oregon State University Variety Trials.

The Washington State University Winter Wheat Breeding and Genetics Program Update

A. Carter, K. Balow, B. Libey, R. Person, and J. Wheeler
Dept. of Crop and Soils Sciences, WSU

The Winter Wheat Breeding and Genetics Program at Washington State University remains committed to developing high yielding, disease resistant, and high end-use quality cultivars to maintain sustainability of production. In 2024 we filled some vacancies in the program and now have three full-time technicians focusing on the field portion of the breeding program. One of those technicians also assists in the greenhouse, along with the full-time greenhouse manager, to assist with transitioning material out of the greenhouse and into field evaluations. We are also in the process of filling a vacant molecular laboratory manager, and hope to have that position filled in the next few months, returning the program to full staff levels. While the past year has been one of change, we welcome the new technical staff and are excited to continue to work towards developing the best cultivars for the growers of the state.

Within the breeding program, we continue to use the most efficient and effective methods to develop new cultivars. Genomic selection/prediction, phenomics, and marker-assisted selection are routine efforts in the breeding program now after years of testing for effectiveness and have enhanced our abilities to develop improved cultivars. We have begun adding environmental data from each location where breeding plots are grown to better understand the interaction of lines across locations, identifying the precise environmental factor that might impact a cultivar. Graduate students are still a strong part of this research, being funded by USDA competitive grants to perform this research which in turn benefits the development of cultivars within the breeding program.

While we are still focusing on developing soft white and hard red cultivars for the state, our efforts are being enhanced to develop cultivars with strong herbicide tolerance. There is a strong pipeline of materials within the program carrying tolerance to imazamox. We have enhanced our efforts to develop CoAXium wheat in recent years and have many hard red and soft white lines in advanced testing for commercial release consideration. With our first release of Metribuzin tolerance wheat through Rydrych MZ last year, we have made several crosses with this line and continue to develop improved cultivars with this herbicide tolerance. In an effort to continue to develop herbicide tolerance in wheat adapted to Washington, this fall we will begin screening 2,800 mutation lines for tolerance to other herbicides that will benefit Washington producers and our diverse cropping systems. This has been a changing priority for the breeding program, and we are enhancing our efforts to develop multiple sources of tolerance to herbicides to provide a variety of options for growers in different cropping systems to rotate through.

We genuinely thank the growers of Washington for their support of the breeding program and look forward to continuing interaction with our stakeholders in the coming years!

Genetics of Acid Soil Tolerance and the Soil-Associated Microbiome in Acid Soils in Wheat

Marita White[1], Timothy Paulitz[2], Kimberly Garland-Campbell[2], Ron Sloot[1], Patricia DeMacon[1], Cody Willmore[2], Nuan Wen[1], and Kurt Schroeder[3]
[1]Washington State University; [2]USDA-ARS; [3]University of Idaho

Use of nitrogen fertilizers acidifies agricultural soil. As soils become increasingly acidic, aluminum normally bound in the soil particles is made available to plants, where it causes issues by stunting root growth and hindering uptake of water and nutrients, resulting in decreased growth and yields. However, some wheat varieties are more tolerant of acidic soil and aluminum than others. This research aims to 1) explore the genetic basis for aluminum tolerance in a group of wheat lines and 2) compare the wheat-associated soil and root microbiome in aluminum-toxic and non-aluminum-toxic soils and with wheat lines that differ genetically in aluminum tolerance. By doing so, we hope to find strategies for wheat that is more resilient to acidic soil.

Figure 1. Four wheat lines grown at Parker Farm near Moscow, ID (pH < 4.2; Al > 470 ppm) displaying variable Al tolerance. From left: moderately tolerant, tolerant, susceptible, susceptible.

This project uses field sites near Rockford, WA, and Moscow, ID for the first aim, and Rockford, WA, Moscow, ID, Pullman, WA, Tensed, ID, and Fairfield, WA for the second aim. These soils have a range of pH and plant-available aluminum (Al) levels. We explored the genetic basis for Al tolerance in a group of wheat lines that were evaluated in the field near Moscow, ID in 2023 and 2024 and Rockford, WA in 2024. This data will be combined with previously collected genetic data as well as previously collected field Al tolerance data on a different group of wheat lines from the USDA and WSU winter wheat breeding programs. These datasets will then be used to identify regions of the wheat genome that may be important for Al tolerance, allowing future work by breeders to improve the Al tolerance of new wheat varieties to help maintain wheat production on acidic soils. The rhizosphere contains the microbial populations from soil that are closely associated with plant roots. These microbes are critical for nutrient uptake in plants. We investigated the wheat microbiome in Al-toxic and non-Al-toxic soils, samples are collected for DNA extraction from the soil, rhizosphere (soil immediately surrounding the roots) and roots for identification of fungi and bacteria using DNA sequencing. So far, soil location and community habitat (soil, rhizosphere, or roots) are the most important factors affecting community composition, but changes in certain microbes between pairs of Al tolerant and susceptible wheat have been observed as well. This data will provide a better understanding of how soil acidification changes the microbiome, and whether the Al tolerance of wheat may be partly mediated by soil microbes. A healthy

Figure 2. AlumPair-01-S (left), an Al susceptible wheat line, and AlumPair-01-R (right), its tolerant counterpart, grown at Parker Farm near Moscow, ID (pH < 4.2; Al > 470 ppm). Note the small root systems with thickened roots in the susceptible line compared to the healthy root systems in the tolerant line.

soil microbiome is important for plants to acquire nutrients and avoid toxins and pathogens. By characterizing the wheat-associated soil microbiome in soils with a range of levels of plant-available Al and in wheat lines that differ for Al tolerance, we will gain a better understanding of how the microbiome is changing under these conditions. This work will lay the groundwork for future studies that find ways to cultivate and maintain a healthy soil microbiome, keeping our soils healthy and productive for future generations.

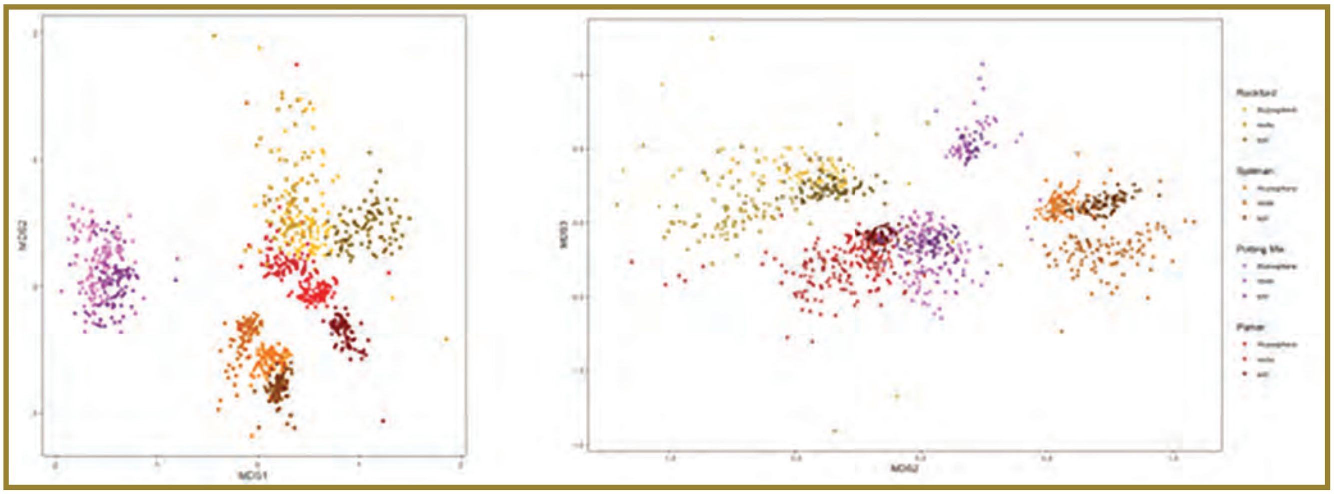


Figure 3. Bray-Curtis NMDS plots for bacterial (left) and fungal (right) sequencing data. These data were collected in a greenhouse experiment where 6 Al tolerant lines and 6 Al susceptible lines were grown in the greenhouse. Soil used in the experiment was from Parker Farm, near Moscow, ID (University of Idaho; pH = 3.83, 359 ppm Al), a grower-collaborator site near Rockford, WA (pH = 3.90, 199 ppm Al), and Spillman Farm, near Pullman, WA (WSU; pH = 4.86, 7 ppm Al), as well as a standard potting mix (Sungro Professional Growing Mix). Points closer together have more similar microbial communities. Sequencing data were resampled 500 times to a sampling depth of 20,000 for fungi and 250 times to a sampling depth of 40,334 before analysis was done to account for sampling depth artifacts introduced during the sequencing procedure.

Assessment of the Variation in Arabinoxylan Concentration in Spring Wheat

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An estimated 95% of Americans consume less than the recommended fiber (USDA-DGA; Thompson and Brick, 2016). On average the gap in fiber intake in the U.S is half (median intake, 12–14 g/d) the recommended target (28–42 g/d). The dietary fiber of interest in this study is arabinoxylan because it correlates nearly perfectly with total dietary fiber. In parallel, because of its high rate of consumption, wheat represents an excellent target to develop varieties with high arabinoxylan content. The gap in fiber intake could be significantly reduced by increasing the arabinoxylan concentration in wheat, especially if the consumption of whole wheat is increased.

The study population used was created by researchers at Washington State University (WSU) using a Multi-Parent Advanced Generation Inter-Cross mating scheme (MAGIC). The MAGIC population was planted in 2023 in paired 1m head rows, spaced 10cM apart, with two replications of a completely randomized complete block design within each block, in Pullman, Washington (WSU Spillman Agricultural research Farm) and Genesee, Idaho (University of Idaho, Kambitsch Research Farm). Arabinoxylan quantification was performed using the method described by Hernández-Espinosa et al. (2024), which has been optimized at the International Maize and wheat Improvement Center (CIMMYT).

Both locations presented similar ranges in arabinoxylan concentrations with values between 38mg/g and 82mg/g xylose (Fig. 1). The distribution of measured values also shows genotypes that had higher concentration of arabinoxylan than all the local variety checks (JD, Glee, Louise, Kelse, Hollis) evaluated in this field experiment suggesting that progress can be accomplished to create higher fiber spring wheat. The European Food Safety Agency (EFSA) recognizes the importance of high-arabinoxylan wheat, and the organization recommends consuming 8g of arabinoxylan-rich fiber per 100 grams of available carbohydrates (EFSA). Based on clinical trials, that target quantity of arabinoxylan was recommended to confer health benefits against the risk of diseases such as diabetes or cancer. In this study we identified two lines with the potential to help reach the EFSA target. Genotype '366b' in the Genesee location had a xylose content of 82.06 mg/g, and the genotype '196a' in the Pullman location had a xylose content of 81.04 mg/g. Therefore, 100 grams of wholemeal of those genotypes reaches the exact target value set by EFSA. Additionally, we investigated the relationship between xylose content and thousand kernel weight, TKW (a proxy for yield). There appears to be no significant correlation between those two traits (Fig. 2). Although ideally a positive relationship would have been preferable, this observation suggests that selection can still be performed independently and simultaneously without negative effect on either trait. Nonetheless, an analysis of variance suggested a significant genotype by environment interaction ($p = 0.0021$) as reported by previous authors (Tremmel-Bede et al., 2020). Therefore, breeding for high fiber content will likely require defining target environments. Future work will contribute to the understanding of the genetic control of arabinoxylan in the study population and the development of genomic breeding approach.

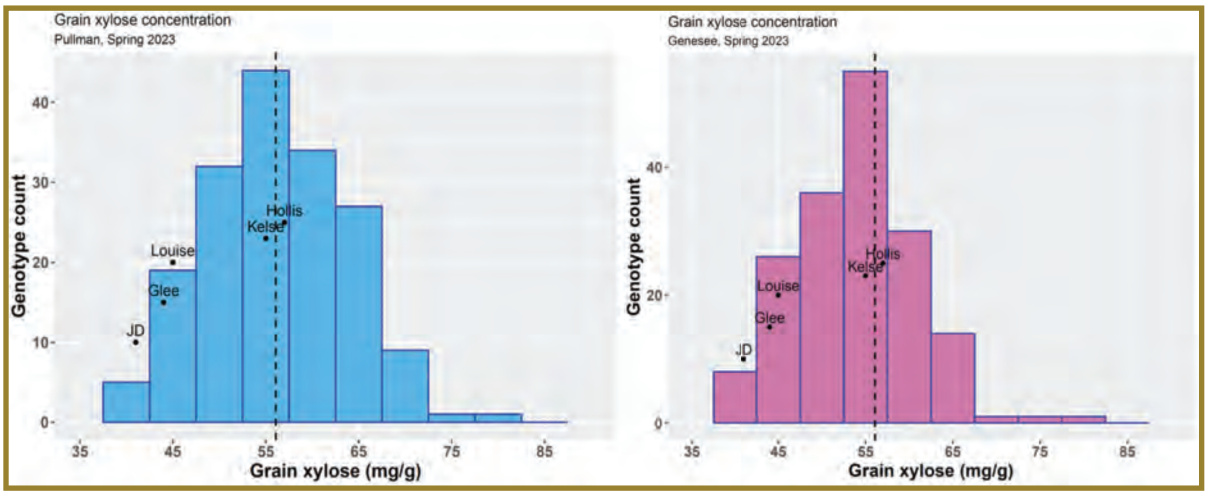

Figure 1. Distribution of the grain xylose content in two field experiments in 2023.

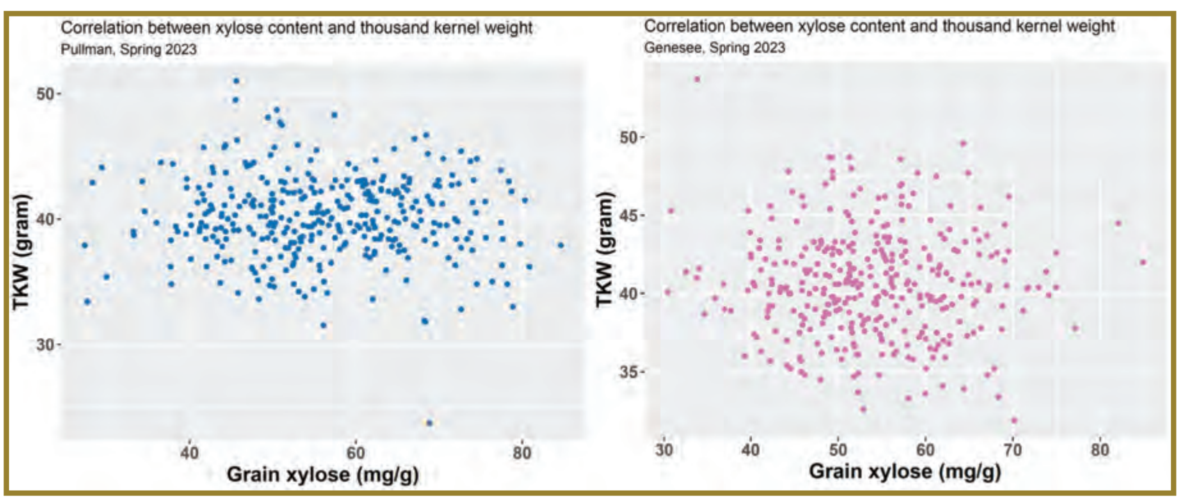

Figure 2. Phenotypic correlation between grain xylose content and grain thousand kernel weight of the two field experiments.

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Fortifying Immunity/Resistance to Hessian Fly in Spring Wheat

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Deployment of resistant spring wheat cultivars is an effective way to reduce Hessian fly (HF) (*Mayetiola destructor*) pressure. Studying the economic impact of HF and benefit of utilizing resistance genes can only be clearly evaluated with the use of near-isogenic lines (NILs). NILs are identical lines developed to have minimal differences in genetic background except for the chromosomal region containing the specific resistance genes in this case being studied, enabling a precise comparison of the impact of these genes on yield under various environmental conditions. Using NILs will allow us to isolate the effects of HF resistance genes from other genetic variables that might influence yield.

Experiments with NILs have been used to quantify the phenotypic effect of specific resistance genes in wheat cultivars, providing valuable insights into the genetic basis of resistance. However, NILs long-term effectiveness in real-world farming conditions remains uncertain due to variable environmental factors. Figuring out how results from NILs experiments can be used over time, where wheat crops face unpredictable challenges, is key. This will help develop spring wheat varieties that can handle climate change and resist HF pressure, supporting the goal of producing enough food for the world by 2050. To address these challenges, two projects are being carried out by the WSU spring wheat program.

In one project we will evaluate the economic impact of resistance genes on spring wheat yield. Previously, we analyzed grain yield and HF data collected from cultivars in the WSU Variety Testing Program. The results (Fig. 1) across different locations and growing seasons indicated that the performance of resistant and susceptible wheat varieties was heavily influenced by a combination of stressors, which include environmental conditions, management practices, and HF pressure. Studies have shown that pests, diseases, and changes in their type/strains can weaken the long-term effectiveness of resistance genes. To use findings from NILs experiments in real-world farming, we would be performing field tests under different locations and weather conditions to see how well these HF resistant genes work in different environments.

Our second project will investigate the impact of extreme temperature on resistance genes. It is important to develop wheat varieties that can maintain resistance to HF in high temperatures. Extreme temperatures have been shown to reduce the effectiveness of resistance genes (Fig. 2). Therefore, to determine the temperature thresholds at which resistance genes are upregulated or downregulated, we will perform a greenhouse experiment to evaluate at what temperatures resistance genes no longer provide defense against HF infestation.

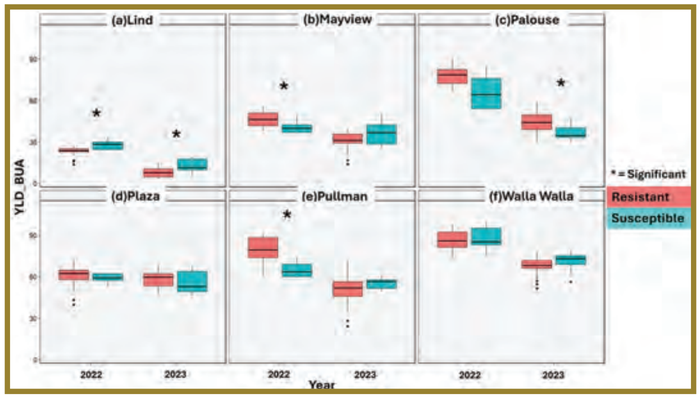

Figure 1. Resistant varieties may not always outperform susceptible varieties.

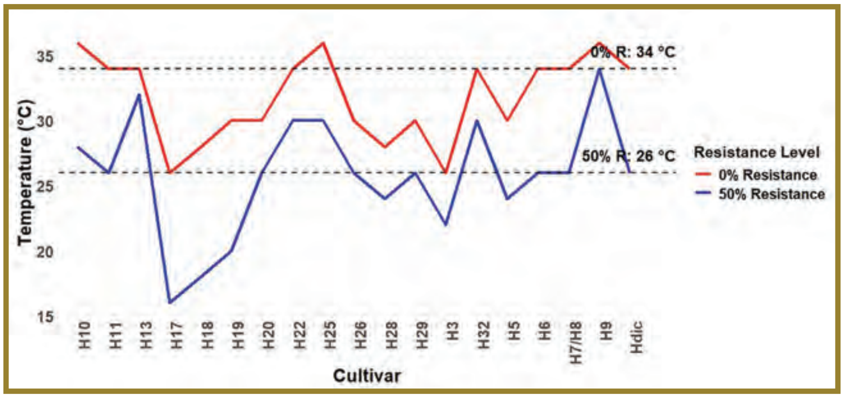

Figure 2. High temperatures can break down resistance in different resistant cultivars (Tang et al., 2018; Melson et al., 2024)

Both projects aim to enhance the effectiveness and economic viability of HF management in wheat production. One looks at how much money farmers can save by using wheat that resists HF, while the other studies how temperature affects the strength of that resistance, thereby informing more targeted and resilient breeding strategies and farmers can choose the right wheat for their local weather.

Artificial Intelligence-Based Predictions of Variety-Level Performance

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Predictive models that accurately forecast crop performance provide valuable insights for agricultural decision-making. Artificial intelligence (AI) models optimize the weighting of key factors—such as genetics, weather, and management practices—generating strong predictive tools. However, their reliance on extensive performance evaluations limits their applicability to newly developed varieties. In contrast, Finlay-Wilkinson (F-W) models—which regress variety performance against environmental means—capture variety-specific plasticity using relatively few evaluations. While effective for characterizing variety performance across tested environments, F-W models alone lack predictive capacity, as environmental means for new environments are unknown. These inherent limitations of AI and F-W models in forecasting variety performance can be reconciled by integrating the two approaches. Specifically, a F-W model can be used to estimate the plasticity of a new variety—that is, how its performance changes relative to environment—using relatively few evaluations. Meanwhile, an AI model can be trained to predict the expected environmental mean performance of a new, untested environment using historical weather and phenotype relationships. By combining these components, it becomes possible to forecast variety-specific performance in new environments

(Fig. 1). Here, we demonstrate the utility of this strategy by predicting performance of 26 spring wheat varieties from the WSU Wheat and Small Grains Variety Testing Trials. This tandem approach accurately predicted grain yields, heading dates, plant heights, and protein contents of all these varieties across the 2019-2023 seasons (Fig. 2). Importantly, prediction accuracy was not dependent on the number of previous evaluations, indicating that this technique could predict variety performance after as little as one year of testing. The capacity to generate accurate, variety-specific predictions has the potential to accelerate the evaluation process of new varieties and to guide future variety selection.

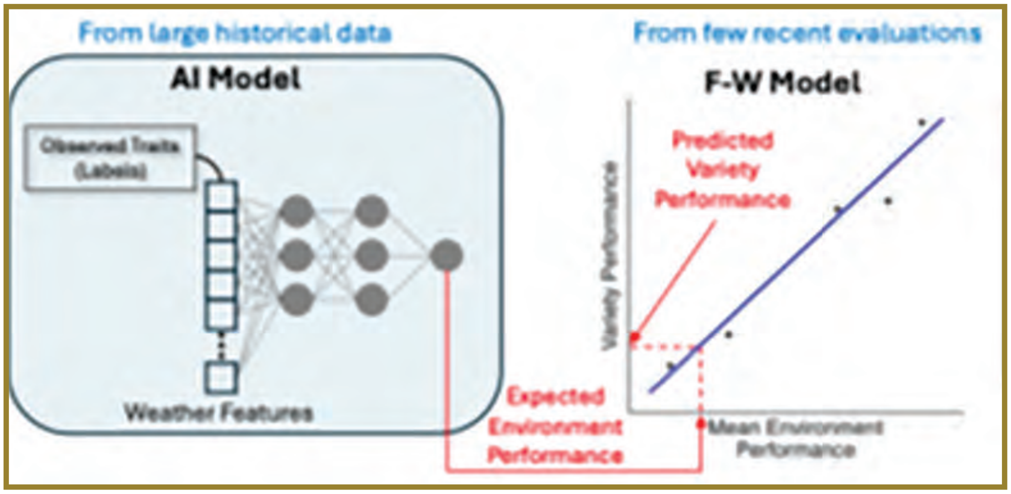

Figure 1. Integration of AI and the F-W model

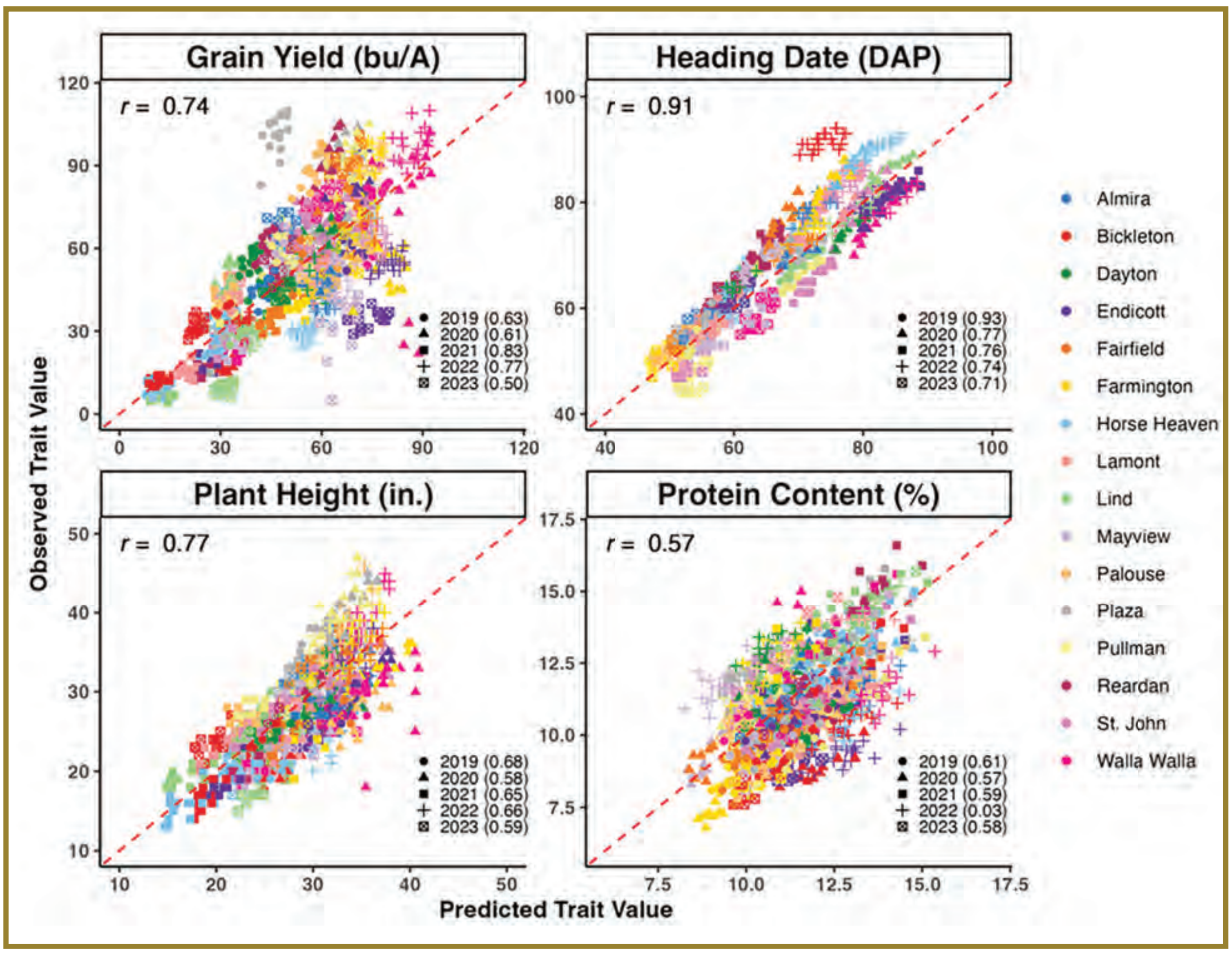

Figure 2. Predicted versus observed trait values for the 26 varieties across 16 locations from 2019-2023.

Utilizing High-Throughput Phenotyping to Identify Metribuzin Tolerance in Winter Wheat

Melinda Zubrod[1], Andrew W. Herr[1], Pia M. Spychalla[2], Elijah Persson-Godon[3], Ian C. Burke[1], and Arron H. Carter[1]
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Plant breeders and weed scientists collaborate to improve weed management by selecting for herbicide tolerance in breeding programs. The application of metribuzin, a Group 5 PSII-inhibiting herbicide labeled for use in wheat, often causes crop injury in current wheat varieties. Developing winter wheat varieties tolerant to metribuzin would enhance integrated weed management strategies by incorporating multiple modes of action. Traditionally, selecting for herbicide resistance in crops has relied on visual estimation, which can be inconsistent and prone to individual bias. This study aimed to improve the accuracy and efficiency of selecting for herbicide tolerance by using a drone-mounted multispectral sensor. Multispectral data was collected on paired rows and advanced generation lines grown in paired plot yield trials. Vegetation indices derived from the multispectral sensor included NDVI, NDRE, TCARI, NWI, and MTVI. Visual assessment of injury, plant height, and grain yield were also measured. The results suggest that vegetation indices from multispectral imagery flown at an altitude of 40 m are not reliable indicators of herbicide injury in single rows due to the small crop canopy not being captured by the sensor (Fig. 1). To improve spatial resolution, the drone could be flown at a lower altitude and slower speed.

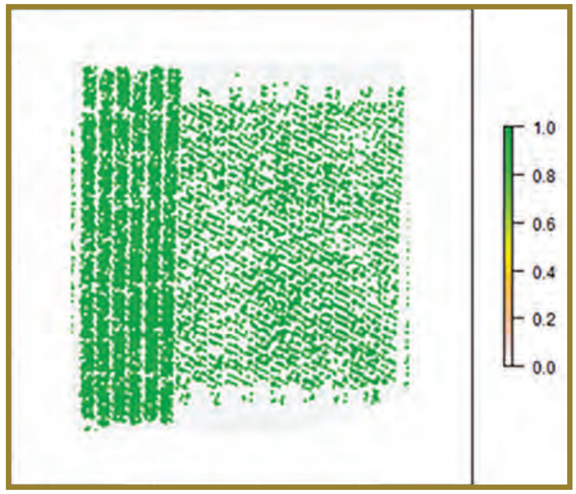

Figure1. Canopy of plots (left) and single rows (right) after a threshold to remove soil background was applied.

At the plot level, correlations between visual assessment of injury, grain yield, and vegetation indices varied due to annual differences in temperature and precipitation, which affected the plant's ability to recover. NDRE showed the strongest and most consistent correlation with visual assessment of injury. However, inconsistencies between years in whether the first or second injury assessment correlated more strongly with vegetation indices highlight the importance of recording multiple assessments for accuracy. NDVI and NDRE had consistently stronger correlations with grain yield compared to visual assessments. Rank change analysis when selecting for yield versus index values suggests that while index values may not be ideal for selecting superior herbicide-tolerant varieties, they may provide a more accurate measure of metribuzin tolerance than visual assessments. Linear regression analyses further indicated that differences in multispectral indices are more reliable

Year	Visual Assessment of Injury Regression (R^2)	Multispectral Regression (R^2)
2020	0.0003	0.3390
2021	0.0946	0.3323
2022	0.1915	0.0802
2023	0.1642	0.5434

Figure 2. Multiple linear regression of visual assessment of injury and difference of vegetation index values on yield difference in plots.

predictors of yield variability than visual assessment of injury (Fig. 2). Overall, these findings suggest that multispectral analysis of metribuzin injury in winter wheat breeding plots is a more accurate indicator of yield loss than visual assessments of injury.

Phenomic Selection as a Low-Cost Alternative to Genomic Selection of Wheat Quality

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Dept. of Crop and Soil Sciences, WSU

Evaluation of wheat end use quality is time consuming, labor intensive, and expensive. For these reasons phenotyping experimental lines for end use quality is normally delayed until yield trials. Genomic selection models, where dense genome-wide markers are used to predict quantitative traits, can permit early generation selection. The cost of genome-wide markers at $15 per sample makes screening large populations with genomic selection expensive. Phenomic data, like spectral reflectance values measured on intact grain, can be acquired inexpensively at around $2.50 per sample. Utilizing five years of soft spring wheat breeding lines submitted for quality evaluation, we compared the prediction accuracies of genomic and phenomic selection models for end use quality traits.

Table 1. The correlation between predicted and observed values for quality traits by year and the average prediction accuracy over five years. For each evaluated year, a set of roughly 150 unique experimental genotypes were used for model validation with the remaining four years used for model training. For all traits besides flour swelling volume, phenomic data offered a superior average prediction accuracy.

Trait	Method	2019	2020	2021	2022	2023	Average
Break Flour Yield	Genomic Selection	0.15	0.46	0.27	0.43	0.34	0.33
	Phenomic Selection	0.68	0.51	0.60	0.51	0.50	0.56
Cookie Diameter	Genomic Selection	0.33	0.22	0.51	0.56	0.27	0.38
	Phenomic Selection	0.54	0.36	0.27	0.67	0.41	0.45
Flour Ash	Genomic Selection	0.10	0.22	0.28	0.22	0.30	0.22
	Phenomic Selection	0.26	0.29	0.31	0.66	0.28	0.36
Flour Swelling Volume	Genomic Selection	0.51	0.53	0.52	0.30	0.51	0.47
	Phenomic Selection	0.49	0.66	0.38	0.10	0.57	0.44
Flour Yield	Genomic Selection	0.53	0.35	0.53	0.60	0.18	0.44
	Phenomic Selection	0.62	0.38	0.73	0.70	0.49	0.58

To compare the cost of implementing each system, we calculated the expected genetic gain from screening 500 experimental genotypes with genomic selection and selecting the best 100 lines for advancement based on the average accuracies outlined in Table 1. We then calculated the required selection intensity with phenomic prediction to match the expected gain from genomic selection.

Table 2. The required selection intensity and associated cost to match the genetic gain from genomic selection with phenomic selection per quality trait are shown on the top portion of the table. The total cost and selection intensity required per method to make equivalent progress for all quality traits is shown in the bottom portion of the table.

Phenomic Selection			
Trait	Selection Intensity	Cost	Genetic Gain
Break Flour Yield	100/380	$950	0.79%
Cookie Diameter	100/540	$1,350	0.48%
Flour Ash	100/385	$962.50	1.22%
Flour Swelling Volume	100/700	$1,750	4.82%
Flour Yield	100/470	$1,175	0.66%
Total Cost			
Method	Selection Intensity	Cost	Average Cost for 1% Gain
Genomic Selection	100/500	$7,500	$4,720
Phenomic Selection	100/700	$1,750	$1,100

The same spectral and genome-wide marker data per sample can be associated with multiple quality traits. This makes the total cost of genomic selection in our example an additional cost of $7,500 for the breeding program. The total cost of phenomic selection to match genomic selection is limited by the trait which requires the largest relative increase in selection intensity, flour swelling volume, leading to a total additional cost of $1,750 annually. These results suggest that adoption of phenomic selection for end use quality traits in spring wheat could be almost four times less expensive than genomic selection to realize the same genetic gain. Phenotyping a single genotype for all studied end use quality traits costs $300. For the same investment of phenotyping six genotypes at $1,800, seven hundred genotypes could be evaluated through NIRS. Phenomic selection during early generation stages will improve selection efficiency while leading to the release of cultivars with exceptional end use quality and export value for PNW growers.

Maximizing Wheat Stands and Yields through Improved Seeding Rate and Seed Size Management

Clark Neely, Aaron Esser, Dale Whaley

Stand establishment is one of the biggest challenges to winter and spring wheat production in the low rainfall production regions of Eastern Washington. Limited published information is available documenting the degree of impact seed size has on not only emergence, but overall growth and productivity. Treatments for this project included two varieties, three seeding rates, and three seed sizes and was conducted for both winter and spring wheat. The overall goal of this project is to improve successful crop establishment and grain yields for dryland wheat growers in the low rainfall region of Washington by altering seeding decisions based on seed size. Initial results show that variety and seed size impacted final grain yield for both winter and spring wheat as well as seeding rate for spring wheat. Variety, seeding rate and seed size also impacted stand establishment for winter wheat. In most cases increasing seeding rate improved stand establishment of smaller seed to a comparable stand of larger seed at a lower seeding rate, however this alone did not necessarily translate into increased grain yield. Because variety accounted for the majority of the variation in observed grain yield for both the winter wheat and spring wheat trials, that indicates variety selection was the most influential treatment in the study and had the largest impact on grain yield. Perhaps more surprising was that seed size played a bigger role in determining grain yield than did seeding rate at Ritzville and Lind. Samples and data are still being processed for biomass, grain yield components and early season canopy cover.

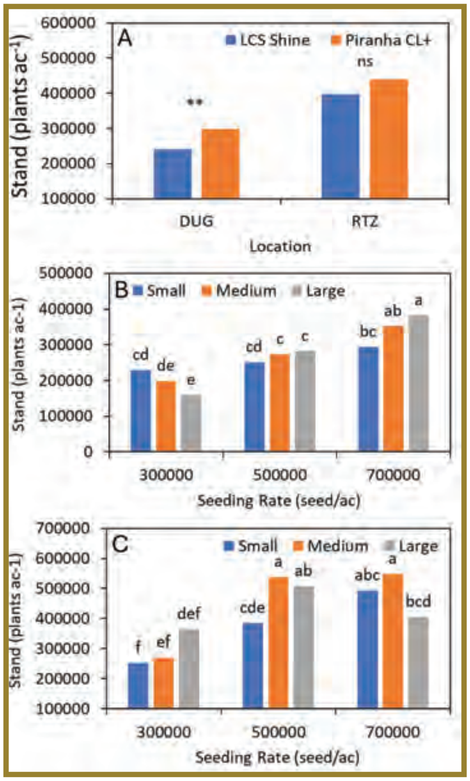

Figure 1. Graphs show impact of winter wheat variety (A) and a seed size x seed rate interaction at Douglas (B) and Ritzville (C) on winter wheat emergence.

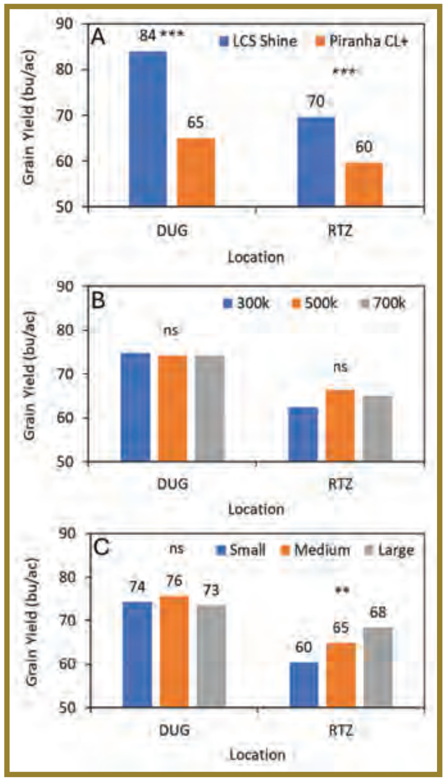

Figure 2. Graphs show impact of winter wheat variety (A), seeding rate (B), and seed size (C) at Douglas and Ritzville, WA on winter wheat grain yield during the 2023-24 growing season.

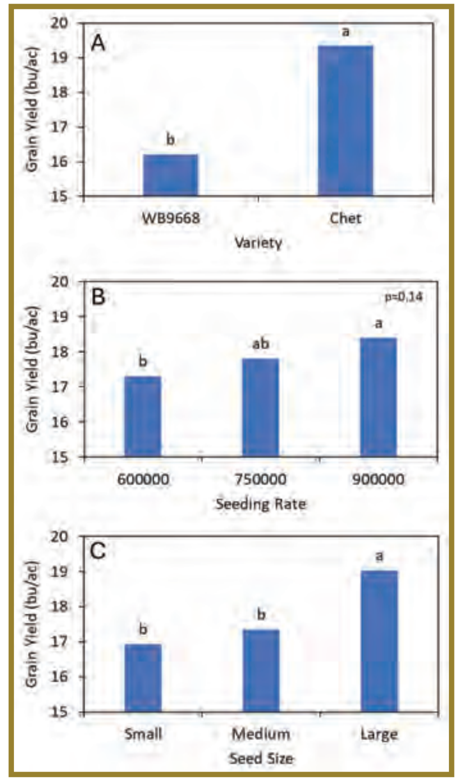

Figure 3. Graphs show impact of spring wheat variety (A), seeding rate (B), and seed size (C) at Lind, WA on spring wheat grain yield during the 2024 growing season.

Discovering Late-Maturity Alpha-Amylase (LMA) in Spring Wheat

Elliott Marston[1] and Deven See[1,2]
[1]Dept. of Plant Pathology, WSU; [2]USDA-ARS, Pullman

The enzyme α-amylase, necessary for the degradation of starch and normal germination in plants, can cause undesirable baking outcomes in high concentrations. The falling number (FN) test is an industry standard for predicting end-use quality of wheat and indirectly measuring α-amylase activity. Low FN scores (high α-amylase) are traditionally attributed to pre-harvest sprouting (PHS), but late-maturity α-amylase (LMA) has led to FN discounts for PNW growers since 2016. LMA is not as well studied as PHS, and genes that provide tolerance are still being identified, which leaves farmers vulnerable to LMA-associated financial losses. A nested association mapping population of 594 lines was created by crossing SWS wheat line WA8124 (LMA-susceptible) to ten LMA-tolerant SWS lines to create ten sub-populations of half-siblings. The population was screened for LMA in a greenhouse setting under three conditions: 1) warm (25°C day/15°C night), 2) a discrete cold shock (12°C day/7°C night for four days at susceptible soft-dough stage), and 3) continuous cold (15°C -17°C day/13°C -15°C night). The α-amylase activity of material was compared between treatments and used to perform genetic mapping analysis. Semi-dwarfing genes *Rht-B1* and *Rht-D1* were also assessed for their effect on LMA.

Generally, lines had the lowest α-amylase activity under warm temperatures and the highest under continuous cold temperature stress (Fig. 1). However, this pattern varied by subpopulation as the Tekoa, S0900317, SW8002-6, and WA8128 subpopulations had the highest α-amylase activity under discrete rather than continuous cold temperatures (Fig. 1). This suggests that tolerance to LMA under discrete vs. continuous temperature stress may be separate mechanisms, akin to seedling vs. HTAP stripe rust resistance, and require that breeders select for both. Semi-dwarf lines carrying either *Rht-B1* or *Rht-D1* reduce the incidence and severity of LMA under warm and cold conditions, though *Rht-D1* appears slightly more effective. Surprisingly, double dwarf lines carrying both *Rht* genes appear as susceptible to cold temperature induced LMA as tall lines (Fig. 2).

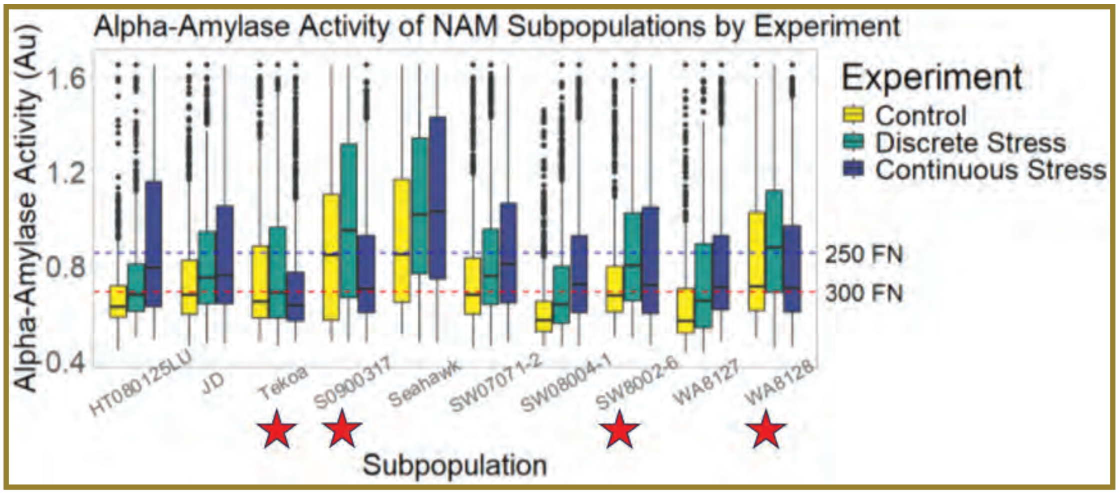

Figure 1. α-amylase activity under warm (yellow), discrete cold (teal), and continuous cold (dark blue) conditions by subpopulation. Subpopulations with higher α-amylase activity under discrete cold than continuous cold are marked with a red star.

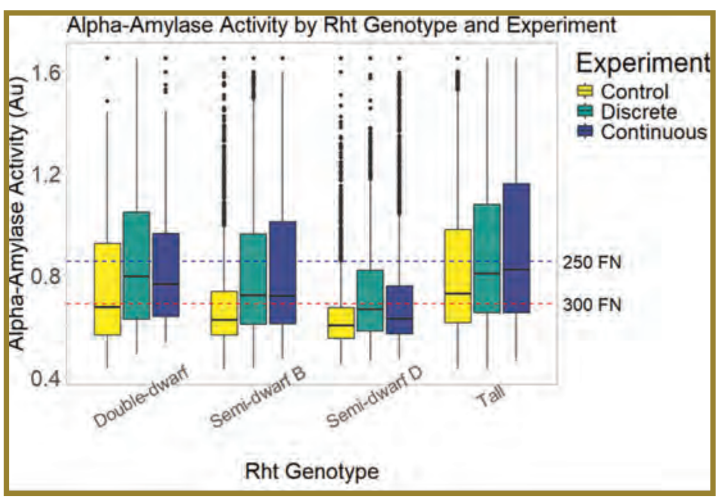

Figure 2. α-amylase activity of combined Rht-B1 and Rht-D1 genotypes by temperature treatment. Respectively, warm (yellow), discrete cold (teal), and continuous cold (dark blue) are plotted from left to right for each Rht genotype

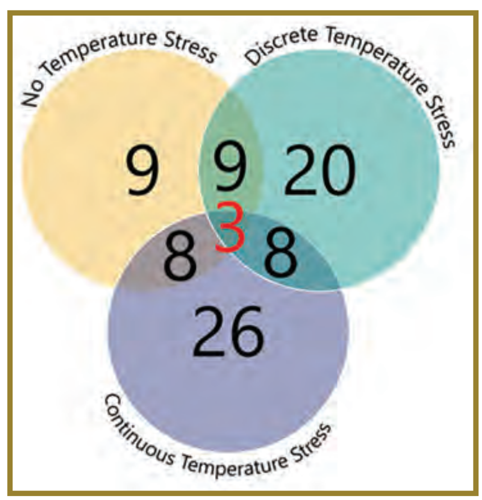

Figure 3. Ven diagram of QTL mapped using different temperature conditions. Clockwise, starting from the top left: Warm/no temperature stress (yellow), discrete cold (teal), and continuous (dark blue).

This experiment identified 83 high interest quantitative trait loci (QTL) – regions of the genome associated with a specific trait – using α-amylase activity under warm, discrete cold, and continuous cold conditions. Approximately half of these are potentially novel LMA-associated QTL. Interestingly, QTL tended to cluster in different regions of the genome depending on the temperature treatment with little overlap between the treatments. Only three QTL were associated with LMA-tolerance across all three treatments. This indicates that genetic resistance to LMA may be temperature specific. Ideal candidate genes for breeding LMA-tolerant lines will offer resistance across a wide range of temperatures and should be prioritized for transfer into elite wheat varieties by wheat breeders. Genetic markers for QTL of interest are being developed for use by WSU wheat breeding programs.

Discovering Late-Maturity Alpha-Amylase (LMA) Tolerance in Winter Wheat

Elliott Marston[1], Deven See[1,2], and Camille Steber[2,3]
[1]Dept. of Plant Pathology, WSU; [2]USDA-ARS, Pullman; [3]Dept. of Crop and Soil Sciences, WSU

The falling number (FN) test is a method for predicting end-use quality of wheat by measuring α-amylase enzyme activity. High levels of post-harvest α-amylase are associated with undesirable baking qualities and may be the result of pre-harvest sprouting (PHS) or late-maturity α-amylase (LMA). Unlike PHS, LMA is characterized as excess post-harvest α-amylase in the absence of sprouting. While PHS is well studied and controlled through traditional breeding methods, LMA is a more recently identified source of low FN. Currently, farmers are unprotected from LMA-associated financial losses and sources of genetic resistance are required to breed LMA-tolerant wheat.

While multiple groups have mapped LMA tolerance in spring wheat, this is the first study to map LMA tolerance in winter wheat. A biparental mapping population of 180 lines was created by crossing soft white winter wheat lines Xerpha (LMA-susceptible) and Bobtail (LMA-tolerant). The population was screened for LMA from 2019 to 2021 at the Spillman Agronomy Farm, Pullman, WA by cold shocking (18°C day/7.5°C night for seven days) field grown material as lines reached the susceptible soft dough stage of grain filling. The α-amylase activity of cold-shocked and untreated material was compared and used to perform genetic mapping analysis. The effects of semi-dwarfing genes *Rht-B1* and *Rht-D1* on LMA were also assessed. Under warm field conditions, most lines had low levels of LMA and lines with one or more *Rht* gene had reduced incidence and severity of LMA (Fig. 1 & 2). Exposure to a cold temperature shock increased α-amylase in LMA-susceptible lines. In 2021, a particularly hot and dry year, cold-induction of LMA caused higher levels of α-amylase activity in a greater proportion of lines, whereas there was no change in untreated material (Fig. 1 & 2). This suggests that a larger temperature drop may increase the severity and incidence of LMA. Lines carrying either the *Rht-B1b* or *Rht-D1b* dwarfing genes have some resistance to cold-induced LMA, but double dwarf lines carrying both genes may be particularly susceptible.

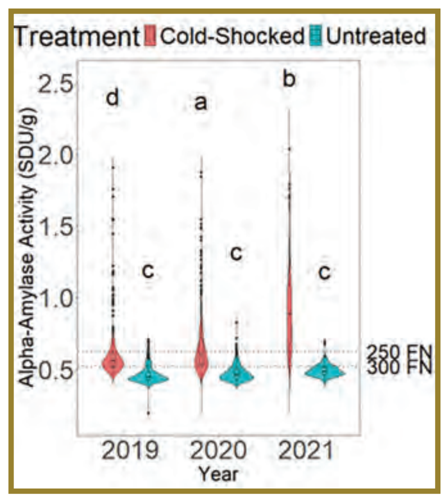

Figure 1. α-amylase activity in cold-shocked (red) and non-cold-shocked (blue) material by year. Statistically significant similarity of groups is indicated by letters. Five LMA-induced replicates (n = 865) and four untreated replicates (n = 692) were performed in 2019 (n = 518), 2020 (n = 691), or 2021 (n = 345).

Ten potential Quantitative Trait Loci (QTL) – regions of the genome associated with LMA tolerance - were identified by this experiment. Of the ten, five were discovered using α-amylase activity data from cold-shocked material, while four were identified with untreated material. A major QTL, Q*Lind-wsu-7A.2*, accounting for 15% of the variation was identified in winter wheat. Interestingly, this QTL has never been mapped in spring wheat and may represent a unique tolerance gene for winter wheat breeding. Genes that offer resistance across a wide range of temperatures are ideal candidates for breeding LMA-tolerant wheat. Genetic markers for these QTL are being developed for use by WSU wheat breeders.

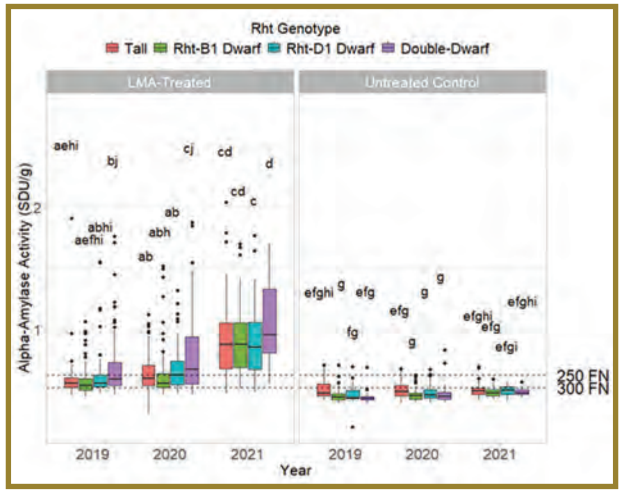

Figure 2. α-amylase activity of combined Rht-B1 and Rht-D1 genotypes by year and treatment type. Respectively, tall (Rht-B1a/D1a), semi-dwarfs (Rht-B1b/D1a and Rht-B1a/D1b), and double dwarfs (Rht-B1b/D1b) are plotted from left to right each year in orange, green, blue, and purple. Statistically significant similarity of groups is indicated by letters.

Non-Destructive Estimation of Soft Wheat Milling Yields

Peter Schmuker[1], Alecia Kiszonas[2], Sheri Rynearson[1], and Michael Pumphrey[1]
[1]Dept. of Crop and Soil Sciences, WSU; [2]USDA-ARS Western Wheat Quality Lab

The WSU Spring Wheat Breeding Program seeks to release soft wheat cultivars with an exceptional quality and agronomic package. Since evaluation of end use quality traits such as flour and break flour yields require destruction of wheat kernels, early generation selection for these traits when seed amounts are limited is not possible. As an alternative, phenomic data, such as Near Infrared Spectroscopy data collected on intact grain, can be associated with flour and break flour yield to permit nondestructive selection of varieties with superior milling yields. We have found that total flour yield, break flour yield, and the difference between total flour to break flour yield can be independently modeled and predicted with spectral data utilizing a robust, multi-year dataset of common soft wheat samples. Each facet in Figure 1 displays a target milling yield phenotype with each group on the x axis showing what milling yield phenotype was used to train the calibration model. For example, with the left most facet, break flour yield records are predicted from a spectral model trained with observations of break flour yield, flour yield, or the difference between flour and break flour yield dubbed milling loss. Models trained with a mismatched milling yield phenotype offer a weak shared spectral signal and resultant low predictive accuracy. Notably, the difference between flour and break flour yield cannot be associated

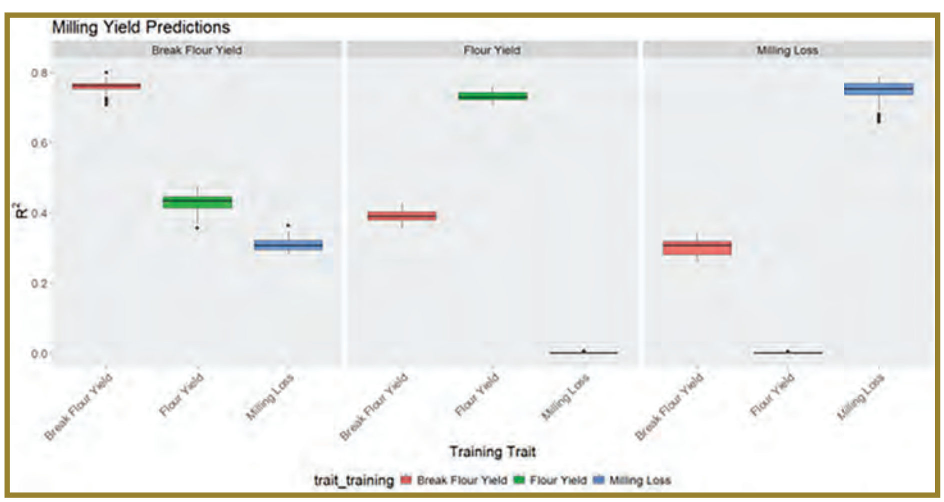

Figure 1. Prediction accuracies when utilizing a spectral calibration to predict several milling yield phenotypes measured by R squared. R squared represents the percentage of variation explained in true phenotypic observations from predicted phenotypes where values closer to 1 represent perfectly accurate predictions.

with the spectral prediction of flour yield. Break flour yield appears to be at least as predictable as total flour yield in soft wheat with an average R2 of 0.78 and 0.73 respectively. This is relevant for growers in the region since a high break flour yield is associated with the quality profile desired by the oversees export market. Evaluating milling yields at private, third-party laboratories costs around $125 per sample. Since the breeding programs already own Near Infrared Spectrometers, the spectral based predictions only cost the time of an undergraduate technician to scan samples at less than $5 per sample. These tools could lead to cost-effective, non-destructive estimation of milling yield properties for experimental genotypes during early generation evaluations in the WSU Spring Wheat Breeding Program.

Stripe Rust Resistance Genes and QTL from Two Pakistani Wheat Lines

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[1]Washington State University; [2]United States Department of Agriculture

Stripe rust is an important above ground disease of common wheat which is mainly managed by spraying fungicides that can control the pathogen or planting cultivars that can better handle exposure to the pathogen. In this study, two plant families of common wheat were created by crossing highly disease susceptible and highly disease resistant parents and self-pollinating each resulting offspring several times. Then, the plant families were inoculated with the fungal pathogen responsible for causing stripe rust in both the greenhouse and in the field, and later inspected for disease severity. Their DNA was coded to indicate whether they resembled their susceptible or resistant parent at each of many genetic landmarks, and later the information about their disease severity and their coded genetic landmarks were overlayed to help find single resistance genes, and clusters of resistance genes that all work together, which are called QTL. When separate segments of DNA between genetic landmarks was compared with individual instances of low disease severity, the segments responsible for low disease severity were located.

Their locations were noted in terms of both the general chromosome and specific chromosome "arm" on which they were found, with basic chromosome anatomy diagramed in Figure 1. Position is measured moving from the tip of the short arm to the middle of the chromosome, called the centromere, and them from middle of the chromosome to the tip of the long arm.

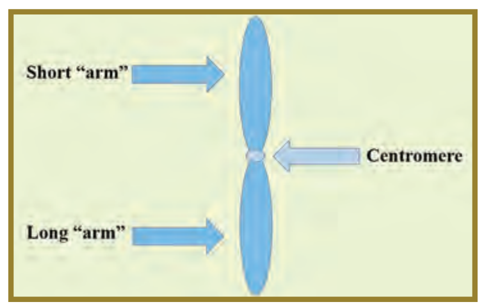

Figure 1.

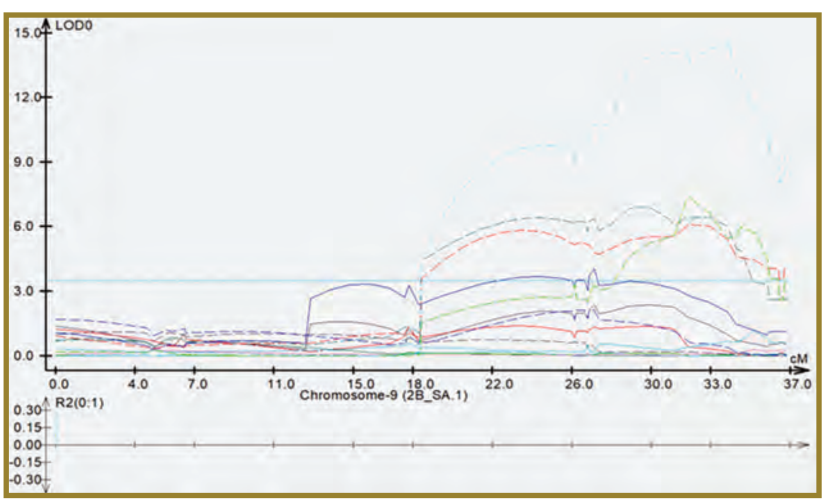

Figure 2. The graph shows a QTL from plant family 1 on chromosome 2B's short arm ("SA").

Figure 2 and 3 show a couple examples of results, one from each plant family, of a peak that rose above a cutoff line, which indicates the DNA segment shown just beneath it is likely to help plants resist disease.

While only one from each plant family are shown above, five were found in each plant family, so ten genetic segments total were found to reduce plant disease severity.

Once the location of these segments and their closest right and left landmarks are made known, breeders can easily find and use them to make new resistant cultivars so farmers can expect more reliable yields, which will help protect both financial and food security.

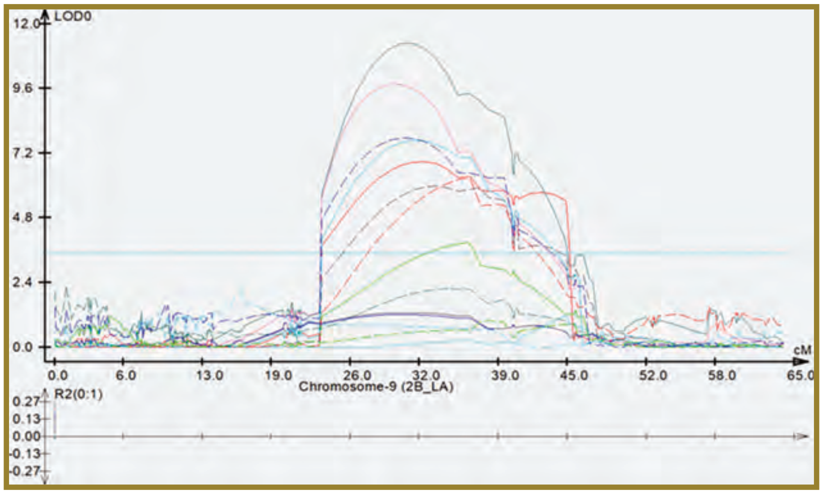

Figure 3. The graph shows a QTL from plant family 2 on chromosome 2B's long arm ("LA").

Unraveling Late-Maturity Alpha-amylase and Preharvest Sprouting in Wheat Seeds: A Proteomics Approach

John H. Kelly[1], Anna Berim[2], Rehana Parveen[1], Camille M. Steber[4], Alison L. Thompson[4], Andy McCubbin[3], Aaron Carter[1], Mike Pumphrey[1], and Amber L. Hauvermale[1]

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Late-maturity alpha-amylase (LMA) and preharvest sprouting (PHS) are two issues in wheat caused by genetics and weather. LMA develops with cold snaps, or dramatic temperature fluctuations during the soft-dough stage of grain development. PHS occurs when mature grain gets wet from rain or fog. Both result in higher levels of an enzyme called alpha-amylase.

Alpha-amylase digests starch in the wheat endosperm into the smaller sugars, maltodextrin and maltose. Starch breakdown is important for fueling a developing seedling, but can lower the quality of food products, causing significant financial losses for farmers. Selecting for wheat varieties that are less susceptible to LMA and PHS induction, along with developing new ways to manage these problems is important, and would benefit from a better understanding of how each event works. Past studies have primarily aimed to understand alpha-amylase expression in LMA and PHS. However, this is seldom done by looking at each in the context of the whole seed proteome. Therefore, we do not fully understand how proteins other than alpha-amylase are involved in LMA or PHS, and details are lacking as to which specific alpha-amylase isoforms are active during each event. Therefore, this study used a proteomics approach to compare proteins in the wheat varieties Jasper and Seahawk under three conditions: Sound (no treatment), LMA (induced in a greenhouse), PHS (sprouted grain). Samples were analyzed using Liquid-Chromatography Mass-Spectrometry (LCMS).

Results of the study found that many of the proteins recovered were the same across all three conditions and in both varieties, suggesting that the physiological differences between LMA and PHS occur from changes in a few important proteins (Fig. 1A&B.). Four proteins were identified as differentially expressed in PHS samples across both varieties: alpha-amylase isoform 1, galactinol-sucrose galactosyltransferase, heat shock 70 kDa protein, and S-adenosylmethionine synthase (Table 1; Fig. 1C&D). Two proteins were identified to be differentially expressed during LMA: beta-amylase and alpha-amylase 2 (Table 1; Fig. 1C&D). Identified proteins could serve as preliminary candidates for use in future immunological tests that can distinguish between LMA and PHS, or help elucidate the underlying physiological processes that occur during both events. Validation of these protein targets is on-going.

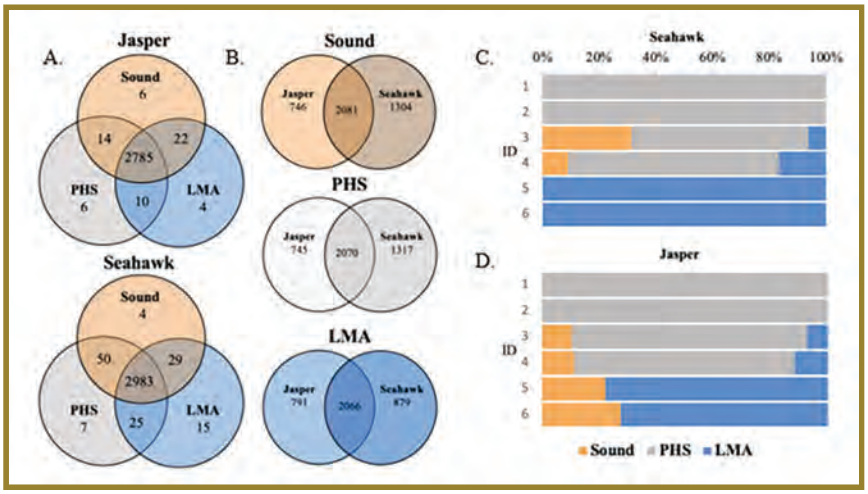

Figure 1. (A) Venn diagrams that include the number of all proteins identified in PHS, LMA and Sound samples for Jasper and Seahawk. (B) Venn diagrams that include the number of proteins in each treatment found in Jasper, Seahawk or both. (C&D) Differentially expressed proteins in PHS and LMA found in both Jasper and Seahawk. ID corresponds with Table 1 protein identification.

Table 1. Summary of proteins differentially expressed in PHS and LMA.

	ID	Name	%SC* (Jasper/Seahawk)	#PSMs** (Jasper/Seahawk)
PHS	1	Alpha-amylase 1	14/6	6/4
	2	Galactinol—sucrose galactosyltransferase	2/2	5/4
	3	Heat shock 70 kDa protein, mitochondrial	10/7	49/58
	4	S-adenosylmethionine synthase	31/30	22/22
LMA	5	Alpha-amylase 2	3/3	2/2
	6	Beta-amylase	19/19	156/214

*Sequence Coverage
**Peptide Sequence Matches

Unlocking Wheat's Potential: Combining Yield-Related Gene in High-Biomass Lines

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[1]Dept. of Crop and Soil Sciences, WSU; [2]CIMMYT, El Batán, Texcoco, México

Improving wheat yield is key for future food production. In this project, we tested a gene on chromosome 4AL from two spring wheat varieties, 'Kelse' and 'Scarlet,' that increases grain number and size. We introduced this yield-related gene into five high-biomass wheat lines developed by CIMMYT (International Maize and Wheat Improvement Center) in Obregon, Mexico, because we believed this combination could maximize yield potential. High-biomass lines have a strong capacity to produce more energy through photosynthesis due to their larger vegetative growth (Zhang et al., 2010). By adding the gene to high-biomass lines, we aimed to enhance their ability to support higher grain production. We created 24 wheat lines, 12 with the gene and 12 without (Fig. 1). Scarlet was backcrossed with five high biomass lines, each has four progenies (two with and two without), and Kelse was backcrossed with only one high biomass line and similarly has four progenies (two with and two without). Field trials in Obregon, Mexico, were done across three growing seasons (2021–2022, 2022–2023, and 2023–2024), covering two early and two late planting dates. In Washington State, trials were conducted in Pullman and Almota in 2022 and Pullman, Almota, Lind, and Dayton in 2023.

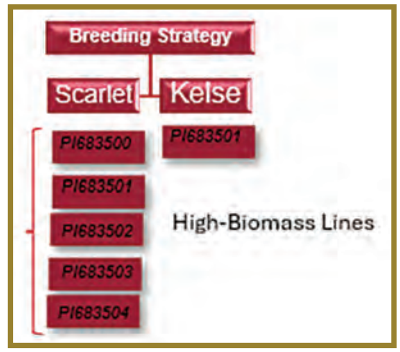

Figure 1. Breeding strategy.

We collected yield and yield-related traits and agronomic and weather data at each location to better understand how wheat performs under different conditions. We performed statistical analyses separately for each location to assess whether the gene improves yield. Within each location, we analyzed Kelse and Scarlet backgrounds separately. The effects of the 4AL gene varied across environments and genetic backgrounds, based on the results from both the CIMMYT trials in Obregon, Mexico and the Washington State field trials. From the Obregon, Mexico, trials, the Scarlet background (Fig. 2) shows that in the 2022–2023 season, especially under both regular and late planting, the gene helped increase overall grain yield. Over all years, the gene consistently led to heavier grains (grain weight) with longer and wider seeds (seed length and width), which helps make bigger grains. Ultimately, this leads to fewer but heavier grains, suggesting a trade-off between grain number and grain size, as the gene did not affect grain number in our study. Because of this, the total yield was not different across environments. The gene did not affect maturity time.

However, when comparing Scarlet and Kelse backgrounds that were crossed to the same high biomass line (501), the 4AL gene improved yield in Scarlet across most environments. This indicates that the gene can increase yield when placed in a compatible genetic background, such as high biomass 501. The gene positively improved grain weight, seed length and width across all environments in both backgrounds. The gene effects in Scarlet data in Washington (Fig. 3) were more variable and environment-specific. While Almota 2022 and Pullman 2022 saw modest yield increases in gene-positive lines, Pullman 2023 and Lind 2023 showed higher yields in lines without the QTL. Test weight, however, showed more consistent improvement with the gene in most environments except Pullman 2023. These variable results across traits and years highlight the importance of environmental conditions; the same gene may influence traits differently depending on the environmental conditions.

These results show that the effects of this 4AL gene depend on the genetic background into which it is introduced and the environment in which it is tested. This means that breeders need to

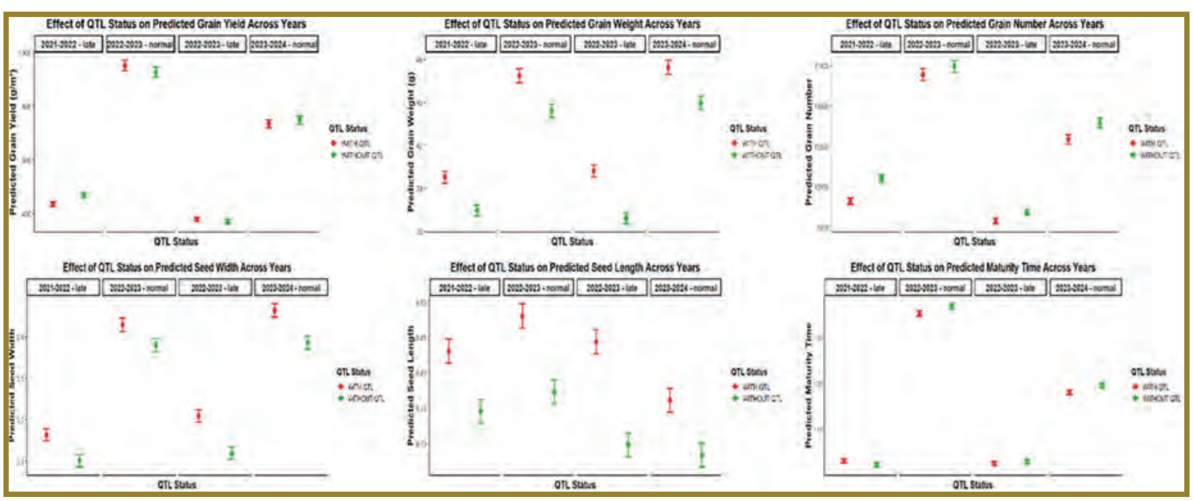

Figure 2. Scarlet Dataset-Obregon Mexico-Effect of QTL/Gene Presence on Traits-With gene (red)/Without gene(green).

consider not just which gene to use but also the genetic makeup of the recipient lines and the environments in which they will grow. Yield improvements can be achieved by matching genes with compatible genetic backgrounds and under appropriate conditions.

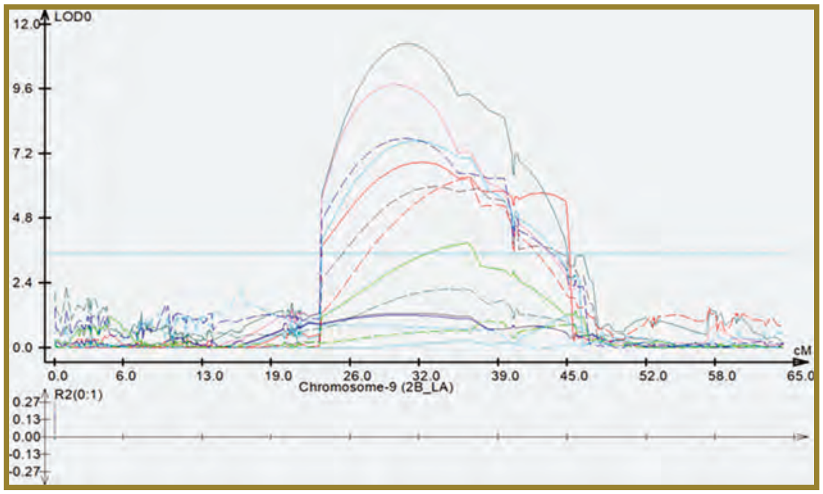

Figure 3. Scarlet Dataset-Washington, USA, Effect of QTL/Gene Presence on Traits-With gene (red)/Without gene(green).

Integrated Phenomic, Genomic, and Environmental Analyses Unveil Modes of Altered Phenotypic Plasticity During Wheat Improvement

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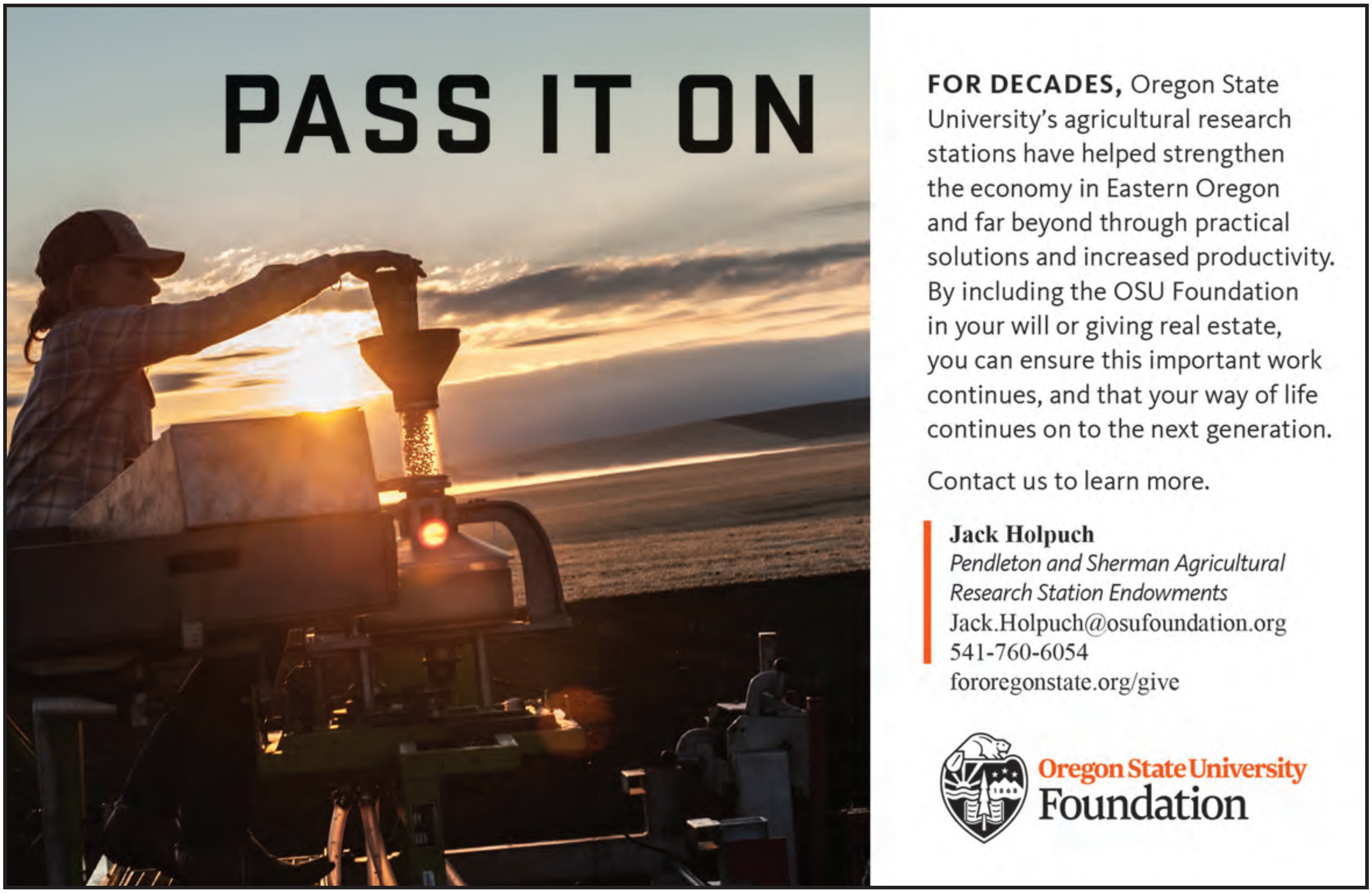
[1]Dept. of Crop and Soil Sciences, WSU; [2]State Key Laboratory for Crop Stress Resistance and High-Efficiency Production, College of Agronomy, Northwest A&F University; [3]USDA-ARS, Wheat Health, Genetics, and Quality Research Unit;[4]Dept. of Agronomy, Iowa State University

Wheat plays a critical role in global food security. A whole suite of traits has been modified to achieve the goal of higher yield of modern cultivars than landraces. However, changes of wheat in responding to environmental conditions, or phenotypic plasticity, during this improvement remains to be elucidated. Comprehensive understanding of phenotypic plasticity is essential for sustainable wheat improvement under changing environmental conditions. We measured 17 traits from a large wheat population consisting of landraces and modern cultivars over 10 environments. With the identified environmental index for each trait, two reaction-norm parameters (intercept and slope) concisely described how each accession responded to external environmental conditions to produce different phenotypic values. An integration of environmental index, intercept and slope, and genomic prediction accurately predicted traits values in various scenarios. GWAS identified loci significantly associated with phenotypic plasticity variations. For two Green Revolution genes, Rht-D1 significantly altered intercept and slope for more traits than Rht-B1. We discovered that, out of nine possible modes in changing intercept and slope from landraces to modern cultivars, three modes contributed to 88% of evaluated wheat traits. Our evaluations shed insights into wheat improvement and underscores the importance of linking phenotypic plasticity with crop improvement to optimize crop in changing climate.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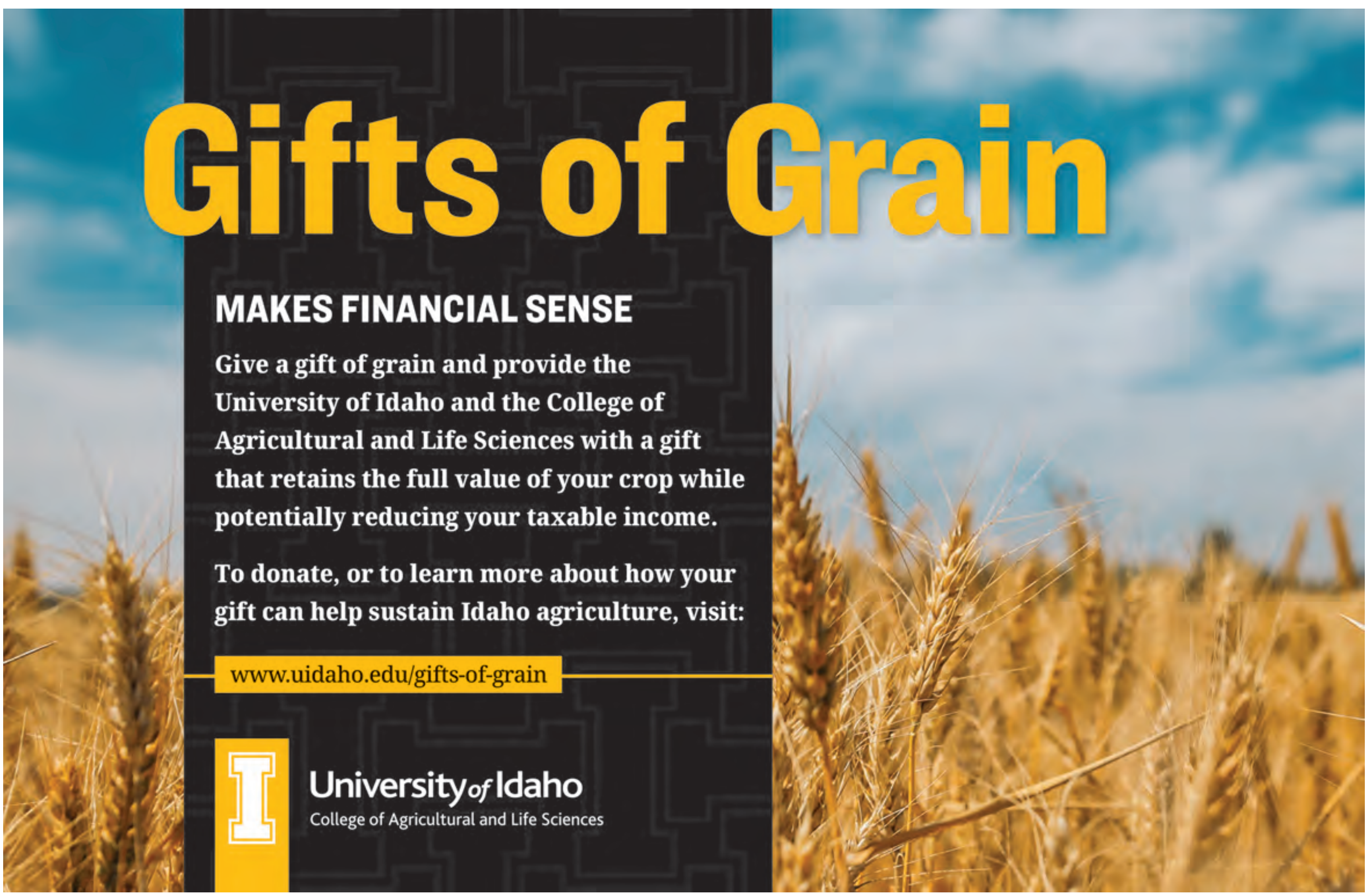
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