2023
Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS

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WASHINGTON STATE UNIVERSITY

University of Idaho

Oregon State University

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Welcome to our 2023 Field Day Abstracts!

2023 Dryland Field Day Abstracts: Highlights of Research Progress

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Washington State University
Department of Crop and Soil Sciences
Technical Report 23-1

Oregon State
University

Oregon State University
Department of Crop and Soil Science
Technical Report OSU-FDR-2023

University of Idaho

University of Idaho
Idaho Agricultural Experiment Station
Technical Report UI-2023-1

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CROPPING SYSTEMS
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2023 Field Days and Tours

WASHINGTON STATE UNIVERSITY

Horse Heaven Crop Tour—June 1
Connell Crop Tour—June 1
Adams County Crop Tour— June 2
Moses Lake Crop Tour—June 13
Harrington Crop Tour—June 14
WSU Weed Tour (Pullman)—June 14
Lind Field Day—June 15
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St. John Crop Tour—June 27
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Wilke Farm Field Day—June 29
Bickleton Crop Tour—June 29

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/

University of Idaho

Lewiston Crop Tour—June 21
Genesee Crop Tour– June 27
Camas Prairie Crop Tour—June 29
Bonners Ferry Crop Tour—June 30

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

Oregon State University

Pendleton Station Field Day—June 13
Sherman Station Field Day—June 14

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https://agsci.oregonstate.edu/cbarc/outreach-0

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Photo by Traci Rauch.

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Part 1. Pathology, Weeds, and Insects

Postharvest Control of Russian Thistle (*Salsola tragus*)

Fernando Oreja, Judit Barroso, and Jennifer Gourlie

Columbia Basin Agricultural Research Center (CBARC), OSU

Russian thistle, one of the dominant broadleaf weeds in semi-arid regions of the PNW, increases root growth after harvest and consumes up to 60% of the water it will use during its entire life cycle. The control of Russian thistle after harvest will prevent this water consumption and the species seed production. Chemical control, the most important weed management tool in no-till systems, is difficult postharvest due to the plant growth stage and the increasing cases of herbicide resistance.

The effect of postharvest application timing and the stubble height on herbicide efficacy was evaluated at the Columbia Basin Agricultural Research Center (CBARC, Adams, OR) in two consecutive years (2020 & 2021). Postharvest chemical treatments were applied at 24h, 1, 2, and 3 weeks after harvest (WAH) in two different stubble heights (15 and 5 inches in 2020, and 11 and 5 inches in 2021). The herbicides used to control Russian thistle postharvest were Gramoxone® SL 2.0 (paraquat), GlyStar® 5 Extra (glyphosate), and Huskie® (bromoxynil + pyrasulfotole). The experimental design was a completely randomized split-split-plot block design with four replications. Maximum and average daily temperatures and precipitation were studied from a local weather station. The year 2021 was drier and warmer than 2020. The accumulated precipitation from March to August in 2021 was 45% lower than in 2020. In 2021, temperatures during June and July were ≈ 4 °C warmer than in 2020 (Fig. 1).

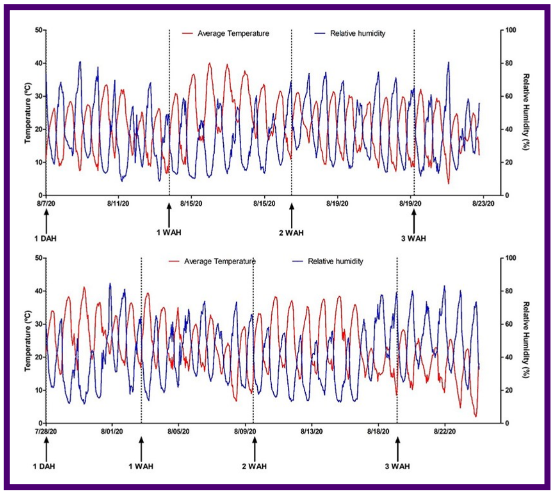

Figure 1. Average temperature (°C) (red line) and relative humidity (%) (blue line) during the time of postharvest applications 1 day (1 DAH), 1 week after harvest (WAH), 2 WAH, and 3 WAH, in a) 2020 and in b) 2021.

Paraquat provided the greatest control in both years, regardless of weather conditions, with no differences in application timing or stubble height. The efficacy was 100% and 98% in 2020 and 2021, respectively. The control with glyphosate and Huskie was similar with both herbicides and years (if stubble height is not considered), but higher in 2020 compared to 2021 (89% with glyphosate and 91% with Huskie in 2020, and 75% and 69% in 2021, respectively). In 2020, a more "normal" year than 2021, there were no differences among application timings for any of these herbicides (Fig. 2a). However, in 2021, a drier year than 2020, application timing affected the herbicide control efficacy. The control in both treatments was reduced when the herbicides were applied 1 WAH. For glyphosate, the control was 30% lower than in the other application timings (51% vs. 83%) and for Huskie, the control 1 WAH was only significantly lower than the application made 2 WAH (60% vs. 77%) (Fig. 2b). Based on weather data (Fig. 1), it seems that

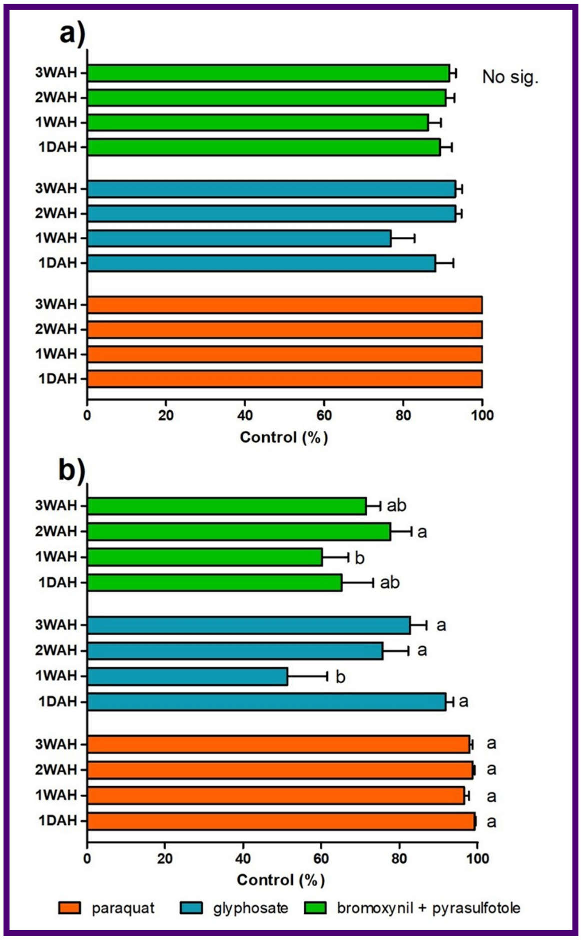

Figure 2. Control of Russian thistle (%) at the Columbia Basin Agricultural Research Center (CBARC, Adams, OR) with different herbicide treatments (paraquat, glyphosate and a pre-mixture of bromoxynil + pyrasulfotole) applied 1 day after harvest (DAH), 1, 2, and 3 weeks after harvest (WAH) in a) 2020 and b) 2021. Bars indicate the means and whiskers indicate the standard error of the mean. Bars with different letters indicate significant differences among application timings for each herbicide, according to Tukey's multiple comparison test ($p < 0.05$).

abiotic factors, such as air temperature and/or air relative humidity, might have played a bigger role in these results than biotic factors (e.g. plant stress levels or plant growth stage). Under this scenario, an application as soon as possible after harvest could be desirable to prevent significant water loss.

Stubble height affected the control of Russian thistle in both years. Tall stubble reduced Russian thistle control by 11% with glyphosate and Huskie in 2020, as well as with glyphosate in 2021 (Fig. 3). Results of this study indicate that short stubble might increase the performance of postharvest Russian thistle chemical control.

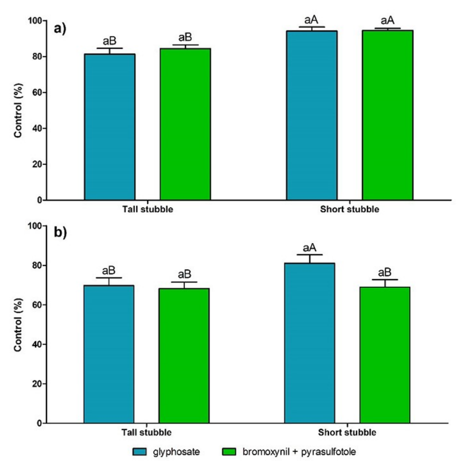

Figure 3. Control of Russian thistle (%) at the Columbia Basin Agricultural Research Center (CBARC, Adams, OR) with different herbicide treatments (glyphosate and the premixture of bromoxynil + pyrasulfotole) and stubble heights (tall and short) in a) 2020 and b) 2021. Bars indicate the means and whiskers indicate the standard error of the mean. Bars with the same lowercase letters indicate that means are not significantly different between herbicides at the same stubble height, and bars with the same uppercase letters indicate no significant difference between the same herbicide across stubble heights, according to Tukey's multiple comparison test ($p < 0.05$).

Evaluation of BAS85101H in Tank Mix Combination with Glyphosate for Russian Thistle Control in Chemical Fallow

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HENRY WETZEL AND DREW LYON

DEPT. OF CROP AND SOIL SCIENCES, WSU PULLMAN

A field study was conducted at the Lind Dryland Research Center near Lind, WA to assess BAS85101H alone and in tank mix combinations with glyphosate for the control of Russian thistle in chemical fallow. BAS85101H is an experimental herbicide in development by BASF Corporation.

The soil at this site is a Ritzville silt loam with 1.3% organic matter and a pH of 5.6. The field was previously in winter wheat. The Russian thistle population was uniform across the trial area but was at a low level of 12 plants per square yard. The plants ranged from 6 to 16 inches in diameter (average = 9.0 inches) and a height that ranged from 2.5 to 10 inches (average = 6.0 inches). Treatments were applied on June 30, 2022, with a CO_2-powered backpack sprayer set to deliver 10 gpa at 47 psi at 2.3 mph. The applications were made at an air temperature of 86°F and relative humidity of 21% and winds out of the south at 8 mph.

The station received 1.73 inches of rain in June (average = 0.78 inches), and only 0.35 inches in July (average = 0.28 inches) following the herbicide applications. Air temperatures were not significantly difference from the normal for this time. Roundup PowerMax applied at either 16 or 22 fl oz/acre did not control Russian thistle (Table). BAS85101H, Sharpen and Reviton all showed quick acting burndown on Russian thistle, seven days after treatment (DAT). Fourteen days after treatment, it was evident that Russian thistle was recovering in the Sharpen- and Reviton-treated plots. This trend continued with these two treatments up to the final rating 27 DAT. BAS85101H provided nearly complete control of Russian thistle through the final rating 27 DAT. The addition of Roundup PowerMax at either rate, did not significantly change the level of Russian thistle control provided by BAS85101H, Sharpen or Reviton as stand-alone treatments. With the average precipitation preceding the study, it was thought that the Russian thistle plants were not under drought stress and that glyphosate would provide control. It may have been that the glyphosate rates chosen in the study were too low to provide control. BAS85101H performed very well in this study. With the spread of glyphosate resistance in Russian thistle throughout the inland Pacific Northwest, having another effective herbicide for post-harvest Russian thistle control will be of great value.

Table. Post-harvest Russian thistle control at Lind, WA in July, 2022.

		Russian thistle control[2]			
		Days after treatment			
Treatment[1]	Rate	7	14	21	27
	fl oz/acre	--------------------- % ---------------------			
Nontreated check		--	--	--	--
Roundup PowerMax	16	20 e	40 e	23 e	5 d
Roundup PowerMax	22	20 e	40 e	23 e	10 d
Sharpen	1.0	98 a	81 bc	68 bc	58 b
BAS85101H	1.4	100 a	100 a	96 a	95 a
Reviton	1.0	93 b	78 cd	63 cd	53 bc
Roundup PowerMax + Sharpen	16 + 1.0	89 b	68 d	50 d	33 c
Roundup PowerMax + BAS85101H	16 + 1.4	100 a	100 a	99 a	95 a
Roundup PowerMax + Reviton	16 + 1.0	99 a	85 bc	70 bc	53 bc
Roundup PowerMax + Sharpen	22 + 1.0	93 a	80 cd	71 bc	58 b
Roundup PowerMax + BAS85101H	22 + 1.4	100 a	99 a	99 a	99 a
Roundup PowerMax + Reviton	22 + 1.0	100 a	93 a	82 ab	71 b

1All herbicide treatments included AMS at 8.5 lb/100 gallons, and all herbicide treatments containing Sharpen, BAS85101H, or Reviton also included MVO at 1% v/v.

2Means within the same column followed by the same letter are not significantly different using a 95% confidence interval, which means that we are not confident that the difference is the result of treatment rather than experimental error or random variation associated with the experiment.

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.

Resistance to Group 2 Herbicides in Downy Brome Populations from Wheat Fields

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Downy brome (*Bromus tectorum* L.) is a troublesome weed species in dryland wheat-producing regions of the Pacific Northwest. If not controlled, downy brome can cause wheat yield losses of up to 92%. Growers rely heavily on a very limited number of POST herbicides for downy brome control in wheat. Many POST herbicides registered for grass control in wheat are from Group 2 (ALS inhibitors). The prevalent and repeated use of herbicides, particularly with the same mode of action, has selected resistant downy brome populations. Therefore, we conducted a study to investigate the evolution of herbicide resistance in downy brome in the wheat-producing region of Oregon.

Survey. In the summer of 2021, we conducted a survey of wheat growers to understand downy brome management practices in Eastern Oregon. Growers were selected randomly and with the help of county extension agents. The survey included four questions about crop rotation, tillage practices, irrigation vs. dryland, and herbicide programs (PRE and POST) from 2017 to 2021.

Survey results. Winter wheat-summer fallow rotation (72%) was the most predominant cropping system. Only one field was tilled and none were irrigated. Pyroxasulfone + carfentrazone (10%) (Groups 15 and 14) and metribuzin (26%) (Group 5) were the most frequently used PRE and POST herbicides in winter wheat, respectively (Fig. 1). Glyphosate (77%) was the most frequently used herbicide in fallow (Fig. 1).

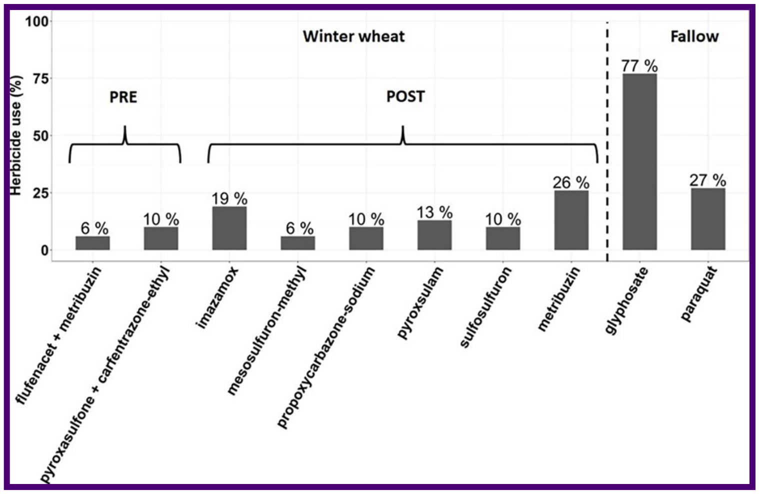

Figure 1. Herbicide use in winter wheat and fallow based on the survey responses. Results are based on 53 cropping years. Winter wheat (n=31) and fallow (n=22) years.

Screening. Seeds from 21 downy brome populations were collected from Gilliam, Morrow, Sherman, and Umatilla Counties for resistance testing. Downy brome populations were tested at Oregon State University, Corvallis using herbicide rates of 0, 1, and 2 times the recommended labeled rate. Herbicides tested were Group 1: clethodim (Select MAX; 1X = 16 fl oz/A) and quizalofop-P-ethyl (Assure II; 1X = 12 fl oz/A); Group 2: imazamox (Beyond; 1X = 4 fl oz/A), mesosulfuron-methyl (Osprey; 1X = 4.75 oz/A), propoxycarbazone-sodium (Olympus; 1X = 0.9 oz/A), pyroxsulam (PowerFlex HL; 1X = 2 oz/A), and sulfosulfuron (Outrider; 1X = 0.66 oz/A); and Group 9: glyphosate (GlyStar Original; 1X = 24 fl oz/A). Herbicides were applied to individual plants at the two- to three-leaf stage using a research track sprayer, delivering a 15 GPA. Downy brome plants were visually assessed as dead or alive, 21 days after treatment. Plants were considered alive when green tissue and evidence of regrowth were observed in plants, whereas completely necrotic plants were considered dead. Populations with >20% survival to the 1X were considered resistant.

Screening results. All populations were susceptible to clethodim, quizalofop-P-ethyl, and glyphosate (Fig. 2). Eighteen of 21 populations were resistant to Group 2 herbicides with different cross-resistance patterns (Table 1). Resistance to mesosulfulron -methyl (86%) and pyroxsulam (81%), were the most predominant followed by propoxycarbazone-sodium (67%), sulfosulfuron (67%), and imazamox (43%) (Fig. 2).

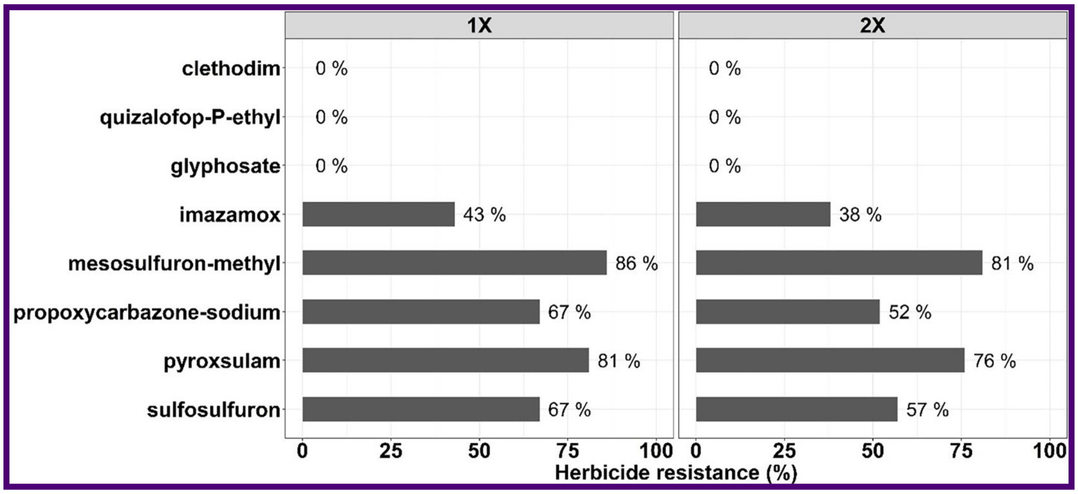

Figure 2. Herbicide resistance (%) in downy brome. Resistance based on 1X (>20% survival). Clethodim (1X = 16 fl oz/A), quizalofop-P-ethyl (1X = 12 fl oz/A), imazamox (1X = 4 fl oz/A), mesosulfuron-methyl (1X = 4.75 oz/A), propoxycarbazone-sodium (1X = 0.9 oz/A), pyroxsulam (1X = 2 oz/A), sulfosulfuron (1X = 0.66 oz/A), and glyphosate (1X = 24 fl oz/A) treatments.

The widespread occurrence of ALS-resistant downy brome populations limits effective POST herbicide options in wheat. The use of quizalofop-P-ethyl (Aggressor) with CoAXium Wheat offers a control option for ALS-resistant downy brome populations. Glyphosate is still an effective option for downy brome control in fallow, but alternative modes of action or tank mixes should be considered to preserve its use. However, downy brome populations resistant to Group 1 or glyphosate have been identified in the PNW.

Table 1. Cross-resistance to Group 2 herbicides. Blue or yellow indicates resistant and susceptible populations, respectively. Resistance bases on 1X (>20% survival).

Populations	Group 2 Herbicides				
	imazamox	mesosulfuron-methyl	propoxycarbazone-sodium	pyroxsulam	sulfosulfuron
GIL1	S	R	S	R	R
GIL2	S	S	S	S	S
GIL3	R	R	R	R	R
MOR1	R	R	R	R	R
MOR2	R	R	R	R	R
MOR3	R	R	R	R	R
MOR4	R	R	R	R	S
MOR5	S	S	S	S	S
MOR6	R	R	R	R	R
MOR7	S	R	S	R	R
MOR8	S	S	S	S	S
MOR9	S	R	R	R	R
MOR10	S	R	R	R	S
SHE1	R	R	R	R	R
UMA1	R	R	R	R	R
UMA2	S	R	S	R	R
UMA3	S	R	R	R	S
UMA4	R	R	R	R	R
UMA5	S	R	R	S	S
UMA6	S	R	S	R	R
UMA7	S	R	R	R	R

Herbicide Resistant Italian Ryegrass Survey in Northern Idaho and Eastern Washington

TRACI RAUCH AND JOAN M. CAMPBELL

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The Pacific Northwest of the United States is a productive wheat growing region that can have 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 of 95 fields in the Palouse region of the inland Pacific Northwest was conducted to determine the extent of Italian ryegrass 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 postemergence herbicides Assure II, Poast, Shadow, Axial XL, Osprey, PowerFlex HL, and glyphosate. Assure II, Poast, and Shadow are ACCase-inhibiting herbicides that are non-selective to grass crops and resistance was observed in 77, 57, and 23%, respectively, in the populations tested. This is a large increase compared to a survey of 75 fields in the same region in 2007, where Assure II, Poast and Shadow resistance was 48, 18, and 13%, respectively. Resistance to Axial XL, an ACCase-inhibiting herbicide used in wheat and barley, occurred in 74% of the populations tested in 2018 compared to 31% in the 2007 survey. Osprey and PowerFlex HL (ALS inhibiting-herbicides used in wheat) resistance was found in 90 and 89% of the populations. In the 2007 survey, Osprey resistance occurred in 34% of the populations. All populations tested were susceptible to glyphosate. Populations susceptible to both ALS-inhibiting herbicides occurred at 9%, while populations susceptible to all four ACCase-inhibiting herbicides occurred at 6%. Only 6% of populations were completely susceptible to all 7 herbicides tested. These results indicate that herbicide-resistant Italian ryegrass populations are increasing across much of the Palouse region in northern Idaho and eastern Washington.

Annual Grass Weed Control and Crop Tolerance with Alion in Kentucky Bluegrass Grown for Seed

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Annual grass weeds are a large pest problem affecting Kentucky bluegrass production in Idaho. Grass weeds are difficult to control in Kentucky bluegrass because they are closely related, and many herbicides cannot be used in the establishment year. Indaziflam is a group 29 cellulose biosynthesis inhibitor with no resistance reported in the Pacific Northwest. In 2020, Alion received a supplemental label for use on established perennial ryegrass, tall fescue, smooth bromegrass and wheatgrass grown for seed and timothy for hay. Studies were initiated in the field in fall 2020 and 2021 to evaluate annual grass control and Kentucky bluegrass tolerance with Alion applied at three application timings at three rates. Alion was applied at 2, 3, and 4 oz/A early fall (preemergence), late fall, and spring. The experimental design was a randomized complete block with four replications. Annual grass control was evaluated visually where 0% represented no control and 100% represented complete weed control. In the Kentucky bluegrass tolerance studies, plots were swathed and threshed for seed yield, and seed germination was determined. In 2021, rattail fescue, wild oat, and Italian ryegrass were evaluated. Rattail fescue control was evaluated in only two replications due to a low population. All rates at both fall application times averaged 99%. Wild oat control was better with preemergence and late fall applied Alion compared to spring application timing. Fall application treatments range from 76 to 97 and 78 to 93% on June 11 and 24, respectively. Wild oat control with spring application treatments was 33% or less. On June 11, the early fall treatment application at the highest rate controlled Italian ryegrass 97% but did not differ from any fall application at any rate. Italian ryegrass control was 51% or less with spring applied treatments. All treatments injured Kentucky bluegrass 0 to 4 and 0 to 1% on May 13 and June 11 evaluation dates, respectively. Seed yield tended to be highest in the untreated check but ranged from 536 to 646 lb/A and did not differ among treatments. Seed germination ranged from 74 to 80% and did not differ among treatments. In 2022, downy brome and interrupted windgrass control was 92 to 99% and 94% to 98%, respectively, for all treatment rates at both fall application times. All Alion treatments controlled ivyleaf speedwell 91 to 99% regardless of application time. Kentucky bluegrass injury tended to be greater at the preemergence timing high rate (18%) and the two higher rates at the late fall timing (19 and 21%) but did not differ among treatments including the untreated check. Seed yield ranged from 735 to 887 lb/A and did not differ among treatments including the untreated check. Seed germination is in progress.

Effect of Stubble Height and Plant Size on Russian Thistle Dispersion

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Russian thistle (*Salsola tragus* L.) constancy and success is due to its dispersion ability and high seed production. After the plant dies at the end of summer, the main stem breaks near the soil surface leaving the plant free to roll and tumble with the wind. The bouncing plant movement causes Russian thistle seeds to scatter in a range of about 0.04 to 2.5 miles from the original position. This dispersion allows the weed to colonize new areas, and spread its progeny, reducing competition among Russian thistle plants and increasing competition with the crop. Bigger plants growing alone are more competitive and produce higher yield losses than smaller plants growing in patches. The distance achieved by a plant from the original spot is highly dependent on extrinsic factors (i.e., wind speed and direction) and intrinsic factors (i.e., shape and weight of plants). Russian thistle plants have a globose-elliptical shape that allows them to roll easily with the wind. In this species, the plant itself acts like a sail "catching" the wind to travel farther distances. Therefore, the bigger the sail, the higher the probability for farther dispersion. However, the remaining stubble from the previous crop, depending on the height, could reduce the wind speed impacting the Russian thistle plant dispersion. Developing weed management practices that reduce Russian thistle dispersion would help to minimize the colonization of new areas/fields and prevent agricultural yield losses. Since Russian thistle seeds have a short viability in soil (no more than 2 or 3 years), avoiding new seed deposition is a beneficial strategy to diminish the infestation quickly if adequate management is applied in the following two years.

An experiment was conducted in two consecutive years (2020 and 2021) at the Columbia Basin Agricultural Research Center (CBARC) (Adams, OR) (Image 1) and in a grower's field near Ione, OR in 2020. At CBARC, the different stubble heights were 15 and 5 inches, and in the grower's field, we compared standing stubble with stubble trampled by the combine wheels. Plant dispersion was evaluated by counting plants right before they were killed by freezing temperatures (end of October) and multiple times during winter and the following spring.

At both sites, the dispersion rate increased with time. At CBARC, a higher plant dispersion was observed on plants growing in short stubble than in tall stubble. In 2020, dispersion in short stubble was 66% compared to 14% in tall stubble, and in 2021, the values were 53% in short stubble compared to 20% in tall stubble (Fig. 1). Near Ione, dispersion in trampled stubble was 88% compared to 43% in standing stubble and big plants were more dispersed than small plants (86% vs. 48% respectively) (Fig. 2).

Image 1. General view of the experiment at the Columbia Basin Agricultural Research Center (CBARC, Adams, OR) in 2020. Photo credit: Judit Barroso, OSU Associate Professor.

For growers that struggle to control Russian thistle post-harvest, leaving the stubble tall at harvest, could reduce Russian thistle dispersion in their fields and neighboring fields. Preventing plants from becoming big (e.g. mowing) as part of an integrated weed management program could also reduce dispersion.

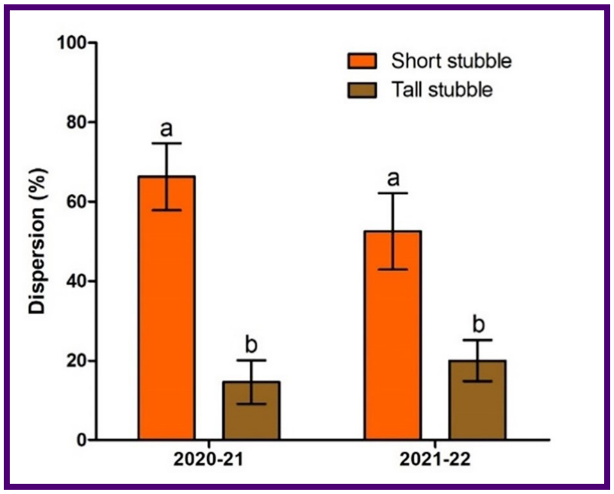

Figure 1. Dispersion of Russian thistle plants (%) at the final evaluation time (April 21 in 2021 and May 26 in 2022), at the Columbia Basin Agricultural Research Center (CBARC, Adams, OR) within to different stubble heights (short and tall) in 2020-21 and 2021-22. Bars indicate the means and whiskers indicate the standard error of the mean. Bars with the same letters are not significantly different according to Tukey's multiple comparison test ($p < 0.05$).

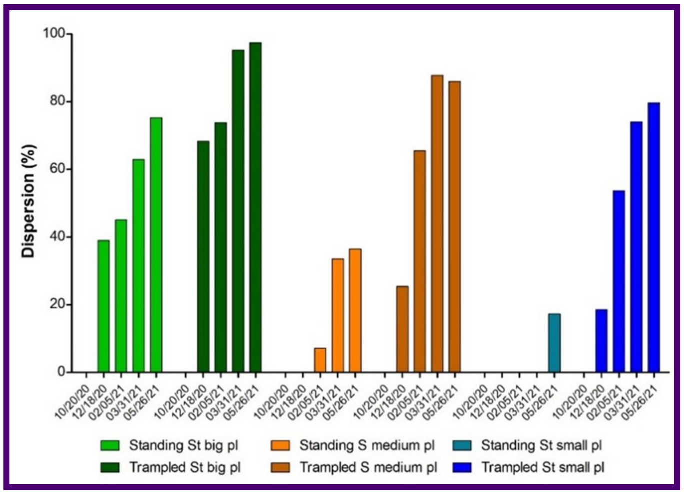

Figure 2. Russian thistle dispersion (%) near Ione for different plant sizes (small, medium and big) and stubble height (standing and trampled). Bars indicate the means.

Stripe Rust Management and Research in 2022

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In 2022, stripe rust was accurately forecasted and monitored in the Pacific Northwest throughout the crop season, and rust updates and advises were provided on time to growers. Moderate stripe rust was forecasted in January and March and occurred in the late growth season. Recommendations were made for implementing appropriate management that prevented major yield loss and reduced unnecessary use of fungicides, saving growers multimillion dollars. We conducted field tests for evaluating 19 fungicide treatments on winter wheat and spring wheat near Pullman, Washington (WA) under severe disease pressure produced by artificial inoculation of the nurseries with stripe rust spores. In the fungicide test on winter wheat, all 19 fungicide treatments significantly reduced stripe rust severity and increased grain yield compared to the non-treated check. Two treatments (Prosaro 8.2 fl oz/A applied at Feekes 8; Trivapro 7.0 fl oz/A at Feekes 5 plus 13.7 fl oz/A at Feekes 8) provided the best control of stripe rust and increasing grain test weight and yield the highest among all treatments. Treatment of Miravis Ace 7.0 fl oz/A applied at Feekes 5 plus Trivapro 13.7 fl oz/A applied at Feekes 8 also produced highest grain test weight and yield. The significant yield responses ranged from 10.0 bu/A (85.7%) to 55.1 bu/A (469.6%). In the fungicide test on spring wheat, all 19 fungicide treatments significantly reduced stripe rust severity and increased grain yield compared to the non-treated check; and 17 treatments had higher test weight than the non-treated check. The significant yield responses ranged from 21.5 bu/A (51.9%) to 46.7 bu/A (115.5%). We also tested 23 commercially grown winter wheat varieties and 23 spring wheat varieties, plus a susceptible check variety in each nursery near Pullman under severe disease pressure created by artificial inoculation. The summarized data are presented in **Table 1**. The two applications of Quilt Xcel significantly reduced stripe rust on 12 commercially grown winter wheat varieties; protected grain test weight of the check by 3.1 lb/bu and 4 commercial varieties by 1.5 to 14.3 lb/bu; made significant yield differences for the susceptible check (53.4 bu/A more in the sprayed plots) and 17 commercial varieties with 9.7 to 68.3 bu/A more grain in the sprayed plots. Six commercial varieties showed no significant yield differences between the no-spray and spray treatments, indicating their adequate resistance to stripe rust. These data indicated that stripe rust caused yield loss of 53.4 bu/A (87.6%) on the susceptible check and 16.8 bu/A (14.4%) yield loss on average across the commercially grown winter wheat varieties under the extremely severe disease pressure from early inoculation of the pathogen in the experimental field. Similarly, in the test of spring wheat varieties, the two applications of fungicide significantly reduced stripe rust severity on the susceptible check and eight commercial varieties; protected grain test weight of the check by 6.7 lb/bu and two commercial varieties by 3.1 to 5.3 lb/bu; made significant yield differences for the susceptible check (39.4 bu/A higher in the sprayed plots) and three commercial varieties with 13.1 to 31.8 bu/A more grain in the sprayed plots, indicating that stripe rust caused yield loss of 51.9% on the check and 6.3% on average across the commercially grown spring wheat varieties. Each variety received a fungicide response (FR) rating based on the grain yield loss. Varieties with FR 0 didn't need, those with FR 1 needed or did not need, while those with FR 2 or higher needed fungicide application under the severe stripe rust epidemic. These results are used for selecting resistant varieties to grown and determine whether fungicides are needed or not needed based on individual varieties and disease pressure.

In the 2022 crop season, we collected and received 330 stripe rust samples throughout the country, of which 206 samples (62%) were collected from WA. From the samples, we identified 22 races of the wheat stripe rust pathogen and 12 races of the barley stripe rust pathogen, of which all 20 (91%) wheat and 12 (100%) barley stripe rust races were detected in WA. The frequency and distribution of each race and virulence factors in WA and the whole country were determined, and predominant races were identified. The information on races and virulence factors is used to guide breeding programs for using effective resistance genes in developing resistant varieties and selected predominant races with different virulence patterns are used in screening for breeding lines of wheat and barley with stripe rust resistance.

In 2022, we evaluated more than 20,000 wheat, barley, and triticale entries for resistance to stripe rust. The entries included germplasm, breeding lines, rust monitoring nurseries, and genetic populations from various breeding and extension programs. All nurseries were planted at both Pullman and Mount Vernon locations, and some of the nurseries were also tested in Walla Walla, Central Ferry, and Lind, WA. Germplasm and breeding lines in the variety trials and regional nurseries also were tested in the greenhouse with selected races of stripe rust for further characterization of resistance. Excellent stripe rust data were obtained from all locations. The disease data of regional nurseries were provided to all breeding and extension programs, while the data of individual programs' nurseries were provided to the individual breeders. 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. In 2022, we collaborated with public breeding programs in releasing and registered 13 wheat varieties. New varieties developed by private breeding programs were also resulted from our tests. In 2022, we completed a study of identifying a new gene for race-specific resistance in club wheat 'Tres', mapped the gene on the short arm of chromosome 1B, determined its difference from other stripe rust resistance genes on chromosome 1B, and officially named the gene as *Yr85*. The results make the gene important in differentiating wheat stripe rust races and in monitoring pathogenic variation in stripe rust pathogen populations. In 2022, we obtained excellent stripe rust phenotypic data of three bi-parental mapping populations at both Pullman and Mount Vernon locations to validate resistance loci previously identified through the bulked analysis of 40 crosses. We selected new wheat germplasm lines with single new genes or combinations of genes for resistance to stripe rust to make them available for breeding programs.

Table 1. Average stripe rust relative Area Under the Disease Progress Curve (rAUDPC), Test Weight (TW), and yield of fungicide-sprayed and non-sprayed plots, yield loss by stripe rust and increase by fungicide, relative yield loss, and Fungicide Response (FR) of winter and spring wheat varieties in Pullman, WA in 2022

	rAUDPC (%)				Test Weight (LB/BU)				Yield (BU/A)				Yield loss (%)	Yield Inc. (%)	Relative	FR
Variety	No spray	Spray^a	Reduction		No spray	Spray^a	Increase		No spray	Spray^a	Increase		by stripe rust	by fungicide	yield loss (%)	rating^b
Winter wheat																
PS 279	100.0	29.7	70.3	*	46.9	49.9	3.1	*	7.6	61.0	53.4	*	87.6	705.3	100.0	6
WB4303	77.5	19.2	58.4	*	41.5	55.8	14.3	*	38.3	106.6	68.3	*	64.1	178.4	73.2	8
UI Magic	63.3	7.0	56.3	*	55.1	59.0	3.9	*	63.4	114.1	50.7	*	44.4	79.9	50.7	6
LCS Jet	46.3	4.0	42.3	*	59.1	61.0	2.0	*	81.2	122.1	40.9	*	33.5	50.3	38.2	5
Otto	28.0	4.6	23.4	*	53.6	55.1	1.5	*	77.5	99.7	22.2	*	22.2	28.6	25.4	3
Mela CL+	26.8	6.2	20.6	*	55.2	56.2	1.1		86.3	107.6	21.3	*	19.8	24.7	22.6	2
ORCF-102	15.8	13.2	2.6		57.8	58.5	0.7		94.4	113.5	19.1	*	16.8	20.2	19.2	2
Curiosity CL+	42.2	9.3	32.9	*	54.9	55.9	1.0		85.1	102.2	17.2	*	16.8	20.2	19.2	2
Puma	16.9	3.9	13.0	*	58.5	59.4	0.9		113.8	129.8	16.0	*	12.3	14.0	14.0	2
Keldin	27.9	4.4	23.5	*	61.9	62.8	0.9		104.8	118.7	13.9	*	11.7	13.3	13.4	2
SY Ovation	12.5	2.4	10.2	*	58.7	59.2	0.5		111.7	125.8	14.2	*	11.2	12.7	12.8	2
LCS Drive	6.9	3.9	3.1		56.9	57.7	0.8		121.1	134.4	13.3	*	9.9	10.9	11.3	2
SY Assure	3.0	2.6	0.4		60.5	60.9	0.4		118.9	131.7	12.8	*	9.7	10.8	11.1	1
SY Clearstone 2CL	19.6	6.5	13.1	*	59.2	60.2	1.1		102.7	113.4	10.8	*	9.5	10.5	10.8	1
Resilience CL+	10.9	8.9	2.0		59.3	59.6	0.3		122.0	133.8	11.7	*	8.8	9.6	10.0	1
LCS Artdeco	16.4	3.0	13.4	*	57.5	58.3	0.8		120.7	131.5	10.8	*	8.2	8.9	9.3	1
Northwest Tandem	6.2	4.1	2.15		58.5	59.5	1.0		125.6	135.6	10.0	*	7.4	8.0	8.4	1
Jasper	3.6	1.8	1.8		58.6	59.1	0.5		142.8	152.5	9.7	*	6.4	6.8	7.3	1
SY Dayton	7.8	3.1	4.6		58.0	59.2	1.2		116.1	123.0	6.8		5.6	5.9	6.4	1
WB1604	2.8	2.2	0.6		61.4	61.6	0.3		122.1	128.0	5.9		4.6	4.8	5.3	1
ARS-Crescent	14.0	5.0	9.0	*	58.1	58.5	0.4		127.2	132.6	5.4		4.1	4.2	4.6	1
M-Press	9.2	7.1	2.1		58.7	59.4	0.7		121.2	124.9	3.7		3.0	3.1	3.4	0
Northwest Duet	9.4	3.7	5.6		59.5	59.9	0.4		130.3	132.6	2.3		1.7	1.8	2.0	0
Bruehl	6.1	4.8	1.3		55.9	55.6	-0.3		126.8	127.1	0.3		0.2	0.2	0.2	0
Mean (excl. PS279)	*20.6*	*5.7*	*14.9*	*	*57.3*	*58.8*	*1.5*	*	*106.7*	*123.5*	*16.8*	*	*14.4*	*22.9*	*16.5*	
LSD (P = 0.05)	7.2				1.3				8.8							
Spring wheat																
AvS	100.0	1.9	98.1	*	53.1	59.7	6.7	*	36.5	75.9	39.4	*	51.9	108.0	100.0	4
WB6341	62.1	6.1	56.0	*	56.7	59.8	3.1	*	55.4	87.2	31.8	*	36.5	57.4	70.2	3
WB-1035CL+	59.1	5.1	54.1	*	50.8	56.1	5.3	*	40.2	61.8	21.6	*	34.9	53.6	67.2	2
Net CL+	9.3	3.1	6.1		58.0	59.7	1.7		48.2	61.3	13.1	*	21.4	27.2	41.2	1
Diva	13.7	3.0	10.7	*	56.5	56.7	0.2		48.0	56.0	8.0		14.2	16.6	27.4	1
Kelse	34.0	4.2	29.8	*	56.7	58.4	1.7		59.0	66.7	7.7		11.5	13.0	22.2	1
Alum	9.4	5.0	4.4		57.5	58.8	1.3		47.6	53.2	5.6		10.5	11.8	20.3	1
Melba	3.4	2.0	1.3		57.6	58.5	0.9		51.5	56.7	5.2		9.1	10.0	17.5	1
Ryan	9.6	4.8	4.9		56.5	57.1	0.6		89.2	94.2	5.0		5.3	5.6	10.2	1
Buck Pronto	22.6	5.3	17.4	*	56.4	56.1	-0.3		54.2	58.4	4.2		7.2	7.8	13.9	0
Solano	13.5	8.2	5.3		56.7	58.5	1.9		69.1	73.2	4.1		5.6	5.9	10.7	0
WB9668	4.2	2.6	1.6		58.7	59.5	0.8		63.0	65.9	2.9		4.4	4.6	8.6	0
Whit	23.9	5.9	18.0	*	54.6	54.7	0.1		56.8	59.1	2.3		3.9	4.0	7.4	0
Louise	14.0	2.9	11.1	*	52.1	51.6	-0.5		43.3	45.2	1.9		4.3	4.4	8.2	0
WB9662	3.6	2.0	1.6		57.5	58.2	0.7		66.6	67.9	1.3		1.9	2.0	3.7	0
Glee	13.6	3.7	9.9	*	57.7	58.2	0.5		67.8	68.2	0.4		0.6	0.6	1.1	0
SY Gunsight	2.6	2.0	0.6		56.8	59.1	2.3		76.9	77.3	0.4		0.5	0.5	0.9	0
WB7202CLP	8.0	3.2	4.8		58.3	58.2	-0.1		76.3	76.4	0.1		0.1	0.1	0.3	0
Tekoa	3.0	2.5	0.5		57.9	58.2	0.3		61.2	60.6	-0.5		-0.9	-0.9	-1.7	0
Chet	8.0	4.2	3.9		61.1	61.3	0.3		64.1	62.8	-1.3		-2.1	-2.0	-4.0	0
SY Selway	8.3	6.1	2.2		55.4	55.7	0.3		59.8	58.3	-1.5		-2.6	-2.6	-5.0	0
Seahawk	2.5	1.9	0.6		58.2	57.2	-1.0		60.6	57.9	-2.7		-4.7	-4.5	-9.1	0
JD	2.9	2.1	0.8		57.2	58.0	0.8		45.6	42.2	-3.4		-8.1	-7.5	-15.5	0
Expresso	4.3	6.8	-2.6		58.1	58.9	0.8		74.3	68.8	-5.5		-8.0	-7.4	-15.4	-1
Mean (excl. AvS)	*14.6*	*4.0*	*10.6*	*	*56.8*	*57.8*	*0.9*		*59.9*	*64.3*	*4.4*		*6.3*	*8.7*	*12.2*	
LSD (P = 0.05)	7.2				3.0				9.7							

[a] For winter wheat, Quilt Xcel at 14.0 fl oz/A was sprayed first time at early jointing stage (Feekes 4-5) on May 10 when stripe rust was absent in the field, and second time on June 1 when plants were at late jointing stage (Feekes 7-8) and the non-first spray PS279 plots had 0.5-5% rust severity. For spring wheat, the same fungicide was applied at jointing stage (Feekes 5) on June 15 when stripe rust just appeared with 0.1% severity on the susceptible variety plots and second time on July 1 at late jointing stage (Feekes 8) when non-first sprayed AvS plots had 15-20% 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 or higher need application.

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

Part 2. Breeding, Genetic Improvement, and Variety Evaluation

An Environmental View of WSU Spring Wheat Variety Trials

Peter Schmuker, Michael Pumphrey, and Clark Neely

Dept. of Crop and Soil Sciences, WSU

Understanding environmental factors that determine differences in performance between spring wheat cultivars can help guide breeding decisions, analysis of variety trial results, and lead to greater understanding of factors that influence agronomic traits. Examination of six years of soft spring wheat trials was conducted to identify environmental factors most influential on yield, protein content, and test weight. Weather variables collected daily from planting to harvest included: temperature, rainfall, relative humidity, vapor pressure, and day length. Daily high and low temperatures were used to calculate growing degree days, with cumulative growing degree days used to estimate several wheat growth stages. All weather variables besides rainfall were averaged within estimated growth stages; cumulative rainfall was analyzed within each growth period. Soil moisture and pH measurements taken at planting were also included in the dataset. In total, 92 soil and weather variables were gathered alongside yield, protein, and test weight data for 90 soft spring wheat trials from 2017-2022.

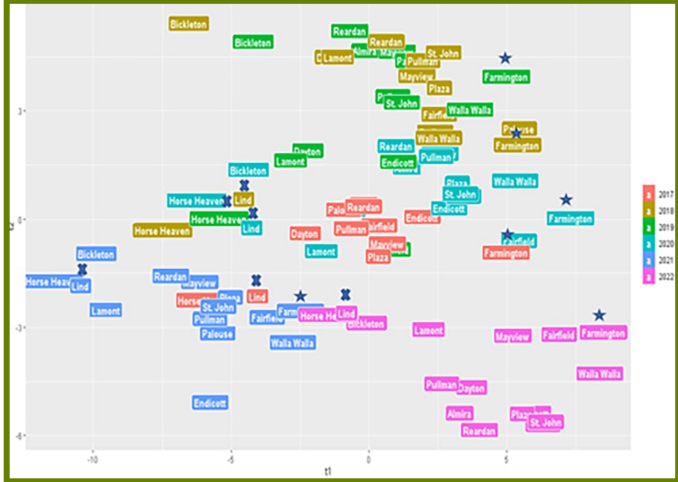


Figure 1. PLS clustering of trials based on environmental impact on yield. Trials in proximity are similar for environmental conditions weighted for their impact on yield. The effect of each year was greater than the effect of location, for example several low rainfall locations in 2017-2019 are similar to high rainfall locations from 2021. A mark is put above Lind and Farmington trials to show movement between years.

Yield PLS model fit R.85

Due to the large number of variables and data, Partial Least Squares modeling (PLS) was employed to calculate important latent variables that explain large portions of variation of yield, test weight, and protein. PLS reduces data down to latent variables that are simpler to interpret and correct for shared information between the different weather and soil datapoints. Surprisingly, soil moisture at planting and precipitation during early growth were not the top factors to influence yield.

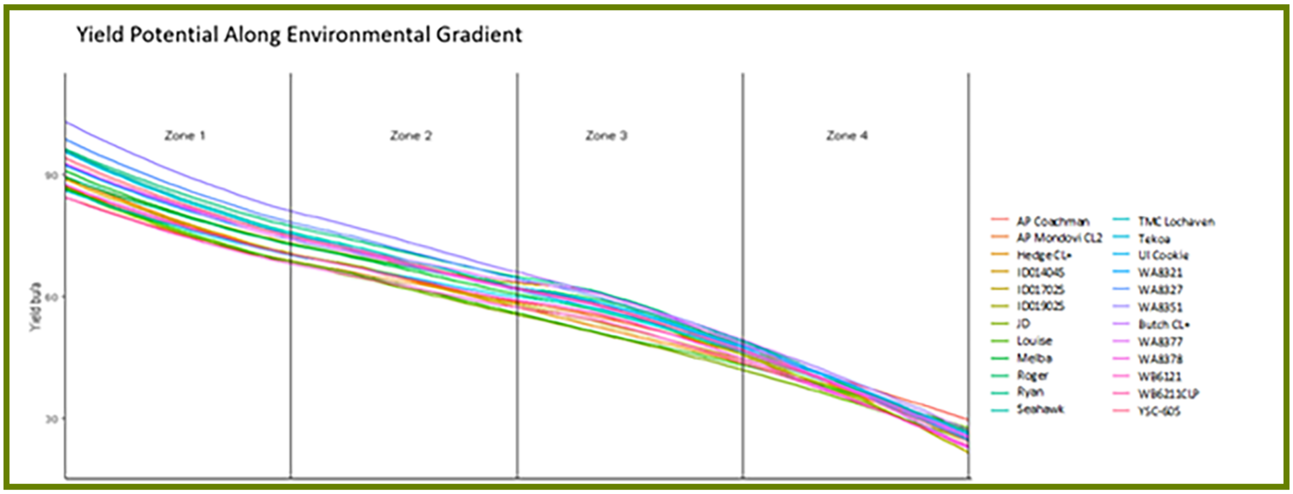


Figure 2. Yield response over the four environmental gradients. Zone one represents greater yield potential declining to lowest potential in zone four. Each colored line represents the performance of a cultivar. Changes in ranks of performance, shown by lines crossing over, mainly occur in the fourth zone.

Instead, relative humidity and vapor pressure deficit during tillering and heading were the strongest individual predictors of yield. Relative humidity and average temperature during heading and grain fill were most important for protein content. Test weight was most significantly influenced by humidity and vapor pressure deficit at tillering and heading.

PLS analysis with environmental information can be applied to analyze cultivar stability and yield potential across environmental gradients. A gradient of environmental conditions was individually calculated by PLS analysis for 2022 soft spring variety testing entries. The gradient was split into four zones of environmental conditions reflecting growing conditions across the region. Zone one represents weather similar to long term averages near Pullman while zone four reflects long term average weather at low rainfall locations like Lind. The top five cultivars were identified within each zone, along with ranks across all zones. Results showed variety release candidate 'WA 8351' was broadly adapted to diverse climatic conditions for yield. This analysis was repeated for protein and test weight. Low rainfall conditions simulated in zone four had the most crossover in ranks for all traits compared to the other three zones. These initial results demonstrate that in Washington, spring wheat evaluation over years is more important than evaluation over many sites within a year due to greater environmental differences across time rather than across space. Growers are advised to strongly evaluate multi-year performance when selecting cultivars.

Table 1. Ranking of cultivars based on performance over the four zones and total potential over all zones. Ranks are from high to low for yield and test weight, and reverse order with first rank having lowest protein content. Transitions between zones roughly represent an average drop around 20 bushels of yield potential starting with 100 bushels in zone one down to 25 bushels in zone four.

	Zone One	Zone Two	Zone Three	Zone Four	Total Potential
Yield	WA 8351	WA 8351	Ryan	WA 8351	WA 8351
	WA 8327	WA 8327	WA 8351	AP Coachman	WA 8327
	Ryan	Ryan	ID01702S	WA 8327	Ryan
	Seahawk	Seahawk	Butch CL+	WA 8321	Seahawk
	Tekoa	Butch CL+	WA 8327	Melba	Butch CL+
Test Weight	WA 8351	WA 8351	Roger	Roger	Roger
	IDO1902S	IDO1902S	Butch CL+	Butch CL+	IDO1902S
	WA 8378	Roger	ID01702S	ID01702S	ID01702S
	JD	ID0172S	IDO1902S	IDO1902S	WA 8351
	Hedge CL	Hedge CL	Hedge CL	Hedge CL	Butch CL+
Protein	WA 8351	WA 8378	Roger	Roger	Roger
	WA 8321	WA 8351	AP Coachman	AP Coachman	AP Coachman
	AP Coachman	WA 8321	WA 8378	WA 8378	WA 8378
	WA 8378	Louise	Ryan	ID01702S	WA 8351
	Melba	Roger	WA 8321	Melba	WA 8321

North Idaho Small Grains and Cool-Season Pulse Variety Testing Program

KURTIS SCHROEDER AND JOHN CODY HOWE

UI EXTENSION, DEPT. OF PLANT SCIENCES, UI

New varieties of crops are continually being developed and released that offer improved disease resistance, improved agronomic performance, superior quality, or a number of other traits. In order to best inform growers and the industry about these new varieties, it is vital that they are tested for adaptability across Idaho's diverse climate. The goals for the north Idaho program are to provide objective and statistically sound evaluations of new releases and advanced breeding lines for their relative performance across diverse climates, and to provide increased visibility and exposure of these varieties to accelerate their adoption.

The north Idaho variety testing program is diverse, testing winter and spring wheat, winter and spring barley, winter and spring pea, lentil and chickpea. There are 16 unique locations across six north Idaho counties and four cool-season pulse locations in eastern Washington. Data collected includes heading or flowering dates, mature plant height, grain yield and postharvest measurements such as test weight and grain protein. All winter and spring wheat entries also are screened for aluminum tolerance. As opportunities arise, the variety testing trials have been used to complement a variety of research projects. Projects have ranged from evaluations for disease resistance to residue management studies to working with engineering teams developing devices to measure straw strength.

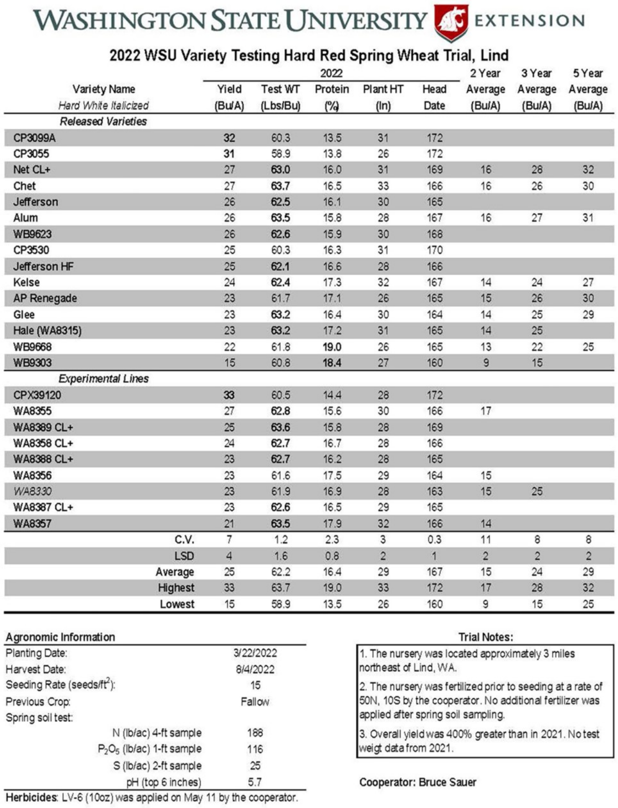
Data generated from these trials is shared via email after harvest and is available on the North Idaho Cereals website (www.uidaho.edu/extension/cereals/north/variety-trials). Trials results are also presented at winter cereal school and field days throughout the year. Data from the north Idaho variety testing program is being contributed to the Western Agricultural Variety Explorer (WAVE, www.westernagdata.org), a Pacific Northwest variety database that will allow users to explore data sets across years and locations.

Washington State University Extension Cereal Variety Testing Program

CLARK NEELY[1] AND BRANDON GERRISH[2]

[1]WSU EXTENSION; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

The WSU Extension Cereal Variety Testing Program conducts variety trials at 42 locations throughout Eastern Washington. In total, the program conducts 24 soft white winter, 18 hard winter, 18 soft white spring, and 21 hard red spring wheat trials in addition to 12 spring barley and 8 winter barley trials. Seven sites are co-managed with WSU and USDA breeders while our Eureka and Walla Walla sites are cooperative sites between WSU and OSU Extension. The Variety Testing Program also works in concert with multiple research programs within WSU, U of I, and USDA to further screen varieties for traits such as end use quality, falling number susceptibility, acid soil tolerance, insect resistance, and disease resistance.



WASHINGTON STATE UNIVERSITY EXTENSION

2022 WSU Variety Testing Hard Red Spring Wheat Trial, Lind

	2022					2 Year	3 Year	5 Year
Variety Name *Hard White Italicized*	Yield (Bu/A)	Test WT (Lbs/Bu)	Protein (%)	Plant HT (In)	Head Date	Average (Bu/A)	Average (Bu/A)	Average (Bu/A)
Released Varieties								
CP3099A	**32**	60.3	13.5	31	172			
CP3055	**31**	58.9	13.8	26	172			
Net CL+	27	**63.0**	16.0	31	169	16	28	32
Chet	27	**63.7**	16.5	33	166	16	26	30
Jefferson	26	**62.5**	16.1	30	165			
Alum	26	**63.5**	15.8	28	167	16	27	31
WB9623	26	**62.6**	15.9	30	168			
CP3530	25	60.3	16.3	31	170			
Jefferson HF	25	**62.1**	16.6	28	166			
Kelse	24	**62.4**	17.3	32	167	14	24	27
AP Renegade	23	61.7	17.1	26	165	15	26	30
Glee	23	**63.2**	16.4	30	164	14	25	29
Hale (WA8315)	23	**63.2**	17.2	31	165	14	25	
WB9668	22	61.8	**19.0**	26	165	13	22	25
WB9303	15	60.8	**18.4**	27	160	9	15	
Experimental Lines								
CPX39120	**33**	60.5	14.4	28	172			
WA8355	27	**62.8**	15.6	30	166	17		
WA8389 CL+	25	**63.6**	15.8	28	169			
WA8358 CL+	24	**62.7**	16.7	28	166			
WA8388 CL+	23	**62.7**	16.2	28	165			
WA8356	23	61.6	17.5	29	164	15		
WA8330	23	61.9	16.9	28	163	15	25	
WA8387 CL+	23	**62.6**	16.5	29	165			
WA8357	21	**63.5**	17.9	32	166	14		
C.V.	7	1.2	2.3	3	0.3	11	8	8
LSD	4	1.6	0.8	2	1	2	2	2
Average	25	62.2	16.4	29	167	15	24	29
Highest	33	63.7	19.0	33	172	17	28	32
Lowest	15	58.9	13.5	26	160	9	15	25

Agronomic Information

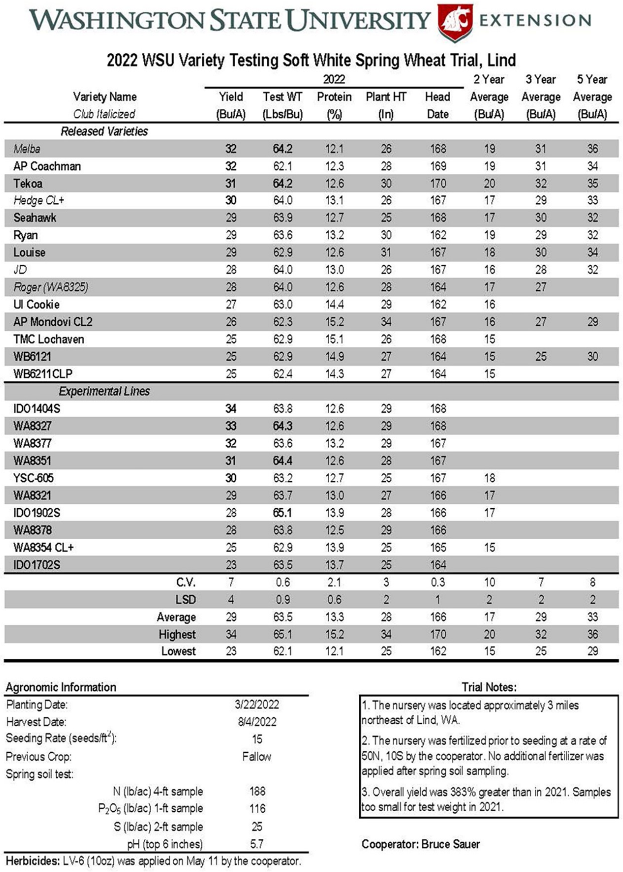
Planting Date:	3/22/2022
Harvest Date:	8/4/2022
Seeding Rate (seeds/ft^2):	15
Previous Crop:	Fallow
Spring soil test:	
N (lb/ac) 4-ft sample	188
P_2O_5 (lb/ac) 1-ft sample	116
S (lb/ac) 2-ft sample	25
pH (top 6 inches)	5.7

Herbicides: LV-6 (10oz) was applied on May 11 by the cooperator.

Trial Notes:

1. The nursery was located approximately 3 miles northeast of Lind, WA.
2. The nursery was fertilized prior to seeding at a rate of 50N, 10S by the cooperator. No additional fertilizer was applied after spring soil sampling.
3. Overall yield was 400% greater than in 2021. No test weigt data from 2021.

Cooperator: Bruce Sauer



WASHINGTON STATE UNIVERSITY EXTENSION

2022 WSU Variety Testing Soft White Spring Wheat Trial, Lind

	2022					2 Year	3 Year	5 Year
Variety Name *Club Italicized*	Yield (Bu/A)	Test WT (Lbs/Bu)	Protein (%)	Plant HT (In)	Head Date	Average (Bu/A)	Average (Bu/A)	Average (Bu/A)
Released Varieties								
Melba	**32**	**64.2**	12.1	26	168	19	31	36
AP Coachman	**32**	62.1	12.3	28	169	19	31	34
Tekoa	**31**	**64.2**	12.6	30	170	20	32	35
Hedge CL+	**30**	64.0	13.1	26	167	17	29	33
Seahawk	29	63.9	12.7	25	168	17	30	32
Ryan	29	63.6	13.2	30	162	19	29	32
Louise	29	62.9	12.6	31	167	18	30	34
JD	28	64.0	13.0	26	167	16	28	32
Roger (WA8325)	28	64.0	12.6	28	164	17	27	
UI Cookie	27	63.0	14.4	29	162	16		
AP Mondovi CL2	26	62.3	15.2	34	167	16	27	29
TMC Lochaven	25	62.9	15.1	26	168	15		
WB6121	25	62.9	14.9	27	164	15	25	30
WB6211CLP	25	62.4	14.3	27	164	15		
Experimental Lines								
IDO1404S	**34**	63.8	12.6	29	168			
WA8327	**33**	**64.3**	12.6	29	168			
WA8377	**32**	63.6	13.2	29	167			
WA8351	**31**	**64.4**	12.6	28	167			
YSC-605	**30**	63.2	12.7	25	167	18		
WA8321	29	63.7	13.0	27	166	17		
IDO1902S	28	**65.1**	13.9	28	166	17		
WA8378	28	63.8	12.5	29	166			
WA8354 CL+	25	62.9	13.9	25	165	15		
IDO1702S	23	63.5	13.7	25	164			
C.V.	7	0.6	2.1	3	0.3	10	7	8
LSD	4	0.9	0.6	2	1	2	2	2
Average	29	63.5	13.3	28	166	17	29	33
Highest	34	65.1	15.2	34	170	20	32	36
Lowest	23	62.1	12.1	25	162	15	25	29

Agronomic Information

Planting Date:	3/22/2022
Harvest Date:	8/4/2022
Seeding Rate (seeds/ft^2):	15
Previous Crop:	Fallow
Spring soil test:	
N (lb/ac) 4-ft sample	188
P_2O_5 (lb/ac) 1-ft sample	116
S (lb/ac) 2-ft sample	25
pH (top 6 inches)	5.7

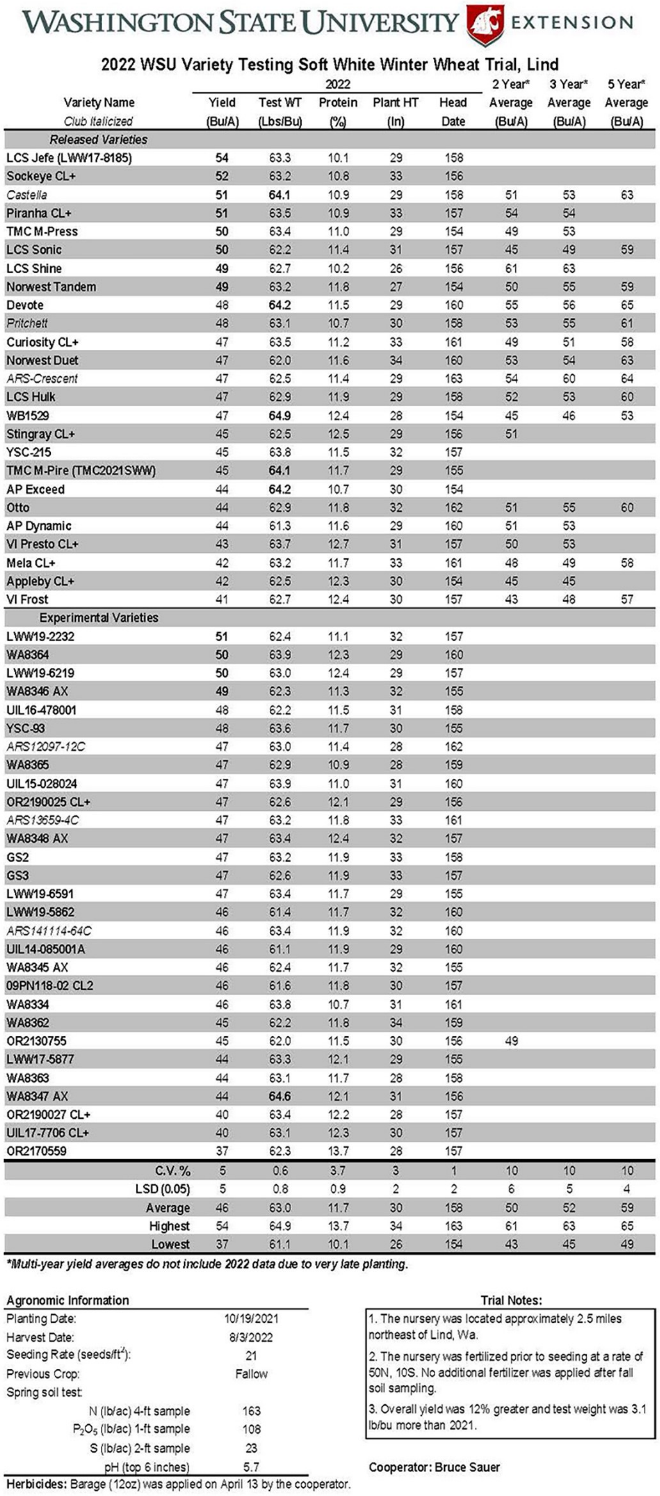
Herbicides: LV-6 (10oz) was applied on May 11 by the cooperator.

Trial Notes:

1. The nursery was located approximately 3 miles northeast of Lind, WA.
2. The nursery was fertilized prior to seeding at a rate of 50N, 10S by the cooperator. No additional fertilizer was applied after spring soil sampling.
3. Overall yield was 383% greater than in 2021. Samples too small for test weight in 2021.

Cooperator: Bruce Sauer

The primary goal of the program is to produce comprehensive, reliable, and unbiased data for growers, agribusiness industry, university researchers and other clientele to use and make informed decisions. The use of sound statistical methodology and uniform testing procedures allow for the comparison of varieties both within and across environments. Trials are grouped together into four precipitation zones, plus irrigated sites, and span from the Highway 2 corridor in the north to the Walla Walla Valley and Horse Heaven Hills in the south in order to capture the diverse climates found in the state.



WASHINGTON STATE UNIVERSITY EXTENSION

2022 WSU Variety Testing Soft White Winter Wheat Trial, Lind

Variety Name *Club Italicized*	2022 Yield (Bu/A)	Test WT (Lbs/Bu)	Protein (%)	Plant HT (In)	Head Date	2 Year* Average (Bu/A)	3 Year* Average (Bu/A)	5 Year* Average (Bu/A)
Released Varieties								
LCS Jefe (LWW17-8185)	**54**	63.3	10.1	29	158			
Sockeye CL+	**52**	63.2	10.8	33	156			
Castella	**51**	**64.1**	10.9	29	158	51	53	63
Piranha CL+	**51**	63.5	10.9	33	157	54	54	
TMC M-Press	**50**	63.4	11.0	29	154	49	53	
LCS Sonic	**50**	62.2	11.4	31	157	45	49	59
LCS Shine	**49**	62.7	10.2	26	156	61	63	
Norwest Tandem	**49**	63.2	11.8	27	154	50	55	59
Devote	48	**64.2**	11.5	29	160	55	56	65
Pritchett	48	63.1	10.7	30	158	53	55	61
Curiosity CL+	47	63.5	11.2	33	161	49	51	58
Norwest Duet	47	62.0	11.6	34	160	53	54	63
ARS-Crescent	47	62.5	11.4	29	163	54	60	64
LCS Hulk	47	62.9	11.9	29	158	52	53	60
WB1529	47	**64.9**	12.4	28	154	45	46	53
Stingray CL+	45	62.5	12.5	29	156	51		
YSC-215	45	63.8	11.5	32	157			
TMC M-Pire (TMC2021SWW)	45	**64.1**	11.7	29	155			
AP Exceed	44	**64.2**	10.7	30	154			
Otto	44	62.9	11.8	32	162	51	55	60
AP Dynamic	44	61.3	11.6	29	160	51	53	
VI Presto CL+	43	63.7	12.7	31	157	50	53	
Mela CL+	42	63.2	11.7	33	161	48	49	58
Appleby CL+	42	62.5	12.3	30	154	45	45	
VI Frost	41	62.7	12.4	30	157	43	48	57
Experimental Varieties								
LWW19-2232	**51**	62.4	11.1	32	157			
WA8364	**50**	63.9	12.3	29	160			
LWW19-6219	**50**	63.0	12.4	29	157			
WA8346 AX	**49**	62.3	11.3	32	155			
UIL16-478001	48	62.2	11.5	31	158			
YSC-93	48	63.6	11.7	30	155			
ARS12097-12C	47	63.0	11.4	28	162			
WA8365	47	62.9	10.9	28	159			
UIL15-028024	47	63.9	11.0	31	160			
OR2190025 CL+	47	62.6	12.1	29	156			
ARS13659-4C	47	63.2	11.8	33	161			
WA8348 AX	47	63.4	12.4	32	157			
GS2	47	63.2	11.9	33	158			
GS3	47	62.6	11.9	33	157			
LWW19-6591	47	63.4	11.7	29	155			
LWW19-5862	46	61.4	11.7	32	160			
ARS141114-64C	46	63.4	11.9	32	160			
UIL14-085001A	46	61.1	11.9	29	160			
WA8345 AX	46	62.4	11.7	32	155			
09PN118-02 CL2	46	61.6	11.8	30	157			
WA8334	46	63.8	10.7	31	161			
WA8362	45	62.2	11.8	34	159			
OR2130755	45	62.0	11.5	30	156	49		
LWW17-5877	44	63.3	12.1	29	155			
WA8363	44	63.1	11.7	28	158			
WA8347 AX	44	**64.6**	12.1	31	156			
OR2190027 CL+	40	63.4	12.2	28	157			
UIL17-7706 CL+	40	63.1	12.3	30	157			
OR2170559	37	62.3	13.7	28	157			
C.V. %	5	0.6	3.7	3	1	10	10	10
LSD (0.05)	5	0.8	0.9	2	2	6	5	4
Average	46	63.0	11.7	30	158	50	52	59
Highest	54	64.9	13.7	34	163	61	63	65
Lowest	37	61.1	10.1	26	154	43	45	49

Multi-year yield averages do not include 2022 data due to very late planting.

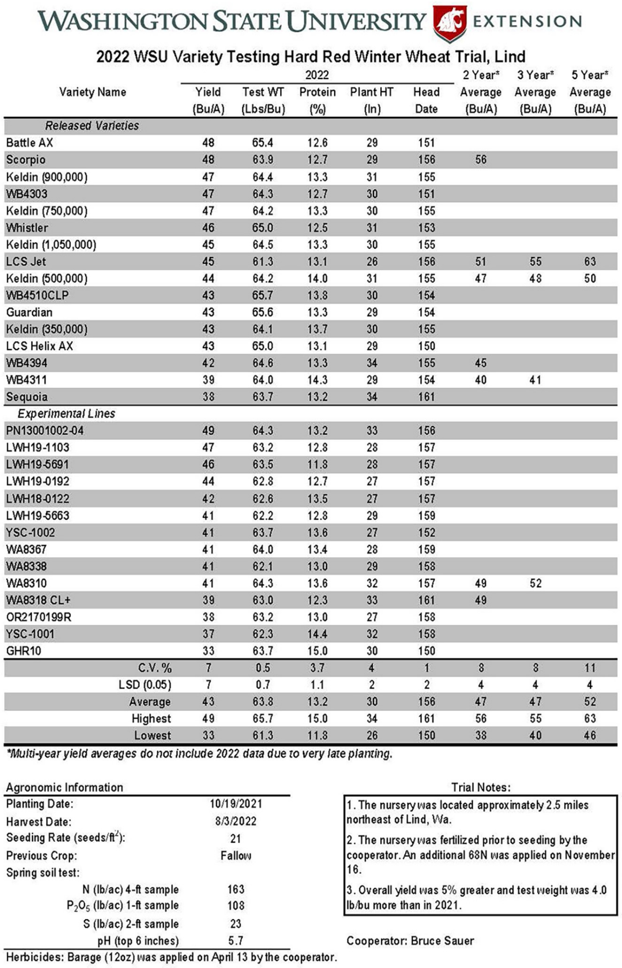
Agronomic Information	
Planting Date:	10/19/2021
Harvest Date:	8/3/2022
Seeding Rate (seeds/ft^2):	21
Previous Crop:	Fallow
Spring soil test:	
N (lb/ac) 4-ft sample	163
P_2O_5 (lb/ac) 1-ft sample	108
S (lb/ac) 2-ft sample	23
pH (top 6 inches)	5.7

Herbicides: Barage (12oz) was applied on April 13 by the cooperator.

Trial Notes:

1. The nursery was located approximately 2.5 miles northeast of Lind, Wa.
2. The nursery was fertilized prior to seeding at a rate of 50N, 10S. No additional fertilizer was applied after fall soil sampling.
3. Overall yield was 12% greater and test weight was 3.1 lb/bu more than 2021.

Cooperator: Bruce Sauer



WASHINGTON STATE UNIVERSITY EXTENSION

2022 WSU Variety Testing Hard Red Winter Wheat Trial, Lind

Variety Name	2022 Yield (Bu/A)	Test WT (Lbs/Bu)	Protein (%)	Plant HT (In)	Head Date	2 Year* Average (Bu/A)	3 Year* Average (Bu/A)	5 Year* Average (Bu/A)
Released Varieties								
Battle AX	48	65.4	12.6	29	151			
Scorpio	48	63.9	12.7	29	156	56		
Keldin (900,000)	47	64.4	13.3	31	155			
WB4303	47	64.3	12.7	30	151			
Keldin (750,000)	47	64.2	13.3	30	155			
Whistler	46	65.0	12.5	31	153			
Keldin (1,050,000)	45	64.5	13.3	30	155			
LCS Jet	45	61.3	13.1	26	156	51	55	63
Keldin (500,000)	44	64.2	14.0	31	155	47	48	50
WB4510CLP	43	65.7	13.8	30	154			
Guardian	43	65.6	13.3	29	154			
Keldin (350,000)	43	64.1	13.7	30	155			
LCS Helix AX	43	65.0	13.1	29	150			
WB4394	42	64.6	13.3	34	155	45		
WB4311	39	64.0	14.3	29	154	40	41	
Sequoia	38	63.7	13.2	34	161			
Experimental Lines								
PN13001002-04	49	64.3	13.2	33	156			
LWH19-1103	47	63.2	12.8	28	157			
LWH19-5691	46	63.5	11.8	28	157			
LWH19-0192	44	62.8	12.7	27	157			
LWH18-0122	42	62.6	13.5	27	157			
LWH19-5663	41	62.2	12.8	29	159			
YSC-1002	41	63.7	13.6	27	152			
WA8367	41	64.0	13.4	28	159			
WA8338	41	62.1	13.0	29	158			
WA8310	41	64.3	13.6	32	157	49	52	
WA8318 CL+	39	63.0	12.3	33	161	49		
OR2170199R	38	63.2	13.0	27	158			
YSC-1001	37	62.3	14.4	32	158			
GHR10	33	63.7	15.0	30	150			
C.V. %	7	0.5	3.7	4	1	8	8	11
LSD (0.05)	7	0.7	1.1	2	2	4	4	4
Average	43	63.8	13.2	30	156	47	47	52
Highest	49	65.7	15.0	34	161	56	55	63
Lowest	33	61.3	11.8	26	150	38	40	46

**Multi-year yield averages do not include 2022 data due to very late planting.*

Agronomic Information	
Planting Date:	10/19/2021
Harvest Date:	8/3/2022
Seeding Rate (seeds/ft^2):	21
Previous Crop:	Fallow
Spring soil test:	
N (lb/ac) 4-ft sample	163
P_2O_5 (lb/ac) 1-ft sample	108
S (lb/ac) 2-ft sample	23
pH (top 6 inches)	5.7

Herbicides: Barage (12oz) was applied on April 13 by the cooperator.

Trial Notes:

1. The nursery was located approximately 2.5 miles northeast of Lind, Wa.
2. The nursery was fertilized prior to seeding by the cooperator. An additional 68N was applied on November 16.
3. Overall yield was 5% greater and test weight was 4.0 lb/bu more than in 2021.

Cooperator: Bruce Sauer

Preliminary data is sent out via email list serve immediately following harvest and then posted online on the small grains website (http://smallgrains.wsu.edu). Printed copies of the data can also be found in the final comprehensive Cereal Variety Testing Annual Report and Wheat Life Magazine articles. Typically, results are discussed and distributed at grower meetings and field days throughout the year. Virtual field days are recorded at select locations and posted on the College of Agriculture, Human, and Natural Resources YouTube Channel (https://www.youtube.com/user/WSUCAHNRS/).

Stakeholders can also access data through either the desktop version of the "Variety Selection Tool" at https://varietyselection.cahnrs.wsu.edu/ or access the tool through the mobile app. Data provided on the tool includes multi-year yield averages, test weight, grain protein, multiple disease ratings, end use quality, falling number rating, and much more. Growers are also welcome to walk the plots at any time. Plot maps are posted on our website with directions to the sites along with hard copies on-site placed in PVC tubes.

OSU Cereal Extension Program Updates

Ryan C. Graebner, Daisy Rudometkin, and Matthew Hunt

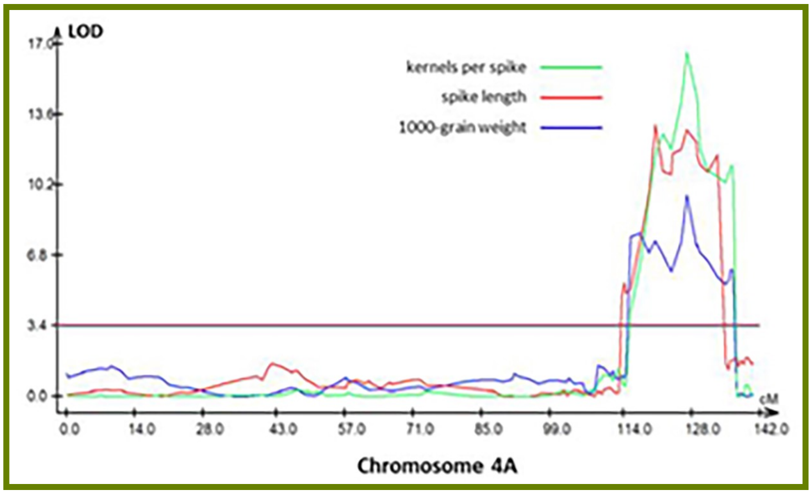
Columbia Basin Agricultural Research Center, OSU

The Oregon Cereal Extension Program provides growers with performance information on commonly grown and newly released wheat and barley varieties from public and private breeding programs. Wheat varieties are evaluated in four trials (the Oregon Soft Winter Wheat Variety Trial, the Oregon Hard Winter Wheat Variety Trial, the Oregon Soft Spring Wheat Variety Trial, and the Oregon Hard Spring Wheat Variety Trial) while barley varieties are evaluated in the Oregon Spring Barley Variety Trial. This year, we are conducting trials in 22 locations throughout Oregon, Southeast Washington, and Northern California. Trial data is released as soon as possible after harvest through our website, https://cropandsoil.oregonstate.edu/wheat/osu-wheat-variety-trials, so that variety testing data can be used to make planting decisions for the following crop year. Key traits we evaluate include yield, test weight, grain protein, plant height, and heading date. In addition, we collaborate with Professor Chris Mundt, Professor Andrew Ross, and the Western Wheat Quality Laboratory to evaluate the entries for disease resistance and end-use quality. Program priorities include ensuring that our testing conditions reflect production conditions, maintaining consistency in the locations we test from year to year, and testing experimental lines as early as possible to develop an understanding of their performance before they are released.

Improving Wheat Yield: A Breeding Target Identification Story

Tyson Koepke, Jayfred Godoy, Sheri Rynearson, Vadim Jitkov, Wycliffe Nyongesa, John Kuehner, Josh DeMacon, Victor DeMacon, and Michael Pumphrey

Dept. of Crop and Soil Sciences, WSU



Wheat growers require varieties with high quality and high yield to produce profitable crops. Yield is a complex trait that can be more easily evaluated when broken in components including kernel weight, kernels per spike, and spike length. 180 recombinant inbred lines (RILs) were developed from a cross of Kelse and Scarlet, two hard red spring wheat varieties. Evaluation of these RILs at two locations over three years, combined with genetic information from ~90,000 sites across the genome, identified a location on chromosome 4A that contributes significantly to heading date, spike length, kernels/spike, and kernel weight. 2,000 lines were developed from two of the RILs and tested to further define the locus controlling these traits. The Scarlet allele at the target marker contributes to ~2 days earlier heading date. The effect of this marker on spike length, kernels/spike, and kernel weight continues to be evaluated. Though work remains to identify a causal gene, breeding efforts to leverage the genetic characteristics of this region are underway to improve yield for Washington wheat growers.

The Washington State University Winter Wheat Breeding and Genetics Program Update

A. Carter, K. Balow, A. Burke, K. Hagemeyer, G. Shelton, and A. Stowe

Dept. of Crop and Soil 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. Our program utilizes research from graduate students to identify new tools and techniques to improve selection efficiency. We have been investigating genomic selection efforts and have found them very useful to remove lines from the breeding program which do not hold potential for cultivar release. This technique also allows us to evaluate lines on their genetic potential, when phenotypic trait data is not available, like for end-use quality during first year yield trials and for years when disease is not present. Collaboratively with the Spring Wheat and USDA Wheat breeding programs, groups in Biological Systems Engineering, and partners at CIMMYT, we have begun investigating the use of UAS imagery in combination with genomic selection, to improve selection efficiency. We have found that when these two techniques are combined, selection efficiency is improved. UAS imagery also allows us to better understand how the breeding lines are interacting with the environment and helps select cultivars which perform well across environments. This has been helpful given the diverse production years we have seen the past five years. We have been partnering with researchers to learn more about the local climate of each testing location and using that information to understand how to better analyze, interpret, and select lines based on local conditions. Working with the WSU Weed Science program we are expanding efforts to develop herbicide tolerance to benefit growers of the state, as well as selecting wheat to be more competitive with weeds. The Winter Wheat Program continues to work effectively and efficiently to develop winter wheat cultivars with high yield potential and required agronomics, disease resistance, and end-use quality parameters for the state of Washington.

Releases from the WSU winter wheat program include the soft white cultivars **Inspire, Jameson, Devote**, **Otto**, **Puma**, **Jasper**, and **Purl**. These cultivars contain excellent disease resistance and are agronomically adapted to different climatic regions. Hard red cultivars include **Scorpio** and **Sequoia.** Scorpio contains resistance to stripe rust, Hessian fly, and low pH soils, and has maintained high yield across multiple years and locations of testing. Our recently released Clearfield cultivars **Sockeye** CL+, **Piranha** CL+, and **Stingray** CL+, continue to maintain high yield in most of the trials they have been tested in and have broad adaptability across rainfall zones and years. They improve upon current Clearfield cultivars by adding very good disease resistance with excellent grain yield. We also participated in the collaborative release of the Clearfield cultivars **Curiosity** CL+, **Mela** CL+, **Resilience** CL+, along with the club wheat cultivars **ARS-Pritchett, ARS-Castella**, and **ARS-Cameo.**

We have received approval for the release of new cultivars. **WA8334** is a soft white line that has shown high grain yield from 2020-2022 in low rainfall areas and combines very good agronomics and disease resistance. **WA8310** is a hard red line that has maintained high grain yield in intermediate rainfall zones and has very good stripe rust and low pH soil tolerance. We continue to work on additional herbicide resistant cultivars and are working toward additional releases of hard red and soft white lines with resistance to Beyond (Clearfield) and Aggressor (CoAXium) herbicides.

The USDA-ARS Western Wheat Quality Laboratory

Alecia M. Kiszonas

USDA-ARS Western Wheat Quality Laboratory, Pullman, WA

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 soft durum wheat, grain hardness, super soft kernel texture, puroindolines, field pea proteins, and waxy wheat. Our recent publications include a global history of U.S. Pacific Northwest wheat during the Cold War. Research on the variation, composition, and genetics of pea proteins published in Cereal Chemistry, and trait associations and genetic variability of field peas in the variety development process also published in Cereal Chemistry. Research on the genetic architecture of end-use quality traits in soft white winter wheat was published in BMC Genomics. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Seahawk, Sequoia, Sprinter, Tekoa, Whit, and Cameo.

Identification of Key Cold Response Determinants in *Triticum aestivum*: Elucidating the Interaction Between Vernalization and Photoperiod for Low-Temperature Acclimation

DYLAN C. OATES[1], TYLER BIGGS[2], STEPHEN FICKLIN[2], KIMBERLEY GARLAND-CAMPBELL[1,3], AND KAREN A. SANGUINET[1]

[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]DEPT. OF HORTICULTURE, WSU; [3]USDA-ARS, PULLMAN, WA

Most temperate crops, including wheat, can cold acclimate when exposed to low, non-lethal temperatures, before undergoing sublethal freezing stress. Chilling and freezing stress (defined as 0 to 15 for chilling injury; <0 for freezing injury) affects all aspects of the plant, such as growth, development, reproductive capabilities, metabolism, and overall plant yield. Cold and freezing stress are perceived by several cellular signaling molecules, some of which are cytosolic calcium, reactive oxygen species, protein kinases, and lipids. When cold temperatures are sensed by membrane receptors, regulation of cold-responsive genes and transcription factors occurs. These include cold-responsive (COR) proteins, late embryogenesis abundant (LEA) proteins, inducer of CBF expression (ICE) proteins, and vernalization (VRN) proteins. The expression of the genes that encode for these proteins are regulated by specific promoter elements that include C-repeat binding factors (CBF) and phytohormone-responsive elements; thus, low-temperature stress is regulated by a complex network of genes and transcription factors. Notably, freezing stress equates to a serious threat to continuous crop yields and can lead to significant crop loss particularly for winter annuals. The Norstar variety of winter wheat, *Triticum aestivum*, is sought after due to its high freezing tolerance. However, preliminary physiological and phenotypic data indicate that if Norstar undergoes flowering induced by a shortened photoperiod without exposure to low temperature, it becomes more susceptible to freezing damage. While vernalization and photoperiod are well described, the way these mechanisms impact freezing tolerance is still considered elusive. Therefore, the goal of this project is to reveal the underlying vernalization and photoperiod determinants driving freezing tolerance in *T. aestivum*. To this end, we performed QTL analyses of three bi-parental mapping populations for low-temperature tolerance using Norstar as a parent in all three populations. We identified 2 QTL in the Norstar by winter Manitou and 5 QTL in the Norstar by Manitou populations, whereas none in the Norstar by Cappelle Deprez population. Next, we performed RNAseq analysis of double-haploid derived population of Norstar F1 progeny that was either vernalized or subjected to photoperiod-induced flowering. We found 480 genes were upregulated and 326 genes were downregulated. We are in the process of validating these by qRT-PCR. Our next step is to evaluate epigenetic differences in DEG identified from RNAseq. Taken together, these data will help to identify genetic markers and genes that can help breed for cold and freezing tolerance wheat varieties to improve winter survival.

Genomic Prediction for Improving Spring Wheat Quality

PETER SCHMUKER, SHERI RYNEARSON, TYSON KOEPKE, AND MICHAEL PUMPHREY

DEPT. OF CROP AND SOIL SCIENCES, WSU

Washington State wheat has a reputation for high quality production of bread, cookies, cake, and noodles due to decades of continuous breeding efforts. Years of record drought and heat like those seen in 2021 have a negative impact on wheat quality. For example, the soft spring wheat variety trials in Lind averaged 14.4% protein in 2021 while the 2022 average protein content was 13.3%. Spring wheat cultivars need to be adapted to adverse and permissive growing conditions in both agronomic and quality traits to meet grower needs. Genomic prediction, a set of data analysis methods that use thousands of genetic markers to predict cultivar performance, can be used to estimate how a line of wheat will perform in different environments.

In this study, 100 hard and 150 soft experimental lines were selected per year out of the WSU preliminary yield trials over 2021 and 2022. Cultivars were genotyped and grain samples sent to the Western Wheat Quality Lab for evaluation of mill score, break flour yield, protein content, test weight and market-class-specific traits such as loaf volume and water absorption for hard wheats and cookie diameter for soft wheat. Within each market class, two genomic prediction models were built per quality trait using: 1) only information from individual years and 2) both years of data with genetic interaction effects specific to year. Prediction accuracy was assessed by comparing the actual performance of lines versus the expected performance of lines within a year.

The comparison of prediction accuracies shows that all traits benefit from combining information from across years and modeling genetic interactions specific to the year. Improved accuracy is explained by certain genes contributing to relatively high quality under drought, but decreased quality in cooler, wetter conditions. The combination of 2021 and 2022 data in building genomic selection models enables the identification of cultivars that are more likely to perform well under varied conditions. Genomic prediction models allow the ability to remove materials predicted to have poor quality early in the breeding cycle so breeding program resources can be focused on more promising materials for later evaluation. Over the long term, use of genomic prediction methods will result in Washington wheat growers having access to spring wheat cultivars with consistently acceptable quality across unpredictable growing seasons.

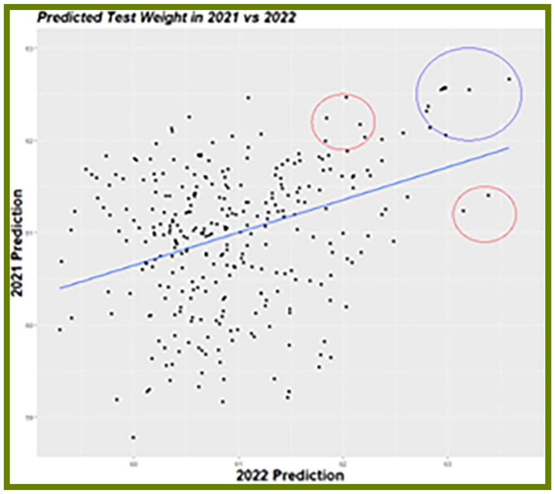


Figure 1. Predicted test weight in 2021 and 2022 for several hundred soft spring lines; each dot represents a line of wheat. Although there is a general correlation between predictions for both years, significant variation is present. A blue circle surrounds lines that show promise for high test weight under both conditions. Red circles are around lines that show relatively high merit in only one year.

Table 1. Prediction accuracies measured by correlation coefficient, a value ranging from -1 to 1, with values closer to 1 indicating higher accuracy and values closer to -1 showing ranks predicted in opposite order of true performance. Each column represents when predictions were evaluated to test model accuracy. Although prediction accuracy for 2021 remains lower than 2022, large increases in accuracy are shown when genetic interactions per year are included in creating the genomic selection model relative to models without year effects.

Hard Wheat	Individual Year Model		Year Effect Included	
Quality Trait	2021 Test	2022 Test	2021 Test	2022 Test
Millscore	0.14	0.18	0.38	0.56
Breakflour Yield	0.14	0.22	0.35	0.47
Protein	0.19	0.11	0.52	0.59
Test Weight	-0.02	0.11	0.35	0.42
Loaf Volume	-0.05	0.09	0.23	0.6
Protein Strength	0.29	0.31	0.67	0.67
Bake Water Absorption	0.09	-0.14	0.45	0.49
Ash	0.03	-0.14	0.38	0.45

Soft Wheat	Individual Year Model		Year Effect Included	
Quality Trait	2021 Test	2022 Test	2021 Test	2022 Test
Millscore	0.33	0.19	0.59	0.73
Breakflour Yield	0.13	0.38	0.42	0.55
Protein	0	-0.04	0.32	0.36
Test Weight	0.06	-0.08	0.37	0.52
Cookie Diameter	0.49	0.6	0.53	0.72
Ash	0.12	0.07	0.32	0.79

Can You Kill Three Birds with One Stone? Looking for Genetic Connections Between Three Causes of Low Falling Numbers in Wheat: Preharvest Sprouting, LMA, and Vivipary

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*The first two authors contributed equally to this work.

The research goal is to reduce the risk of low falling numbers in PNW wheat by identifying resistance genes for use in early generation selection in breeding programs. Low falling numbers result from elevated levels of the enzyme alpha-amylase in wheat grains. Alpha-amylase causes an increased risk of poor end-product quality because it digests starch leading to reduced gelling capacity when wheat flour is used in baked goods or pasta. There are two major causes of low falling numbers: preharvest sprouting is the initiation of mature grain germination on the mother plant when rain occurs before harvest and LMA (late maturity alpha-amylase) is the induction of alpha-amylase in response to cold during the soft dough stage of seed maturation. The soft dough stage typically occurs as the wheat plants lose their green color. We discovered that when wheat was placed in a cold chamber (65°C day/7.5°C night) to induce LMA, it could initiate germination if the humidity was too high. This premature germination is called "vivipary". Does this mean that we now need to select for resistance to all three problems independently in the breeding program? LMA, vivipary, and preharvest sprouting? Or are they genetically related phenomena that could be selected using some of the same molecular markers?

We previously mapped 7 LMA resistance loci/genes in a panel of 250 spring wheat lines by association mapping. In this study, 29 loci/genes for preharvest sprouting tolerance were mapped in the same population based on visible sprouting in spike-wetting tests over 2 years. Of the 7 LMA loci, five had map positions that were so close to sprouting tolerance loci that they might be due to the same genes (Fig. 1). As we found 24 sprouting tolerance genes that were unrelated to LMA and 2 LMA genes unrelated to sprouting, it appears that we must still screen for both traits. But this genetic overlap is encouraging because it suggests that if we make certain that these 5 loci/genes are in our crosses and early breeding lines, it may be possible to stack the deck in favor of resistance to both LMA and preharvest sprouting. The LMA and preharvest sprouting traits were significantly correlated in this population. When we examined vivipary in a subset of the spring lines, vivipary was also significantly correlated with LMA ($r = 0.6$, $p = 6.4 \text{ x} 10^{-5}$) and preharvest sprouting ($r = 0.66$, $p = 4.6 \text{ x } 10^{-6}$). These correlations suggest that breeding programs that select for sprouting tolerance may also enrich for LMA or vivipary tolerance. This is good news because it is more difficult to screen for LMA and vivipary.

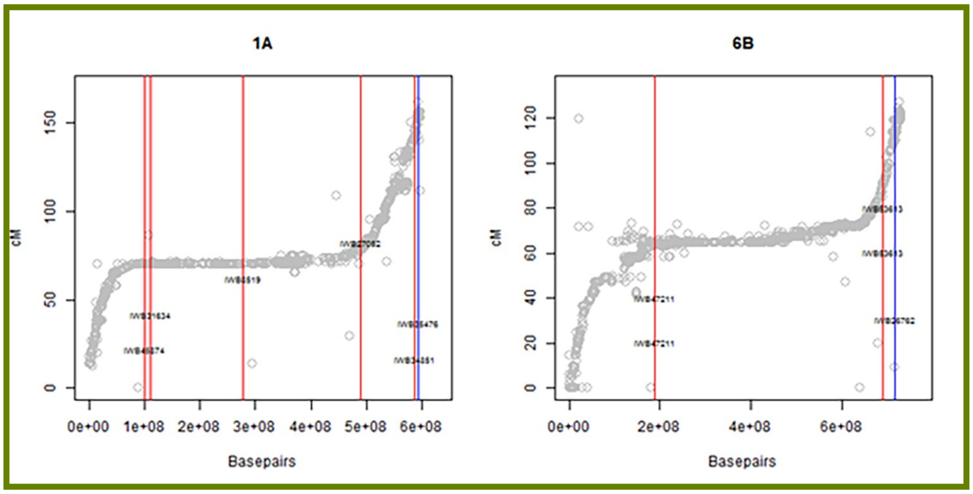

Figure 1. Map positions of LMA and PHS QTL identified by GWAS of the TCAP on chromosome 1A and 6B. The known SNP positions (Wang et al., 2014; Appels et al., 2018) were graphed based on their physical (Mbp) and genetic (cm) map locations. QTL associated with LMA tolerance are shown in vertical blue lines and the red vertical lines represent PHS tolerance.

Part 3. Agronomy and Soils

Multi-Species Cover Crops Affect Microbial Communities and Enhance Trophic Relationships in the Soil Food Web

BRONTE SONE[1], DANE C. ELMQUIST[2], SANFORD D. EIGENBRODE[2], AND MICHAEL S. STRICKLAND[1]

[1]DEPT. OF SOIL AND WATER SYSTEMS, UI; [2]DEPT. OF ENTOMOLOGY, PLANT PATHOLOGY AND NEMATOLOGY, UI

Some producers in the Inland Pacific Northwest want to incorporate cover crops into their wheat-based rotations to promote soil health and agricultural sustainability. However, it is unknown how cover crop species or species mixtures impact the diversity of soil organisms and influence trophic relationships within the soil food web. Plants fuel soil food webs through rhizodeposits, including root exudates. Root exudates provide a source of carbon (C) directly to soil microorganisms and can vary by type and amount depending on plant species. Greater plant diversity leads to greater diversity of root exudates and potentially to root biomass and surface area. More C and habitat affect the abundance and diversity of soil microbial communities that, in turn, become prey for common soil arthropods like Collembola, also known as springtails. The interactions between microbial communities and Collembola contribute to soil ecosystem services including nutrient cycling and crop growth.

The objective of this study was to evaluate the impact of different cover crop treatments on the relationship between microbial biomass and activity, and Collembola populations. Cover crops were grown in small-scale replicated plots (*n* = 3) (5.5 x 8 ft^2) in Pullman, WA. The cover crops investigated were flax, sunflower, spring pea, and sweet clover. Treatments included each of these species planted individually, a mixture of all four species, and a fallow control. Soil samples were collected for determination of microbial activity, microbial biomass, and Collembola abundance.

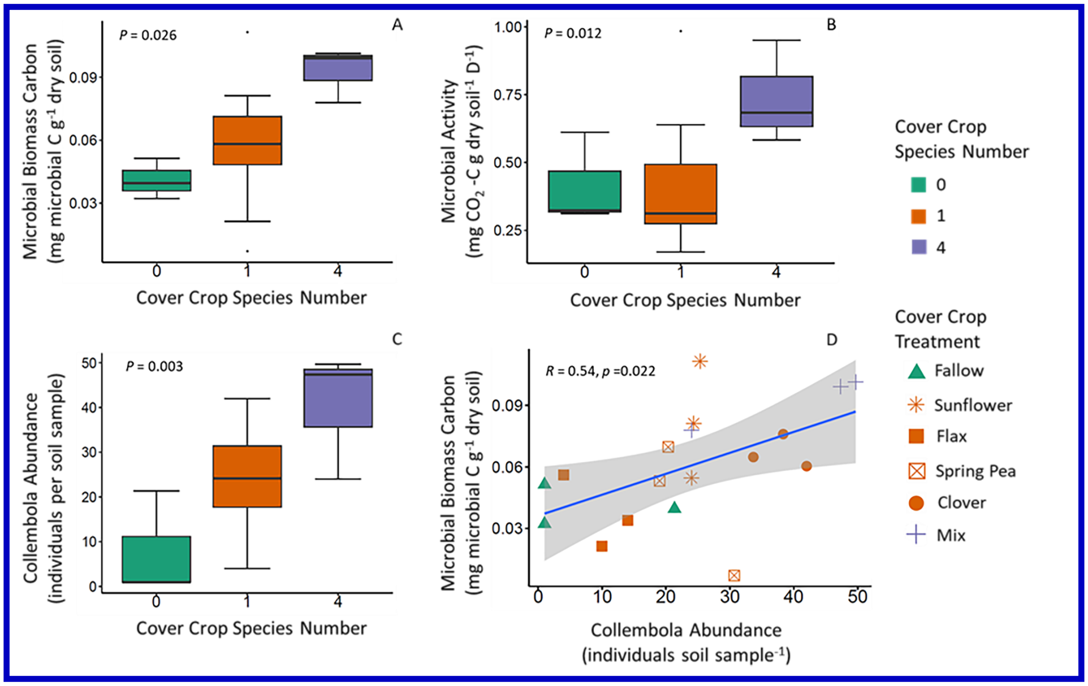

Fig. 1 Effects of cover crop treatment on microbial biomass (A), microbial activity (B), Collembola abundance (# individuals 2 L-1 soil) (C), and relationship between collembola abundance and microbial biomass (D). Significant differences ($p<0.05$) based on ANOVA. Mix= mix of all four cover crop species. Shaded areas in 1D represent 95% confidence intervals.

The four-species cover crop increased microbial biomass (Fig 1A), microbial activity (Fig 1B), and Collembola abundance (Fig 1C) relative to other treatments. Fallow tended to have the lowest values and single species cover crops were intermediate. Microbial biomass and Collembola abundance were positively correlated (Fig 1D), likely resulting from bottom-up effects on microbe-feeding Collembola. Collembola grazing can liberate labile C and other nutrients from microbial biomass that also readily bind with soil minerals potentially promoting long term organic matter storage. Despite increased soil respiration, which could result in loss of C, microbial biomass increased in this study, which suggests greater potential for soil C storage. Finally, the effect of individual cover crops varied significantly between species, but the effect of the mixture was, on average, greater than that of individual species. The study indicates that multi-species cover crops have positive effects on soil biota and soil food webs, known to be conducive to agricultural productivity.

Soil Carbon Changes at Cook Agronomy Farm, 1998-2015

CLAIRE PHILLIPS, DAVE HUGGINS, JOAQUIN CASANOVA, AND QUIPING PENG

USDA-ARS NORTHWEST SUSTAINABLE AGROECOSYSTEMS RESEARCH UNIT

A long-term study was initiated at the Cook Agronomy Farm in 1998 to evaluate spatial variability in performance of no-till wheat-based cropping systems, including impacts of no-till on soil erosion and soil organic carbon (SOC). SOC changes were measured to 153 cm depth at the study outset in 1998, and again in 2008 and 2015 at approximately 170 geo-referenced locations across the 37-ha field. SOC changes through time were calculated using an 'equivalent soil mass' approach, which accounts for changes in bulk density that can also occur through time. These results provide information on the potential for conservation tillage to sequester carbon, within the context of ecosystem service markets and other conservation incentive programs.

Overall, SOC stocks to 153 cm declined by 12.7 (S.D. 24.3) Mg ha^{-1} between 1998-2015 (Table 1). In the top 30 cm, which is the depth evaluated for carbon markets, SOC loss was 3.3 (S.D. 7.7) Mg ha^{-1}. However, in the top 0-30 cm SOC increased during the first ten years following no-till adoption (Table 1). In 2008, the planting implement was changed from a Great Plains drill to a Horsch drill, which has a hoe-type opener to better penetrate dry soils in the fall. However, the Horsch drill also creates more inversion tillage, and caused SOC losses in the top 0-30 cm during 2008-2015 that exceeded initial SOC gains.

In the soil subsurface (30-153 cm), SOC stocks declined during both the 1998-2008 and the 2008-2015 periods (Table 1). Spatial variability was considerable, however, with some locations experiencing no change, and others gaining SOC.

It was expected that steep hillslope positions would experience the greatest carbon gains following conversion to no-till, due to reduced erosion. However, this was not the case. From 1998-2008, near-surface SOC gains corresponded with residue carbon inputs (Fig. 1a). Residue inputs were smaller on steep backslope positions relative to shoulder, footslope, and toeslope positions (Fig. 1b and 1c), possibly due to soil degradation. From 2008-2015, SOC accumulation actually decreased at higher levels of residue input (results not shown), for reasons that are not yet understood.

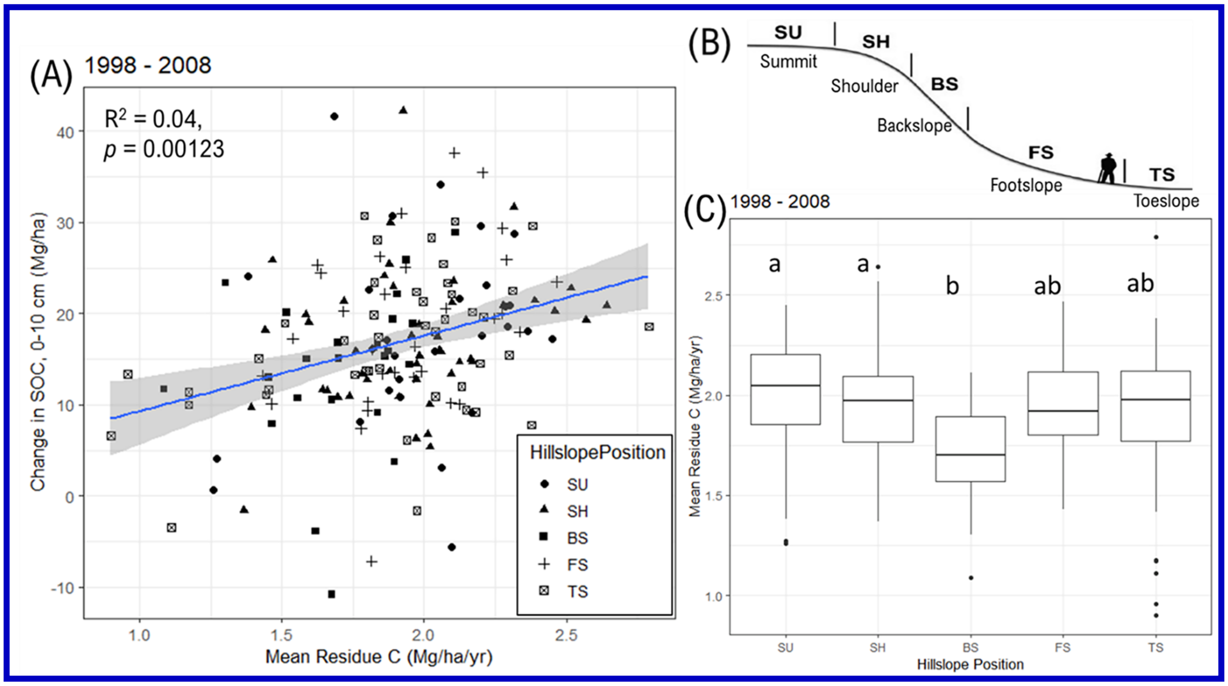

Figure 1. Select spatial patterns in SOC changes. (A) Correlation between SOC change in the near surface and residue input rate. (B) Schematic of hillslope positions. (C) Residue input rates for different hillslope positions. Positions not sharing the same letter had significant differences ($p \le 0.06$).

Over 17 years following no-till adoption, average trends showed SOC was gained and subsequently lost at the soil surface, while SOC in the subsurface was continually lost. Spatial heterogeneity was considerable. Only a small portion of the heterogenous changes in SOC was explained by rates of residue inputs.

Table 1. Summary statistics for SOC stock changes at different depth intervals.

	MG/HA		
Statistic	1998-2008	2008-2015	1998-2015
0—10 CM			
mean	16.8	-14.7	2.1
sd	8.6	8.1	3.7
min	-10.8	-40.1	-11.9
max	42.2	13.0	16.1
0—30 CM			
mean	12.9	-16.1	-3.3
sd	11.0	9.7	7.7
min	-36.5	-49.0	-27.5
max	41.9	17.9	20.4
30—153 CM			
mean	-6.2	-3.9	-9.7
sd	19.5	13.0	19.9
min	-96.1	-42.7	-105.6
max	107.2	50.7	97.8
0—153 CM			
mean	6.7	-20.1	-12.7
sd	24.8	15.1	24.3
min	-103.7	-57.5	-121.5
max	149.1	36.4	118.2

Lime Injection at a Long-Term No-Till Research Farm to Neutralize Stratified Soil Acidity

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USDA-ARS NORTHWEST SUSTAINABLE AGROECOSYSTEMS RESEARCH UNIT, PULLMAN, WA

Soil acidification results from nitrification of ammonia followed by nitrate leaching, and from removal of base cations including potassium, calcium, and magnesium via leaching of soil profiles and harvest of grain and crop residues. This process alters the bioavailability of aluminum, manganese, and essential nutrients resulting in toxicities and deficiencies that limit crop growth. Lime amendments can be used to neutralize soil acidity, but these amendments are costly, and their short- and long-term impacts on crop and soil health are difficult to predict. Twenty years of no-till management at the R. J. Cook Agronomy Farm long-term research site in Pullman, WA has concentrated soil acidity in the fertilizer band at 4-inch depth. Several rates of liquid lime were targeted to this acidified soil layer in eight 12- x 30-foot plots at four topographic positions via sweeps with injectors at 3-inch spacing. Soil cores have been collected in transects and split into 1-inch depth increments for pH, total C, and carbonate measurements to assess the distribution and efficacy of the liquid lime and to inform the collection of additional soil cores and rhizosphere samples for detailed chemical and microbiological analyses. The objectives of this research are to determine the efficiency of liming with this application method and to develop a deeper understanding of the root zone chemistries and ecologies that influence crop responses to soil acidification and lime amendments.

A) Liquid lime injection at 4-inch soil depth to target the acidified fertilizer band at the Cook Agronomy Farm. B) Winter wheat rhizosphere samples collected from the plots prior to liming.

Grain Mineral Density of Pacific Northwest Winter Wheat

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[1]USDA-ARS; [2]OREGON STATE UNIVERSITY; [3]UNIVERSITY OF IDAHO; [4]WASHINGTON STATE UNIVERSITY

The U.S. Pacific Northwest (PNW) region is a major exporter of cereal grains, including multiple market classes of wheat, but particularly soft white winter wheat. Much of the product is exported to Asia, including to developing nations with populations that are afflicted by mineral nutrient deficiencies. Billions of people worldwide experience mineral deficiencies, especially Zn and Fe, particularly in regions with predominantly cereal-based diets. One route to improve human nutrition is enhancing mineral density of diet staples, such as wheat. But for *winter* wheat produced in the PNW, there is hardly a baseline of knowledge on mineral density, though one report suggested that soft white *spring* wheat produced here had declined in mineral density over time (due to selection for low ash), while hard red spring wheat had not. Therefore, the objective of this study was to gain a better understanding of grain mineral density (P, K, Mg, Ca, Mn, Fe, Zn, and Cu) of PNW winter wheats, including testing for differences among N fertilizer rates and wheat varieties, and making comparisons among wheat market classes (soft white and hard red) and many production sites (in Oregon, Idaho, and Washington). To provide a broader perspective, the average mineral densities for each test site were also compared to standard densities obtained by synthesizing worldwide data reported in the scientific literature. Among agronomic factors affecting grain mineral densities, N fertilizer typically had little impact, while wheat variety and production site had greater effects. For example, in a two-year test involving four N rates, four wheat varieties, and two sites, grain Zn differed by up to 7.5%, 13%, and 27% among those factors, respectively. In comparisons of many wheat varieties at six production sites, statistical differences among varieties in mineral density were widespread. The differences were often substantial enough to provide a basis for breeding more nutritious wheat varieties, depending on specific mineral uptake heritability. In five side-by-side comparisons of soft white and hard red winter wheat variety trials, there was no evidence that these market classes systematically differed in density of any tested minerals. When mineral results for all test sites were compared to worldwide standards derived from the literature, individual minerals at individual sites differed from the standards, but there were few differences on average. The exceptions were grain P and K, which were commonly lower in grain from PNW sites than the standards. Since much of PNW wheat is processed (i.e. milled and refined) before consumption, samples from two variety trials were milled to produce straight-grade flour (the most commonly consumed flour product), enabling calculation of mineral reduction with processing. The minerals most negatively affected by processing were P, Mg, Mn, Fe, Zn, and Cu, with reductions ranging from roughly 50% to 90%. Percent reductions in individual minerals were comparable for hard red and soft white wheats. Overall, these results illustrate that the mineral density of PNW winter wheat is comparable to wheat generally, with no evidence that soft white winter wheat was less nutritious in minerals. The natural variation in grain minerals that exists among sites and wheat varieties can be utilized to customize or enhance wheat nutritional profile. Importantly, consumption of whole-grain wheat products should be expanded and promoted to preserve and utilize the inherent nutrition of wheat in relieving human mineral deficiencies.

Soil Health Management in Washington's Dryland Wheat: Survey Responses

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Background: Wheat producers manage over 25% of Washington's agricultural land and contribute up to $1 billion to its economy every year. Washington wheat is primarily grown in low rainfall zones without supplemental irrigation. As such, it is vulnerable to increased drought, heat, and extreme weather events. Studies show that soil management may play a role in increasing resilience. Practices that can increase soil organic matter and improve soil health include reduced till, livestock integration, cover cropping, and adding organic matter. While these conservation practices may deliver benefits in some contexts, results are not universal. Furthermore, multiple complex barriers may prevent conservation practice adoption, even when benefits are likely.

Methods: In 2022 the Washington State Department of Agriculture (WSDA) conducted a survey of wheat producers as part of the Washington Soil Health Initiative (WaSHI). The goals were to understand how soils are managed, and the benefits and challenges of using conservation practices.

Results: WSDA received 97 responses from producers in 12 counties (Fig. 1), collectively managing over 450,000 acres across diverse rainfall zones and farm sizes. Of these acres, 71.8% are cultivated using reduced or no till, 13.3% receive organic matter amendments, 4.8% are grazed by livestock, and 3.2% are cover cropped. While impacts of the 2021 drought were near universal (96.9% reduced yield and 94.8% reduced soil moisture), respondents overwhelmingly reported benefits from the use of conservation practices, including increased yields and increased soil moisture. Table 1 summarizes the benefits from each conservation practice included in the survey.

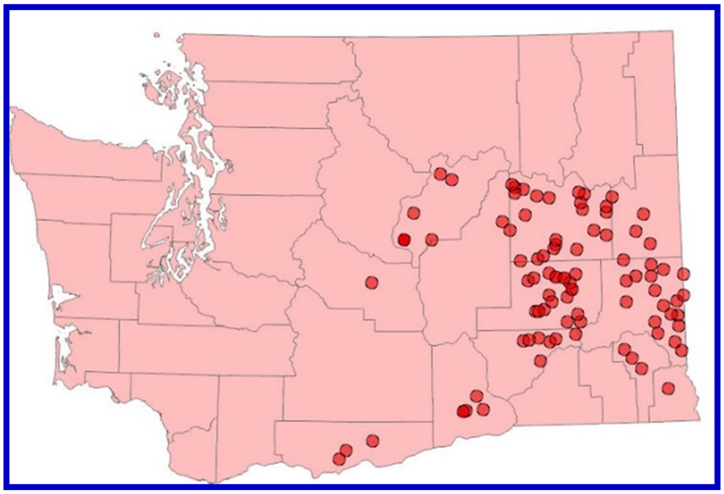

Figure 1. Distribution of survey respondents across Washington State

While soil health benefits and cost savings were experienced by the majority using conservation practices (Table 1), adoption of most practices remains low. Respondents reported various barriers and challenges. For example, 80.5% of producers who practice reduced till cited equipment costs as a challenge, while 50% who use conventional till cited costs as a barrier to tillage reduction. Reduced till producers commonly reported purchasing the following: higher horsepower tractors (61%), additional drills (65%), mowers (51%), and self-propelled sprayers (49%). This equipment can cost producers well over $1 million. By contrast, the majority of cover crop producers received incentive payments, and did not report purchasing new equipment. Depending on the seeding rate and species mix, seed costs were estimated between $40 and $240 per acre. Lack of information about how to implement a practice was also reported as a primary challenge, and was a particularly noteworthy barrier for both cover cropping and adding organic matter. Table 2 summarizes these barriers and challenges, along with the percentage of adopters receiving cost share payments.

Next steps: More research is needed on the conditions in which conservation practices lead to economic and environmental benefits, and how to support practice adoption in those contexts. Responses collected as part of this survey inform the policies and programs of WSDA and WaSHI. To learn more about ongoing research, technical assistance, and economic development efforts, visit the WSDA WaSHI webpage (www.agr.wa.gov/departments/land-and-water/natural-resources/soil-health) or contact dgelardi@agr.wa.gov.

Table 1. Reported benefits in soil health and variable costs from implementing conservation practices.

Benefit	Reduced or no till (n = 77)	Livestock integration (n = 18)	Cover cropping (n = 10)	Adding organic matter (n = 28)
	% reporting benefit from the use of above conservation practice			
↑ yield	46.8%	22.3%	20%	57.1%
↑ soil moisture	71.5%	x	60%	32.2%
↓ runoff and erosion	88.3%	x	60%	21.4%
↓ compaction	44.5%	x	50%	14.3%
↓ fertilizer use	27.3%	11.1%	30%	35.7%
↓ pesticide use	5.2%	11.1%	50%	14.3%
↓ labor costs	71.5%	11.1%	10%	3.6%
↓ equipment use	89.5%	16.7%	30%	7.1%
↓ equipment maintenance	55.9%	16.7%	20%	3.6%

n = number of survey respondents using each practice; x = question was not asked for this practice

Table 2. Reported challenges and barriers to implementing or maintaining conservation practices

	Producers using practice				Producers not using practice		
	n	Costs are a challenge	Lack of info is a challenge	Received cost share	n	Costs are a barrier	Lack of info is a barrier
Reduced or no till	77	80.5%	10.4%	57.1%	20	50.0%	5.0%
Livestock integration	18	44.4%	11.1%	16.7%	79	15.2%	8.9%
Cover cropping	10	60.0%	40.0%	80.0%	87	25.3%	19.5%
Adding organic matter	28	25.0%	10.7%	3.6%	69	66.7%	27.5%

n = number of survey respondents in each category

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 include fallow, winter wheat and spring wheat. Four plots are in an intensified 4-year crop rotation that include fallow, winter wheat, spring broadleaf, and spring wheat. The north side of the farm remains in an intensified rotation that forgoes summer fallow and is in a continuous crop production system. 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 (Figure 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 continuous rotation and four-year rotation have averaged returns above input costs of $149 and $145 per acre, respectively, and are not significantly different. The three-year rotation has averaged $127/acre return above cost 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/.

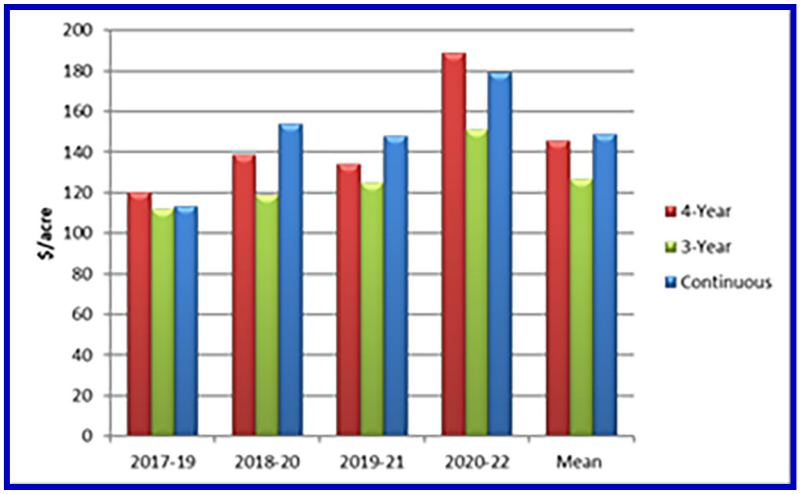

Figure 1. Three-year average economic return over input costs of 3-year, 4-year, and continuous cropping systems at the WSU Wilke Farm. Costs do not include fixed costs associated with the farm. Means within columns assigned different case letter are significantly different ($P<0.10$).

How Soil Health Interactions Contribute to Nematode Community in Wheat-Fallow Cropping Systems in Northeastern Oregon

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COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER (CBARC), OSU

Nematodes, though small creatures, can play a large role in soil ecosystems. Their feeding habits contribute to stability in soil food webs, influence plant growth and crop productivity, and can cause economic impact in agricultural systems. Plant parasitic nematodes, such as root-lesion (*Pratylenchus spp.*), deteriorate roots and reduce the efficiency of nutrient and water uptake, affecting crop yield. This study aims to analyze the interactions that exist between the nematode community and agricultural practices used in northeastern Oregon. Different fertilizer treatments (nitrogen (N), manure, pea-vine) and residue-burning treatments (spring, fall-burn) were studied in a wheat-fallow long-term experiment at the Columbia Basin Agricultural Research Center. A control treatment of no fertilizer and no burning was also applied. We considered the entire nematode community and five trophic groups (root-lesion, fungal-feeding, bacteria-feeding, spiral, stunt) are present in sampled soil. We found that the abundance of each trophic group is treatment dependent (Fig. 1). Our results indicate that the abundance of root-lesion nematodes is related to N-fertilizers and spring burn treatments, the abundance of fungal-feeders is related to N-fertilizer treatments, the abundance of bacteria-feeders is related to no-burn treatments, and the abundance of spiral and stunt nematodes is related to pea vine and manure fertilizer treatments (Fig. 2). These treatments have direct effects on soil Total Carbon (TC), Total Nitrogen (TN) and pH and we obtained data for these variables from each treatment. We predict that changes in these soil health characteristics between treatments is

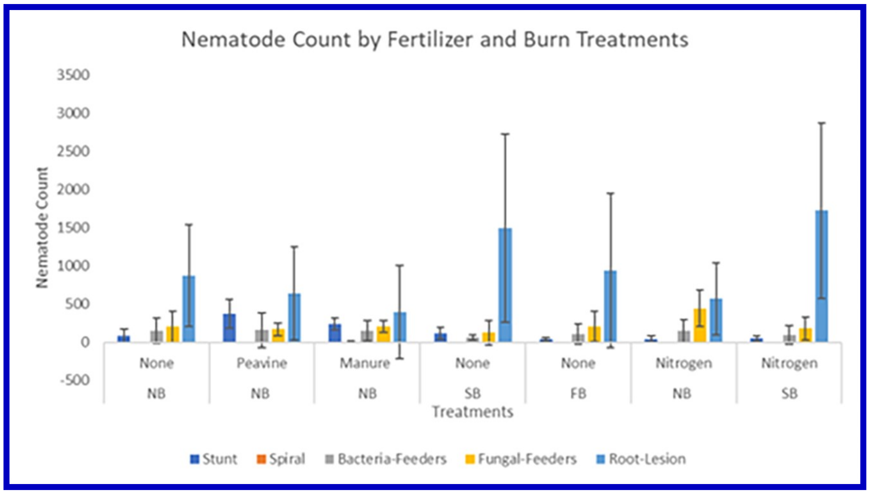

Figure 1. This figure shows nematode count on the y-axis and fertilizer and burn treatments on the x-axis with color of the bars corresponding to nematode group. The abundance of each trophic group is treatment dependent which likely points to relationships between nematode group and treatment.

what results in differences in the nematode community. These relationships demonstrate the role of soil health on nematode abundance and draw attention to the role nematodes could play in plant-soil interactions. Additionally, understanding these interactions can give insight into how field management practices influence plant-parasitic nematodes.

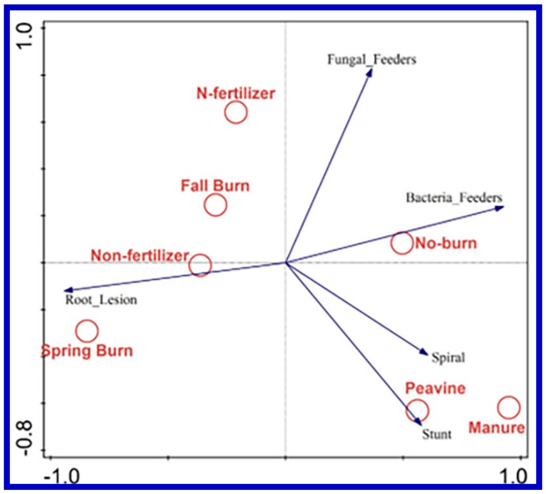

Figure 2. This figure shows a multivariate analysis of the relationship between root-lesion nematode count and treatment. the abundance of root-lesion nematodes is related to N-fertilizers and spring burn treatments, the abundance of fungal-feeders is related to N-fertilizer treatments, the abundance of bacteria-feeders is related to no-burn treatments, and the abundance of spiral and stunt nematodes is related to pea vine and manure fertilizer treatments.

Soil Spectroscopy: An Alternative Method for Monitoring Soil Quality in Dryland Wheat Systems of Eastern Oregon

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Paulina B. Ramírez, Stephen Machado, Rachael Plunkett, Surendra Singh, Larry Pritchett, Linnea Kriete, David Larson, and Francisco Calderón

Carbon Center, Columbia Basin Agricultural Research Center, OSU

Increasing our understanding of soil organic matter (SOM) dynamic may influence agroecosystem resiliency in a changing climate. In this context, it has been demonstrated that applying mid-infrared spectroscopy (MIR) is a viable alternative to conventional laboratory methods. This approach could help us deal with the problem of analyzing large quantities of samples at a low cost for fine-scale soil mapping and precision agriculture. An important benefit of spectroscopy is that it can provide soil chemical information with only an air-dried and sieved soil sample. In addition, MIR is able to take rapid and non-destructive measurements of different soil properties using a small quantity of soil. The Columbia Basin Agricultural Research Center (CBARC) laboratories currently operate near-infrared (NIR) and MIR spectrometers to infer soil properties in long-term plot experiments (LTE) initiated in 1931 and their corresponding archive soil samples. One such LTE is the crop residue (CR) experiment, which studies a wheat-fallow conventional tillage system (CT) that includes plots that are annually burned in fall and spring in addition to plots treated with pea vine residue, farmyard manure and different rates of N fertilizer (Fig 1A). Numerous studies of the CR experiment at the CBARC have demonstrated a continuous decrease in total soil carbon (TC) content under all types of management treatment relative to grassland, except farmyard manure treatment, which has maintained the same TC levels as

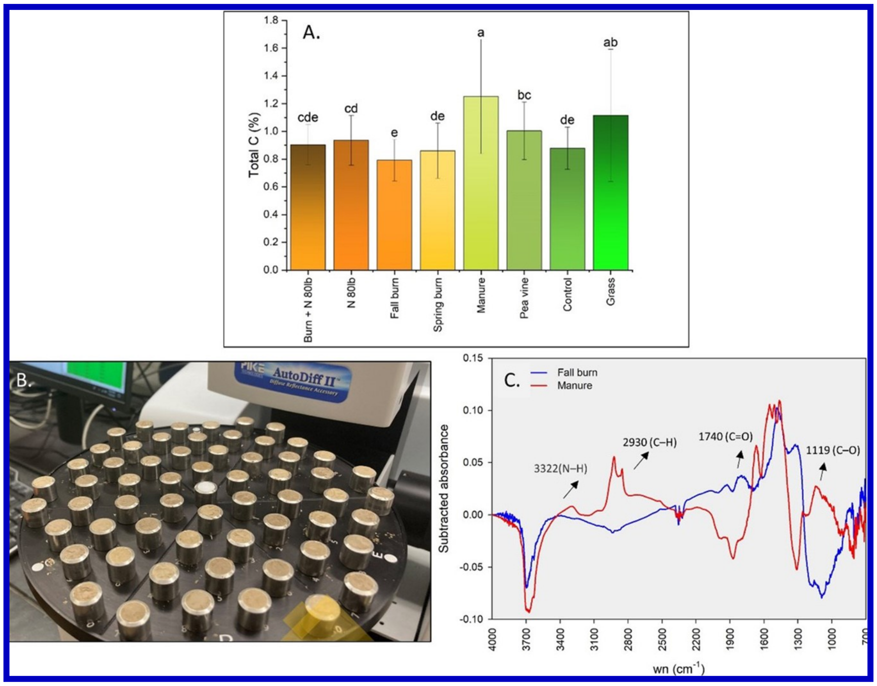

Figure 1. Crop Residue Long-term Experiment (CR-LTE) analysis (A) Changes in total C (TC) in CR-LTE plots (1ft depth) that are annually-burned (Fall and spring burn, 0 lb N/acre), treated with N fertilizer (80 lb N/acre), pea vine residue, or farmyard manure. (B) Diffuse reflectance Fourier transform mid infrared spectrometer (MIR) fitted with a Pike AutoDIFF diffuse reflectance autosampler, (C) Spectral MIR changes associated with soil C variations in CR-LTE plot in fall-burn and farmyard manure.

the baseline grassland. Fall-burned plots have decreased TC by 40% in the topsoil over the past 80 years (Fig. 1A). We qualitatively explored these changes in TC content by performing MIR on samples collected at 1 ft depth. The results show that the high TC content in manure-treated soil was associated mainly with changes attributed to aliphatic, aromatic C, carboxylic acids, and amides (Fig 1B and C). The chemical patterns presented here are valuable for screening the direction of changes in SOM. In addition, MIR spectroscopy coupled with partial least squares (PLS) regression was used to obtain calibration models in order to determine soil properties for our dataset (Fig. 2). With this purpose, the relevant information was mathematically extracted from the spectra to correlate with soil properties. Our findings show that TC, total N (TN), and pH can be accurately predicted in our LTE. Furthermore, our results suggest that MIR is suitable for long-term soil C monitoring programs. This efficient, scalable, and cost-effective approach offers insight into soil nutrient dynamics, providing reliable estimations for some soil parameters.

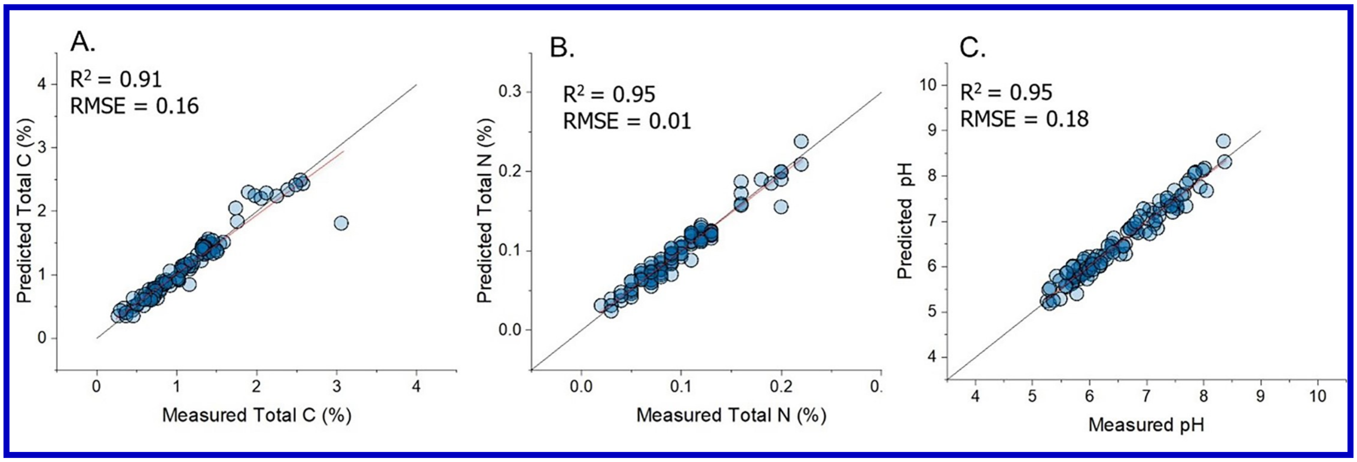

Figure 2. Correlation between measured values using conventional laboratory techniques and predicted values using mid-infrared (MIR) coupled with partial least square (PLS) model for (A) total carbon (TC), (B) total nitrogen (TN), and (C) pH.

Sampling Strategies and Nutrient Stratification Control Soil Health Indicator Responses in Dryland Wheat Systems

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Surendra Singh[1], Stephen Machado[2], Paulina Ramirez[2], Linnea Kriete[2], Larry Pritchett[2], Rachael Plunkett[2], and Francisco Calderon[2]

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Take homes:

- Stratification of soil health indicators & nutrients is present, especially in no-till systems.
- In general, no-till showed relatively higher values for selected soil health indicators.
- Fine-scale sampling strategies showed better responses than conventional sampling.
- Stratification (depth-gradient) was major driver of the indicator responses than tillage in dryland wheat-pea systems.

Soil properties, generally referred as soil health indicators, are measured as proxies for assessing soil health in agroecosystems. Variability of these indicators across different agroecosystem management strategies (conventional vs. conservational) dictates the soil health status. Soil biological indicators, along with soil physical and chemical indicators, play a key role in determining the status of agroecosystem soil health. Despite the use of numerous soil biological indicators, knowledge around the sampling depths influence on variability of the biological indicators remains elusive, especially in dryland agroecosystems. Therefore, this study was conducted to investigate if the sampling depth can alter the responsiveness of the selected soil biological indicators. We leveraged an ongoing long-term (since 1963) wheat–pea study at the Columbia Basin Agricultural Research Center at Pendleton, OR. We studied influence of two tillage treatments (moldboard plow and no-tillage) and two soil sampling strategies, (i) fine-scale soil sampling (0-2, 2-4, 4-6, 6-8, 8-10, 10-15, 15-20, 20-25, 25-30, 30-35, and 35-40 cm) and (ii) conventional soil sampling (0-10, 10-20, 20-30, and 30-40 cm) on selected soil biological indicators (total soil carbon (TOC), permanganate-oxidizable C, 24-hr soil respiration, and 96-hr soil respiration). Results indicated that the sampling depths significantly influenced the responses and management-sensitivity of indicators under both sampling strategies ($P<0.0001$). In fine-scale sampling, interaction (sampling-depth X tillage) controlled the responses of all the indicators ($P<0.0001$), while only TOC was influenced by this interaction in conventional sampling (Table 1). Fine-scale sampling showed better management-sensitivity of the tested indicators than the conventional sampling (Figs. 1 & 2).

These results clearly indicate that stratification of soil health indicators is present, especially under no-till systems. Overall, depth-gradient was major driver of the indicator responses than tillage in dryland wheat-pea systems. This highlights the need for cross-regional standardization of soil sampling depths for better understanding of soil health in different agroecosystems.

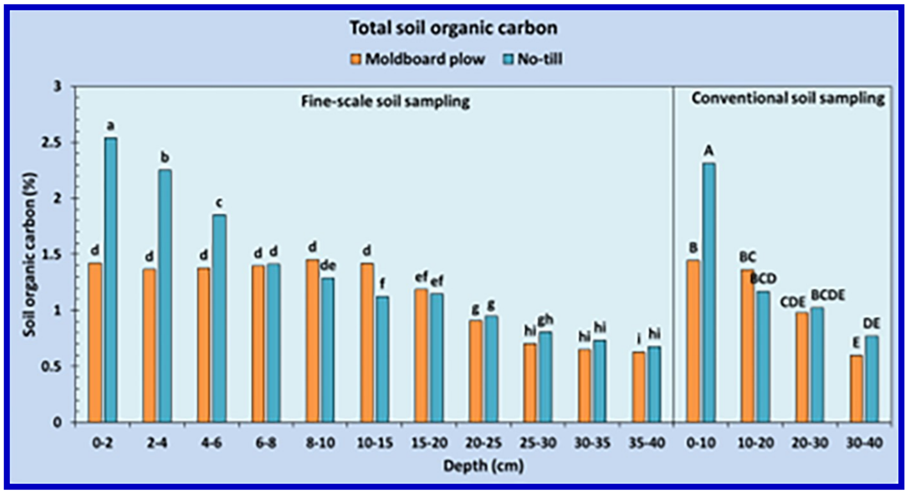

Figure 1. Total soil carbon under moldboard plow and no-tillage treatments across different depths and soil sampling strategies.

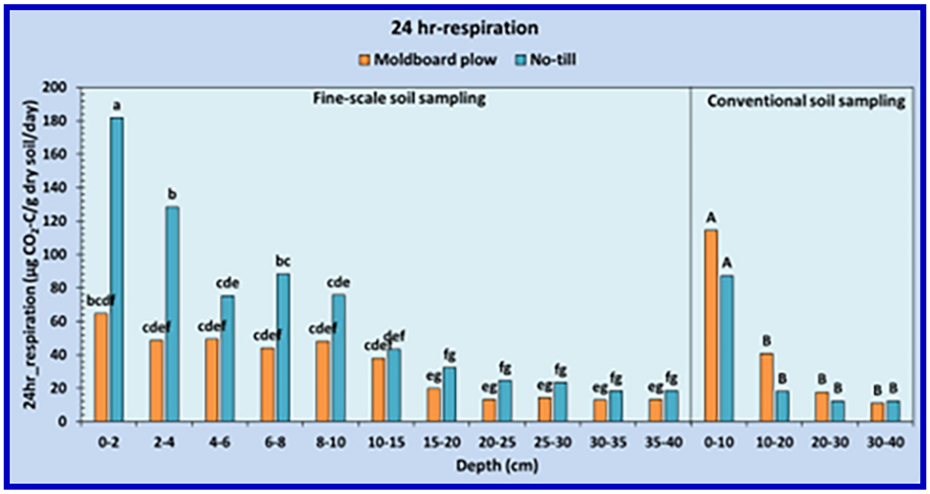

Figure 2. 24-hr respiration under moldboard plow and no-tillage treatments across different depths and soil sampling strategies.

Table 1. P values summary of soil health indicator response to tillage treatments and sampling depths.
TOC: Total Soil Carbon, POXC: Permanganate-Oxidizable C, 24-hr CO_2: 24-hr Soil Respiration, 96-hr CO_2: 96-hr Soil Respiration, NS: Non-significant.

Treatments	Fine-scale soil sampling			
	TOC	POXC	24-hr CO_2	96-hr CO_2
Tillage	0.0444	NS	NS	NS
Depth	<0.0001	<0.0001	<0.0001	<0.0001
Tillage*Depth	<0.0001	<0.0001	0.0056	<0.0001
	Conventional soil sampling			
Tillage	NS	NS	NS	NS
Depth	<0.0001	<0.0001	<0.0001	<0.0001
Tillage* Depth	0.0103	NS	NS	NS

Comparing No-till and Minimum Tillage Wheat-Fallow Systems for Soil Carbon

Stewart B Wuest[1], William F. Schillinger[2], and Stephen Machado[3]

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Soil organic carbon (SOC) is an important soil quality factor that influences plant nutrition, productivity, water storage, and erosivity. Therefore, it is critical that tillage practices adopted should preserve or increase soil organic matter in the long run. The question of whether no-till practices on low precipitation PNW soils will improve SOC compared to minimum tillage methods will become an increasingly important issue as dependence on herbicides becomes more expensive.

We conducted an intensive soil sampling campaign in three long-term cropping system experiments at Echo, OR; Moro, OR; and Ritzville, WA to assess the effects of tillage practices on SOC. At each site, replicated large-plot experiments compared winter wheat—summer fallow using no-till versus minimum tillage. The experiment at Echo, OR had been in place for 12 years, the Moro experiment had been in place for14 years, and the Ritzville site had been in place for 8 years. Soil samples were collected from the top 8 inches every month for 3 years from 16 plots at Echo, 12 plots at Moro, and 24 plots at Ritzville for routine SOC analyses.

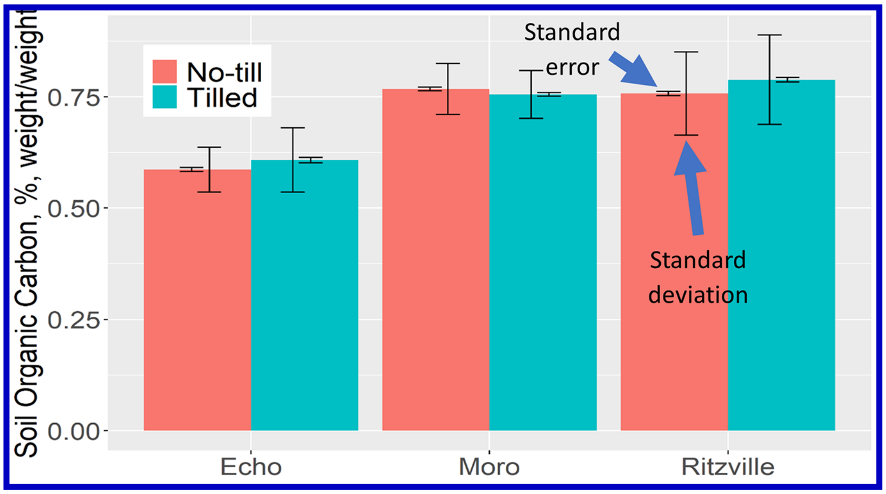
At the Echo and Ritzville sites, SOC content was greater in the minimum tillage plots than the no-till plots ($p < 0.027$, $p < 0.001$). At the Moro site there was no significant difference in SOC content between the two tillage practices (although slightly greater in the no-till plots than the minimum tillage plots). The combined-sites data indicate a 2.45% (relative) greater SOC in minimum tillage plots ($p < 0.004$) than no-till plots.

There was no trend for an increase or decrease over the three-year measurement period, and no periodic seasonal pattern. Because there were over 160 data points to compare, the standard errors of the final average results were small, and we could detect the very small difference between minimum tillage and no-till. On the other hand, the average standard deviation (average difference between a single measurement and the overall mean) was very large from sample to sample and month-to-month. This is a problem for getting repeatable results from a small number of samples at a single point in time. We don't know the source of the large standard deviation, but it is common in soil carbon research. It could be labile carbon such as particles of incompletely decomposed plant matter, or variations in microbial biomass, but nothing is obvious yet. Analyzing samples of the exact same dry soil mass ("mass depth") and carefully cleaning particulates out of the soil samples helps somewhat but does not substantially reduce month-to-month variability in soil carbon measurements.

For details or a copy of the paper below, contact Stewart.Wuest@usda.gov

REFERENCE

Wuest, S. B., Schillinger, W. F., & Machado, S. (2023). Variation in soil organic carbon over time in no-till versus minimum tillage dryland wheat-fallow. Soil and Tillage Research, 229, 105677. https://doi.org/10.1016/j.still.2023.105677



Providing a Long-Term Solution to Soil Acidity in the PNW Wheat Production through Soil Microbial Carbonate Biosynthesis

AUGUSTA FINZEL, TARAH SULLIVAN, AND MIKE PUMPHREY

WASHINGTON STATE UNIVERSITY

Increasing soil acidity is one of the largest issues facing cropland ecosystems, affecting greater than 40% of croplands globally. The pH of soils of the Palouse has been declining from around a neutral pH of 7.0 sixty years ago to less than 5.0 in many areas in recent years. The soils of the Palouse are composed of aluminum-silicate minerals, and when the pH decreases below 5.5, the aluminum in the soils becomes soluble which can lead to aluminum toxicity. This can affect crop resiliency and lead to overall yield decreases.

The ability to better characterize and understand microbial communities and their roles within agricultural ecosystems has suggested a method to offset rising acidity. The goal of this project is to increase the soil pH by promoting plant-associated microbial communities capable of producing calcium carbonate (the main component in agricultural lime) through their synergistic interaction with certain spring wheat varieties.

To date we have collected preliminary data comparing yield and the rhizomicrobiome of 20 different wheat varieties on limed and unlimed plots at the WSU Wilke Farm using both aluminum susceptible and aluminum resistant varieties of wheat developed by Dr. Mike Pumphrey. The soils will also be analyzed for total DNA, bacterial and fungal community composition and cultivable organisms, water soluble aluminum, and soil pH. The organisms we can cultivate will also be tested for microbially induced carbonate precipitation.

This coming year, the wheat varieties with the highest yield will be planted at Wilke Farm as well as at a site in Rockford, WA which is known for its extremely acidic soils. In addition to the analyses above, rhizobial endophytes will also be analyzed. We hypothesize that the indigenous microorganisms present in the rhizosphere and tissues of healthy wheat plants will contain microorganisms capable of microbially induced carbonate precipitation and other plant growth promoting traits. These organisms will be assessed for their ability to be an effective inoculant both individually and as a community of organisms. Inoculants will be tested in greenhouse trials using soil from the most acidic site with the most vigorous wheat varieties. The wheat varieties with the greatest inoculum survival as well as the greatest yield, plant vigor, and improvements to soil health and pH will be pursued for further breeding efforts.

Cover Crop to Enhance Fallow

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[1]WSU EXTENSION; [2]WSU CENTER FOR SUSTAINING AGRICULTURE AND NATURAL RESOURCES

A cover crop study was initiated at the WSU Wilke Research and Extension Farm located on the eastern edge of Davenport, WA. This project is funded by the US Department of Energy's Bioenergy Technologies Office in partnership with Pacific Northwest National Laboratory (PNNL). The goal is to have actively growing roots on no-till fallow for 7-8 months and maintain or enhance winter wheat production over time and improve soil health factors including organic matter and soil pH. In the fall of 2021, four treatments were established in a randomized complete block design with 4 replications and plots are 200 feet long and 25 feet wide. The four treatments are a check (no-till fallow with no cover crop), winter triticale, winter pea, and a winter triticale-winter pea mix. This was seeded into a field fallowing spring wheat and going into no-till fallow. The trial was seeded on October 15, 2021. The winter pea treatment was terminated with a glyphosate application on May 25, 2022 because of a high weed population and very little pea growth and production. The plots were split-in-half and biomass was removed from half the plot and left standing in the other half on June 2. Overall, on average there was 4,389 lbs/acre biomass produced in the triticale and mix plots and no significant difference between the two treatments. No biomass was removed from the pea plots or check. The whole study was terminated on June 7, 2022 with a glyphosate application. The study was soil sampled on sampled Sept 13, 2022 and seeded to Piranha CL+ WW on Sept 15, 2022. Overall soil moisture in the top foot was not significantly different averaging 1.8 inches of moisture over all 4 treatments, however, there was significantly more moisture in the top foot when the residue was left standing averaging 2.0 inches of precipitation, compared ton 1.8 inches when the residue was removed. Differences were detected in nitrate nitrogen (NO3-N) as well with the check and pea averaging 171 lbs N/acre in the top 3 feet and the mix and triticale averaging only 104 lbs N/acre in the top 3 feet. Removing the biomass also significantly decreased NO3-N with the removal treatment averaging only 123 lbs N/acre compared to leaving the residue standing which averaged 150 lb N/acre. Grain yield, test weight and protein will be collected in the summer of 2023 and a second study location was seeded on October 21, 2022.

Part 4. Oilseeds and Other Alternative Crops

Water Use and Economic Viability of Important Oilseed Crops for Washington Low Rainfall Zones

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To improve sustainability and yield, it is increasingly important for dryland wheat growers in Washington state (WA) to intensify their crop rotations especially in low rainfall zones where soil erosion during summer fallow is a major problem. Diversifying crop rotations to reduce fallow periods would not only help mitigate soil erosion immediately, but also help build healthier, more sustainable soils for the future. This research project aims to evaluate the suitability of pennycress and camelina as both full crops and cover crops to improve ecosystem services in the low rainfall zones of WA. Unfortunately, the pennycress plots failed the first year of this project particularly due to poor emergence and the need for fall moisture. However, the camelina plots were successfully sown with good emergence and stand establishment, and ultimately consistent yields. Overall, the spring biotypes flowered significantly earlier (7.7 days; p-value = 0.0003) and reached harvest maturity significantly earlier (9.7 days; p-value = 0.0008) than the winter biotypes. Average yield across all camelina varieties was 1146 kg/ha (1022 lbs/acre). The highest yielding variety, Calena, yielded 1595 kg/ha (1423 lbs/acre) and the lowest yielding variety, Cheyenne, yielded 901.2 kg/ha (804.0 lbs/acre). On average, spring biotypes yielded higher (270 kg/ha or 240.8 lbs/acre; p-value = 0.94) than the winter biotypes, although this difference was not statistically significant. This first year of this project demonstrated it is possible to successfully grow camelina in the low rainfall zones of WA. The second year of the project will seek to validate these results, as well as quantify the economic impact on the subsequent wheat crop to estimate the economic feasibility of incorporating camelina into these low rainfall wheat rotations. We will also assess the agronomic quality of the oilseeds produced in these trials by seed testing for protein, oil content, and moisture, as well as 1000 seed weight. Our hope is to provided growers in the low rainfall zone of eastern WA sustainable options for crop rotation to improve agroecosystem services.

Table 1. Yields of camelina varieties tested in year.

Variety	lbs/acre	kg/ha
Calena	1423	1595
Suneson	1202	1347
Bison	943.8	1058
Joelle	896.6	1005
BSX-WG1	865.8	970.4
Cheyenne	804.0	901.2

The Microbiome of Camelina Grown Across Eastern Washington

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Camelina (*Camelina sativa* L.) is a biofuel, oilseed and rotation crop grown in dryland farming systems. The agronomic characteristics of camelina have been extensively investigated in the inland Pacific Northwest. Camelina is fairly disease resistant, has good tolerance to frost and drought, and can be grown under low input conditions. Although the acreage in WA is small, it still has potential as a rotation crop. In 2020, the Department of Energy funded a large grant with collaborators in WA, MT and CA to investigate the nitrogen use efficiency, genetics and microbiology of camelina. We are screening over 200 lines in the field for nitrogen use efficiency. We hypothesized that the rhizosphere microbiota (the community of microbes associated with plant roots) may play a role in nutrient uptake. We sampled 33 locations across eastern Washington covering different precipitation zones, from wheat fallow to annual cropping. After planting camelina in soil collected from 33 locations, we isolated over 3000 bacterial isolates from camelina roots, the largest collection of root-associated bacteria on this crop. The rhizosphere culture collection was dominated by a small number of bacterial genera (Fig. 1). We are currently testing these for their ability to increase camelina growth, and have identified isolates of *Pseudomonas* that stimulate growth with urea as the N source. We also used high-throughput DNA sequencing to characterize fungal and bacterial communities. Location was a significant driver of camelina microbiome composition. Rhizosphere bacteria communities were dominated by *Sphingomonas*, which we did not isolate very frequently in culture. Further, *Rhizobium* was the dominant genus inside the root, again not represented in our collection. Future work is focused on identifying isolates that will promote growth, increase N uptake, protect against disease and confer drought resistance to camelina.

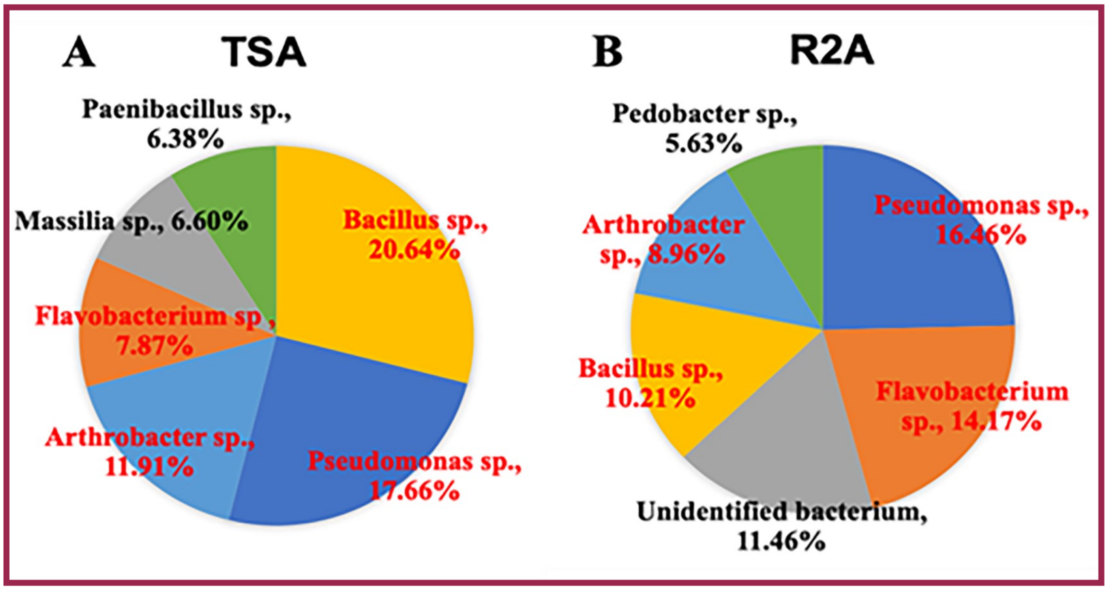

Figure 1. Most abundant bacteria isolated from roots of camelina. TSA= tryptic soy agar. R2A is another type of medium for slower growers.

The Microbial Community Diversity of Field Pennycress (*Thlaspi arvense*) Mutants and its Impact on Plant and Soil Health

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Field pennycress (*Thlaspi arvense*) is a winter annual in the Family Brassicaceae undergoing development as a cash and cover crop intended for bioenergy. It has a quick growth period that can fit between rotations of other crops without competing with them, displays high cold tolerance, and has no food use that might impact the price or compete with biodiesel production. This allows for energy production that does not require additional land development and does not compete with the food supply. While currently largely grown in the Midwest United States, these traits make it a good candidate for winter oilseed farming and cover cropping in Eastern Washington. This has the added benefit of providing a variety of benefits to soil health like plant diversity, support of pollinators, soil cover, and allowing continual root growth. However, it must be studied to create successful agronomic practices and expand adoption. Many studies have pointed to the benefits of fungi and bacteria in the rhizosphere of agricultural plants. Studying its microbial community gives us insights into what lines might thrive in this environment and what amendments might help both soil and plant health. The core pennycress genotypes were planted at three sites across Eastern Washington with identical soil types. We used a random block design with Camelina (*Camelina sativa*) as a control. At flowering we harvested these plants and removed the roots with rhizosphere soil attached. The aerial parts of the plants were weighed once dried to get plant biomass data. The Spring32-10 fad2 genotype was found to have greater biomass than three other mutant lines (MN106 tt8-2, MN106 tt8-3, and MN106 ind fae rod) at the site with the driest conditions. The rhizosphere soil DNA was extracted and used to generate amplicon libraries for both 16S and ITS subunits to obtain data on bacterial and fungal communities respectively. ANCOM analysis found that the Spring32-10 fad2 genotype had enriched populations of multiple beneficial microorganisms. These include *Flavobacterium, Pseudomonas, Mortierella, Trichoderma spirale, Methylobacterium goesingense,* and *Planifilium.* This makes it a good candidate for the expansion of Field Pennycress cultivation in the Pacific Northwest.

Do Winter Wheat Cultivars Impact Spring Canola Stand Establishment Differently?

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Differences in wheat cultivar allelopathy on canola have been observed and documented in other parts of the United States and in other countries. To date, no work has been published on wheat cultivar differences in the inland Pacific Northwest with its unique climate, soils, and winter wheat cultivars. This study will document differences in emergence, early plant vigor and yield of spring canola following different winter wheat cultivars. The objective of this study is to identify whether differences exist among winter wheat cultivars on the early season plant growth and final yield of subsequent spring canola in the rotation.

Initial results did detect differences among winter wheat varieties on subsequent spring canola growth, but it was difficult to pick out many varieties that had consistent negative or positive impacts on canola growth, and importantly, any differences measured did not translate into yield penalties. Of the soft white winter wheat varieties that were planted at both sites, AP Dynamic produced consistently lower canopy cover while ARS Crescent produced consistently higher canopy cover at both sites. Also, SY Clearstone CL2 reduced both canopy cover and stand at one location. LCS Shine reduced canopy cover at one site and delayed germination in the lab while AP Exceed did just the opposite. One of the most consistent varieties to lower canola performance in the laboratory was Sockeye CL+, which delayed germination, decreased radicle length and lowered final seedling biomass.

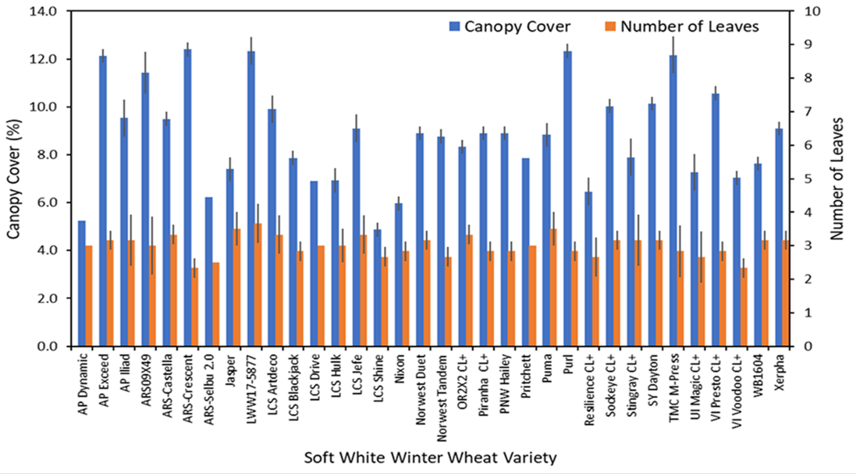

Figure 1. Previous soft white winter wheat variety impact on percent canopy cover and number of leaves plant-1 in subsequent spring canola at 5 WAP in Pullman, WA. Bars indicate standard deviation.

Regardless of the documented impact, or lack thereof, on early season growth of canola in this study, planting canola into heavy residue is a major obstacle in establishing canola. Selecting winter wheat varieties that either produce less straw, or straw that decomposes quicker would be advantageous. Based on our results, residue from Puma, Sockeye CL+, and LCS Blackjack all saw negligible decomposition over the winter months while varieties Millie, AP18AX, Cameo, Norwest Duet and WA8309 had some of the greatest decomposition. Also, ARS-Selbu 2.0, LCS Drive, LCS Shine, WB4311, AP18AX, LCS Jet, UI Bronze Jade, VI Presto CL+, WB1529 and WB4311 all produced some of the lowest straw yields in at least one location. Differences were likely less detectable in 2021, however, due to the extreme drought and limited yields.

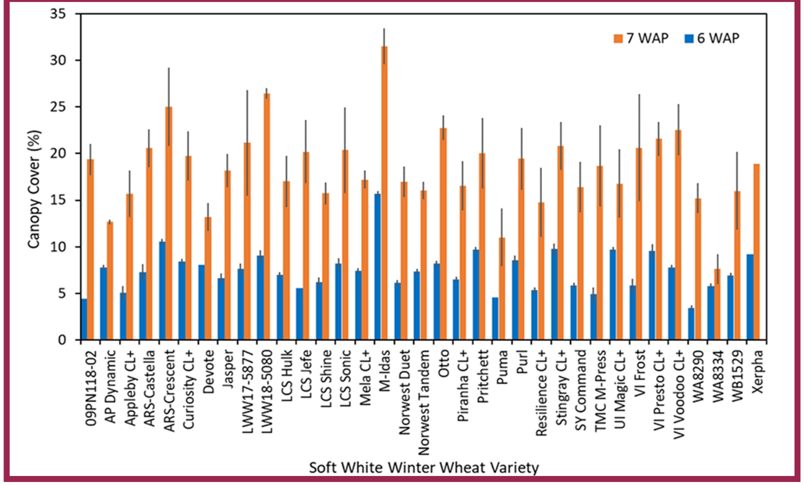

Figure 2. Previous soft white winter wheat variety impact on percent canopy cover in subsequent spring canola 6 and 7 WAP in Reardan, WA. Bars indicate standard deviation.

Lastly, growers should be cognizant of fertility programs. Based on the field results from Reardan, nitrogen fertility can influence seed protein, and indirectly, seed oil content. In some instances where seed oil content is marginal and premiums are offered for a minimum seed oil content, there may be an economic penalty for excessive applied or residual soil nitrogen.

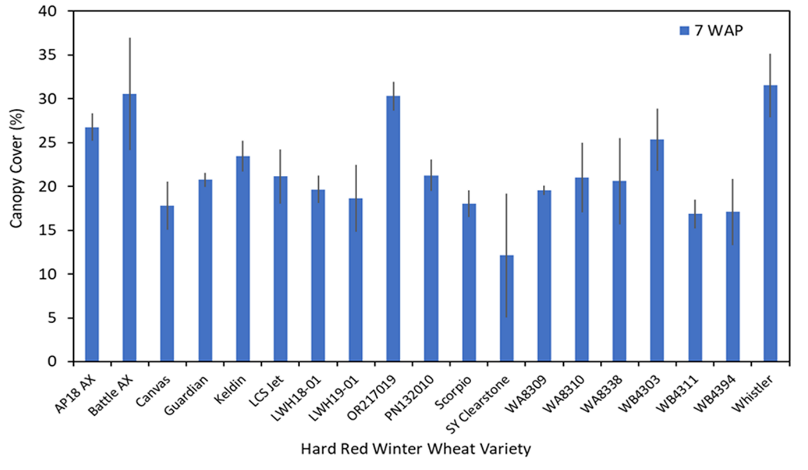

Figure 3. Previous hard red winter wheat variety impact on percent canopy cover in subsequent spring canola at 7 WAP in Reardan, WA. Bars indicate standard deviation.

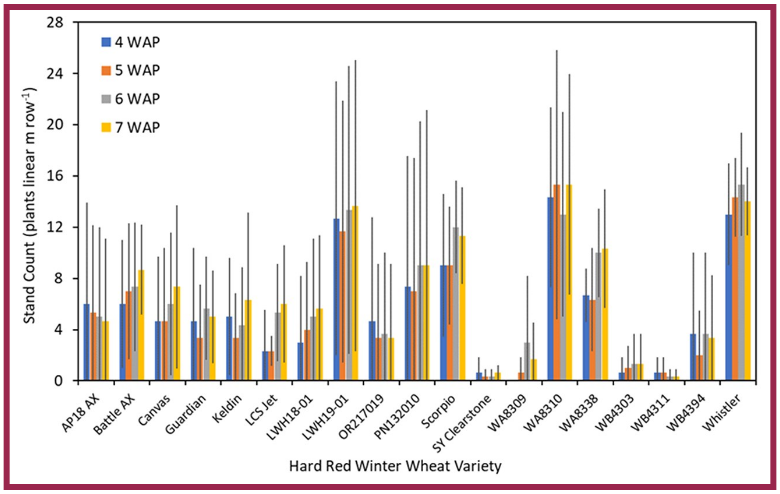

Figure 4. Previous hard red winter wheat variety impact on stand count in subsequent spring canola 4, 5, 6, and 7 WAP in Reardan, WA. Bars indicate standard deviation.

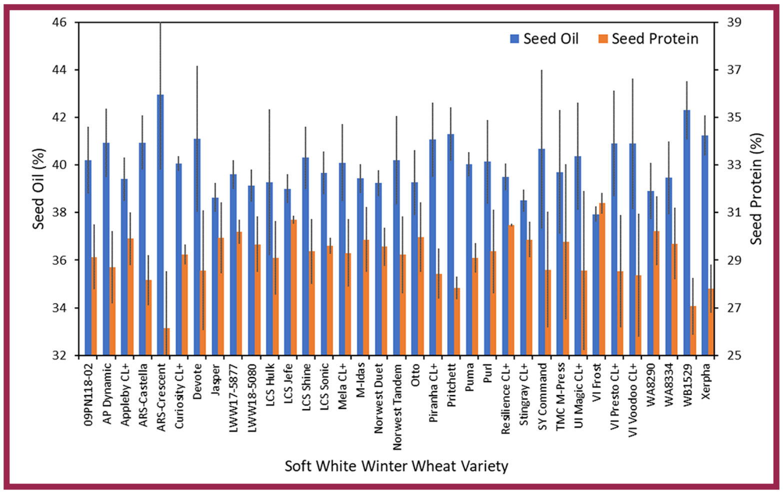

Figure 5. Previous soft white winter wheat variety impact on seed oil and protein in subsequent spring canola in Reardan, WA. Bars indicate standard deviation.

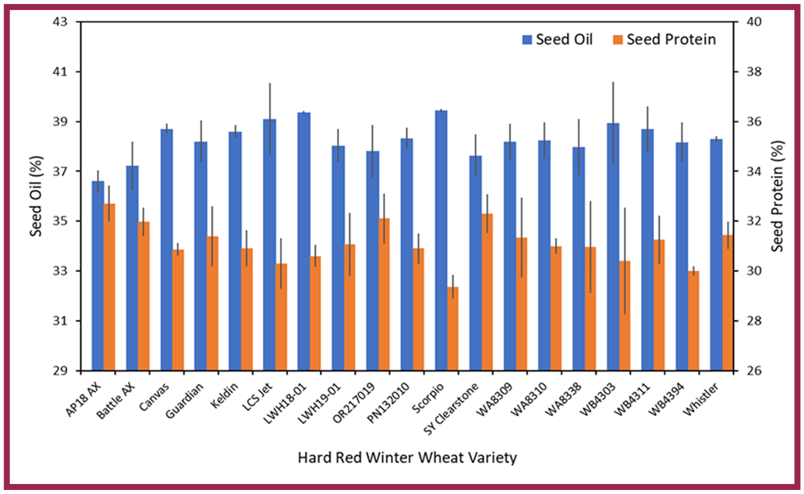

Figure 6. Previous hard red winter wheat variety impact on seed oil and protein in subsequent spring canola in Reardan, WA. Bars indicate standard deviation.

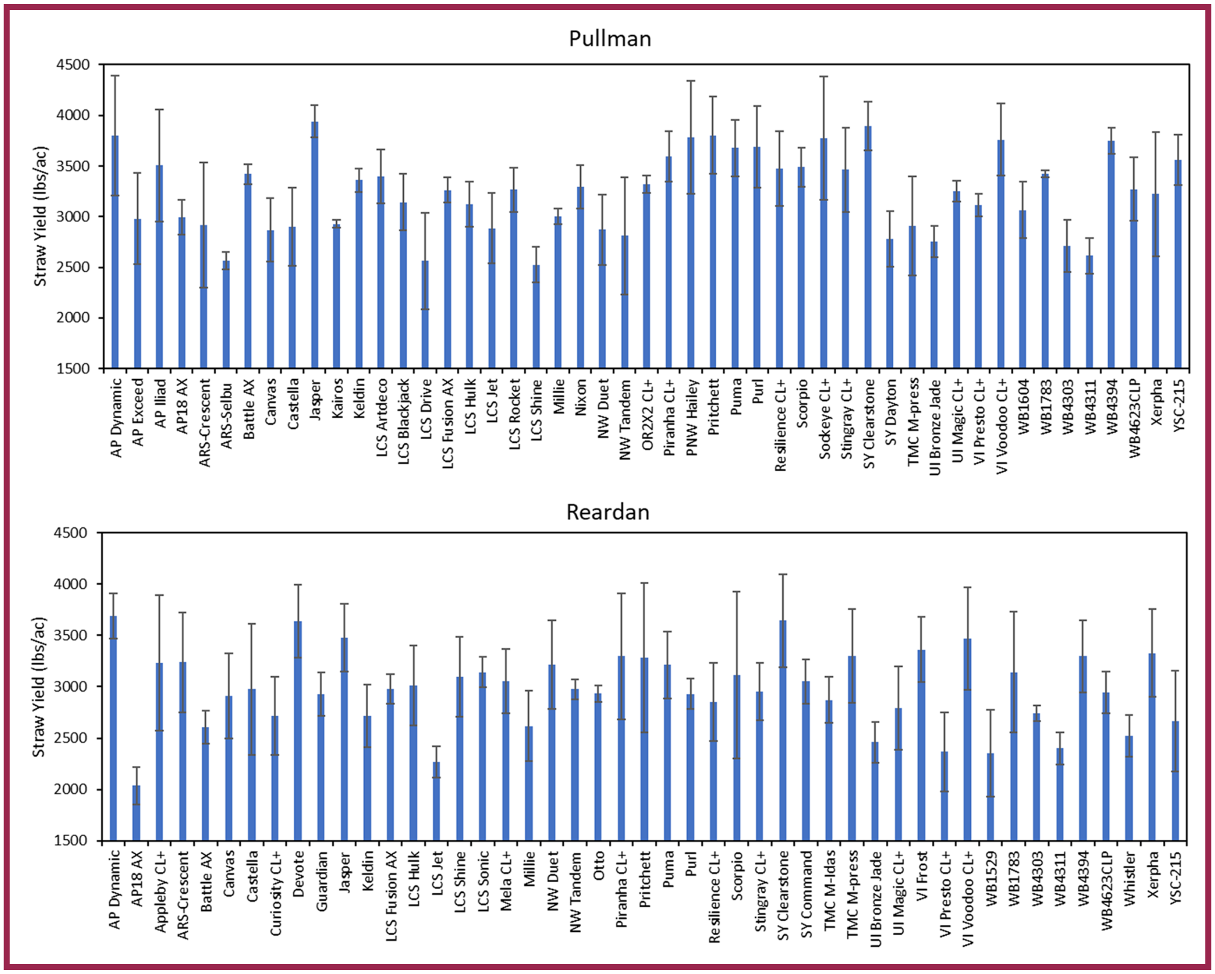

Figure 7. Straw yield for winter wheat varieties at trials in Pullman and Reardan, WA in 2021. Bars indicate standard deviation.

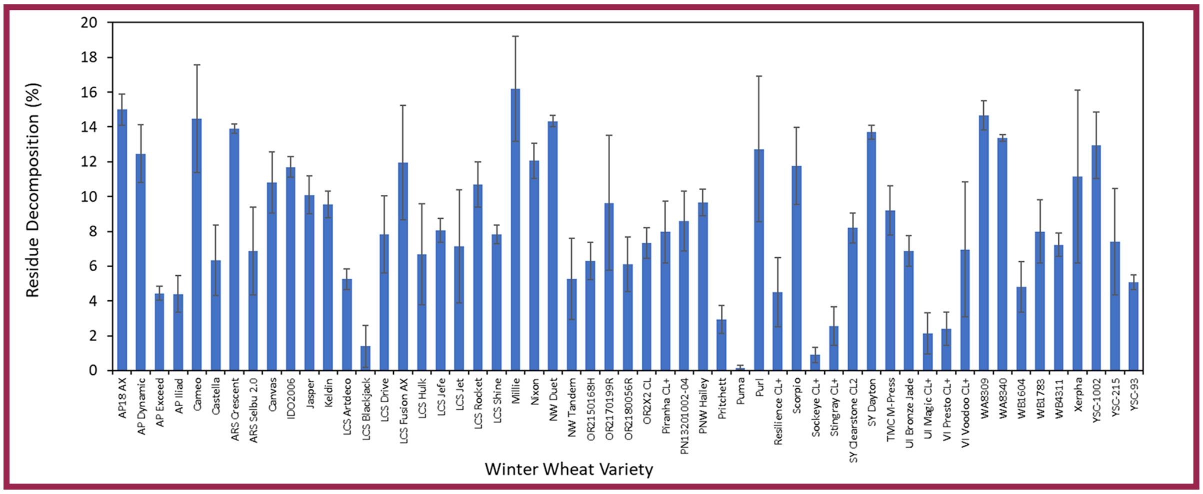

Figure 8. Percent residue decomposition at Reardan, WA based on winter wheat variety. Bars indicate standard deviation.

Use of Agronomic and Transgenic Approach to Improve Stand Establishment In Winter Canola

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Expanding oilseed cultivation in the PNW is essential for edible oil production for human consumption and as a rotation crop with winter wheat. Winter survival of canola depends on many factors, including the planting date, seeding depth, seeding rate, plant stature, and cultivar genetics. In this project, our lab used a combination of molecular and agronomic approaches to study and improve the winter survivability of winter canola in the inland PNW.

In our transgenic approach to improve crop establishment, we used a Neff lab-identified variant of DNA-binding protein SOB3/AHL27, *At-Sob3-6*, which regulates seed size and seedling development in *Arabidopsis* and *Camelina sativa*, both belong to the same family as canola. In *Camelina sativa*, our lab developed transgenic plants that resulted in longer hypocotyl and improved emergence at greater planting depths (Fig. 1A) (Koirala and Neff, 2019). We used the same allele to make transgenic canola through tissue culture to develop plants with improved seed size and seeding growth habits. In our study, overexpression of the same variant in canola increased hypocotyl length and seed size compared to the non-transgenic control (Fig. 1B). The increase in seed size in our transgenic resulted in improved emergence when planted four inches deeper in soil (Fig. 1C). This new germplasm could be used to plant deeper where lack of moisture in the upper surface results in poor stand establishment.

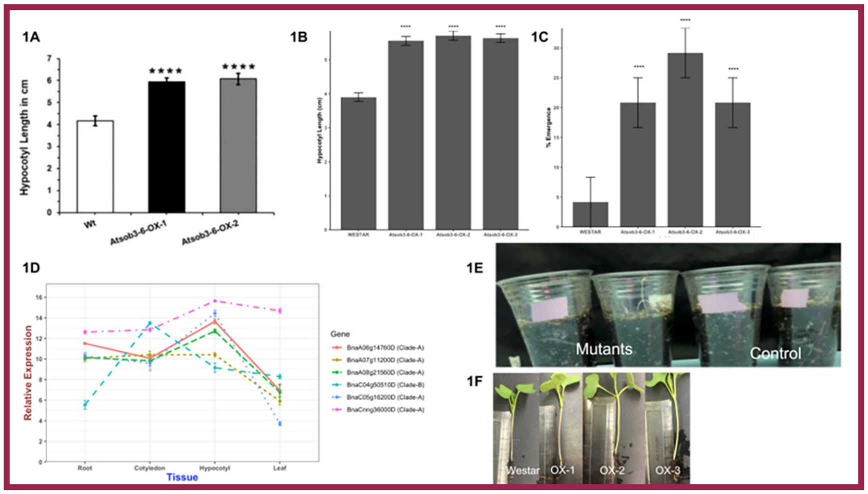

Figure 1. Role of AHLs in hypocotyl growth in Brassica napus. 1A. At-sob3-6 increased hypocotyl length in Camelina sativa. 1B-C. Transgenic canola with At-Sob3-6 showed an increase in hypocotyl length and emergence. 1D. The gene expression analysis of SOB3 homologs in Brassica napus showed increased transcript accumulation in the hypocotyl. 1E-F. At-Sob3-6 showed an increase in emergence and hypocotyl length in transgenic canola

While we explored the role of *Arabidopsis* AHLs (*At-Sob3-6*) in the hypocotyl length of canola (*Brassica napus*), a comprehensive genome-wide analysis AHLs was also carried out in *Brassica napus* to understand their role in canola plant development and biotic and abiotic responses. We identified 111 AHL genes in *Brassica napus* which were further divided into clade-a (52 genes) and clad-b (59 genes). The gene expression analysis of these genes showed their role at all developmental stages. We further tested the expression of genes using RT-qPCR at the time of emergence to identify candidate genes in seedling development. Several genes with a role in hypocotyl development were identified, making them ideal candidates to improve stand establishment in canola (Fig. 1D). The information from this project will lay the foundation for further investigation of this family's biological function for enhancing productivity and stress tolerance.

Improved stand establishment via early planting in dryland regions to use soil moisture results in an increase in plant size; however, it can favor winter kill. In contrast, late planting results in seedlings that are too small to withstand winter kill. Thus optimum plant size is essential in winter canola varieties for their survival through harsh winter conditions. Our second approach used the plant growth hormone to manipulate plant development. An application of paclobutrazol at the rate of 2.5 oz/acre applied at the 2nd leaves stage reduced the seedling height significantly (Fig. 2A-B), with the crown closer to the surface (Fig.2C) compared to the control water application. Crowns in the treated plots were significantly thicker than the control, with more growth around the growing tip. Similarly, the leaves in the treated plots grew parallel to the ground giving cover to the growing tips of the canola plant compared to the control, which showed a more upright growth. The application of paclobutrazol showed no effect on final plant height and yield (Fig.2D).

Expanding canola and industrial rapeseed in the pacific northwest also requires stable genotypes across the different environments with better stand establishment and winter kill. We investigated the effect of genotype X environment interaction on genotype performance for winter tolerance-related traits in three locations and years (environmental conditions, i.e., E1, E2, and E3). The first year of planting at Pullman was completed on August 30, 2020 (E1), whereas the second-year trial at the same location, but a different plot was planted on September 13, 2021 (E2). The experiment at Wilke Research and Extension Farm was planted on July 26, 2021 (E3), following no-till practices (Fig. 3A). Genotype's performance was evaluated based on their height before winter, total height, plant establishment before and after winter, and final yield. The genotypes were further evaluated regarding their seed oil content and fatty acid composition to assess their suitability for edible or industrial purposes.

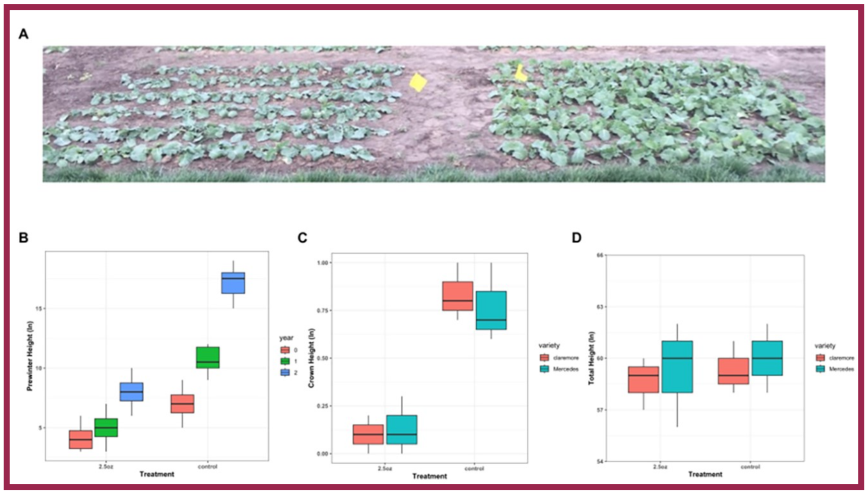

Figure 2. Use of Paclobutrazol to control early seeded canola height. 2A. A comparison of heights in treated (left) and control (right). 2B-C. Paclobutrazol application reduced plant and crown height before winter in Canola. 2D. Pre-winter application of paclobutrazol showed no effect on final plant height.

The analysis of variance revealed a significant genotype X environment interaction for all the phenotypic traits except for total plant height. Further genotype X interaction effects analysis using AMMI1 biplot revealed G4, G110, G20, and G115 as suitable genotypes across all three environments. The suitability of genotypes across all environments was further assessed using GGE Biplot analysis. Genotypes were plotted using mean vs. stability and ranking of genotype with respect to the ideal genotype to aid in selecting favorable accessions for winter-kill-related traits (Fig. 3B). The ranking of the environment analysis revealed E1 as an ideal environment for the final yield. Late sowing and lower temperature in late spring significantly affected the genotype's performance in E2, as genotypes produced significantly shorter plants with lower yields than E1 and E3 (Figure 3C-E). The fatty acid analysis revealed diversity among the genotypes regarding their fatty acid composition. The erucic acid analysis identified 49 canola accession to 93 industrial rapeseed in the panel. This fatty acid profile and the phenotypic performance of genotypes across different growing conditions will allow breeders to incorporate stable genotypes with favorable oil properties in commercial oilseed-rape breeding programs suitable for the Pacific Northwest.

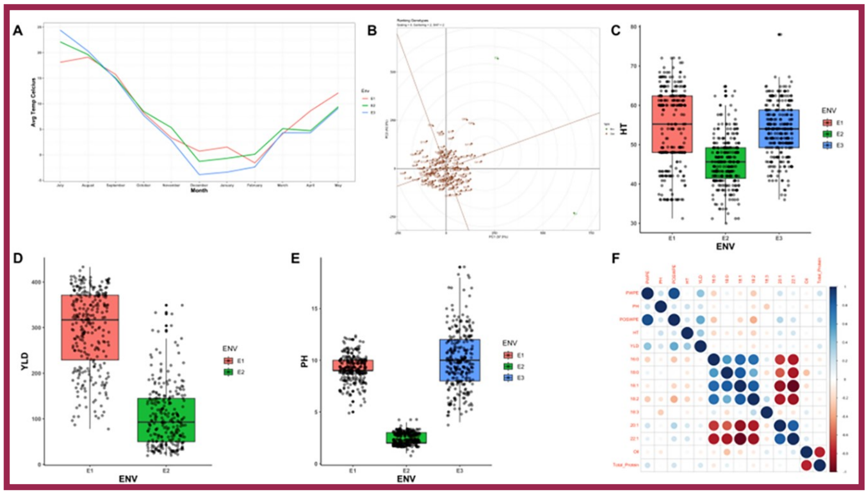

Figure 3. Stability assessment of winter-type Brassica napus accessions under different environments. 3A. The comparison of weather conditions under three environments. 3B. The ranking of genotypes based on the average final yield in E1 and E2. 2C-E. The comparison of average total plant height (in), final yield (g), and plant height before winter (in) under all environments. 2F. The correlation analysis among agronomic and fatty acid traits under all three environments.

Together with these transgenic and agronomic approaches, we aim to develop new agronomic practices and germplasm with better stand establishment and winter-kill tolerance. Addressing these problems through these studies may help farmers in the inland PNW plant more acres of canola in the future.

Measuring and Modeling the Impact of Plant Dimensions of Winter Canola on Winter Survival

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Canola (*Brassica napus* L.) has grown in popularity as a rotational crop in eastern Washington over the past decade due to its benefits in the traditional winter wheat cropping rotations. However, winter canola has lagged behind spring canola adoption in the region. This is partly due to highly variable rates of winter survival across the region. Plant dimensions such as crown height and leaf count have been used to predict winter survival in canola. This study used measurements of 1470 plants across eastern Washington to discover if plant dimensions could be used to predict the probability of winter survival. The measurements included crown height, crown width, number of leaves per plant, and canopy width for each plant. Weather data including growing degree days, precipitation, minimum temperature, and temperature cycles were also collected from weather stations near each experiment. This study found that a crown height less than 2 centimeters (cm), a crown width greater than 1 cm, a canopy width greater than 24 cm, and 6 or more leaves all provide a high chance of winter survival.

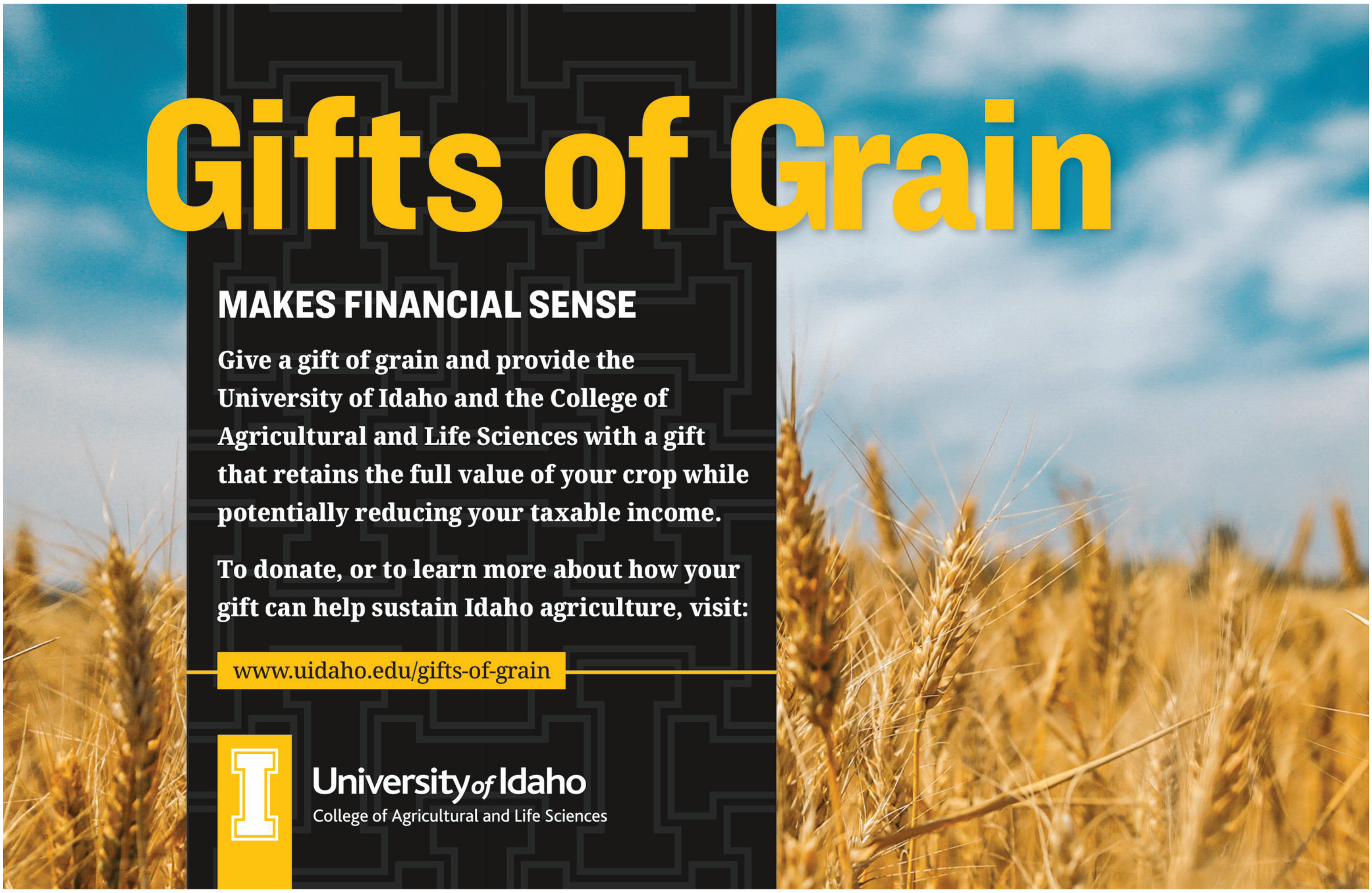
This research found that accumulating over 1000 GDD's was not typically detrimental to the survival of winter canola. Two locations had 100 percent survival, 2020-2021 LaCrosse and 2021-2022 Valleyford with 1282 and 1573 GDD respectively. However, seeding winter canola too early can lead to excessive plant growth and water uptake which results in drought stress and leaf desiccation in late summer. Regrowth does not occur until fall precipitation arrives and winter canola plants in this situation often have little aboveground biomass to provide insulation to the crown. Furthermore, the unique topography of eastern Washington can result in lower lying portions of a field experiencing much colder temperatures than other areas within the field. The low rate of survival (20 percent) site near LaCrosse in 2022 was a consequence of excessive summer plant growth resulting in leaf desiccation and being located in a low-lying portion of the field. Similarly, at Davenport in 2021, a mowing treatment was applied as part of a 28 different experiment at the site of winter survival observation. Plants that received the mowing treatment had much less leaf biomass than their non-mowed counterparts and plants within the mowing treatment had much lower rates of survival (27%) than the rest of the trial (48%). A grazing trial near Edwall was severely grazed up to the fall sampling date of November 17th and had little aboveground biomass entering winter and only 24 percent survival was recorded.

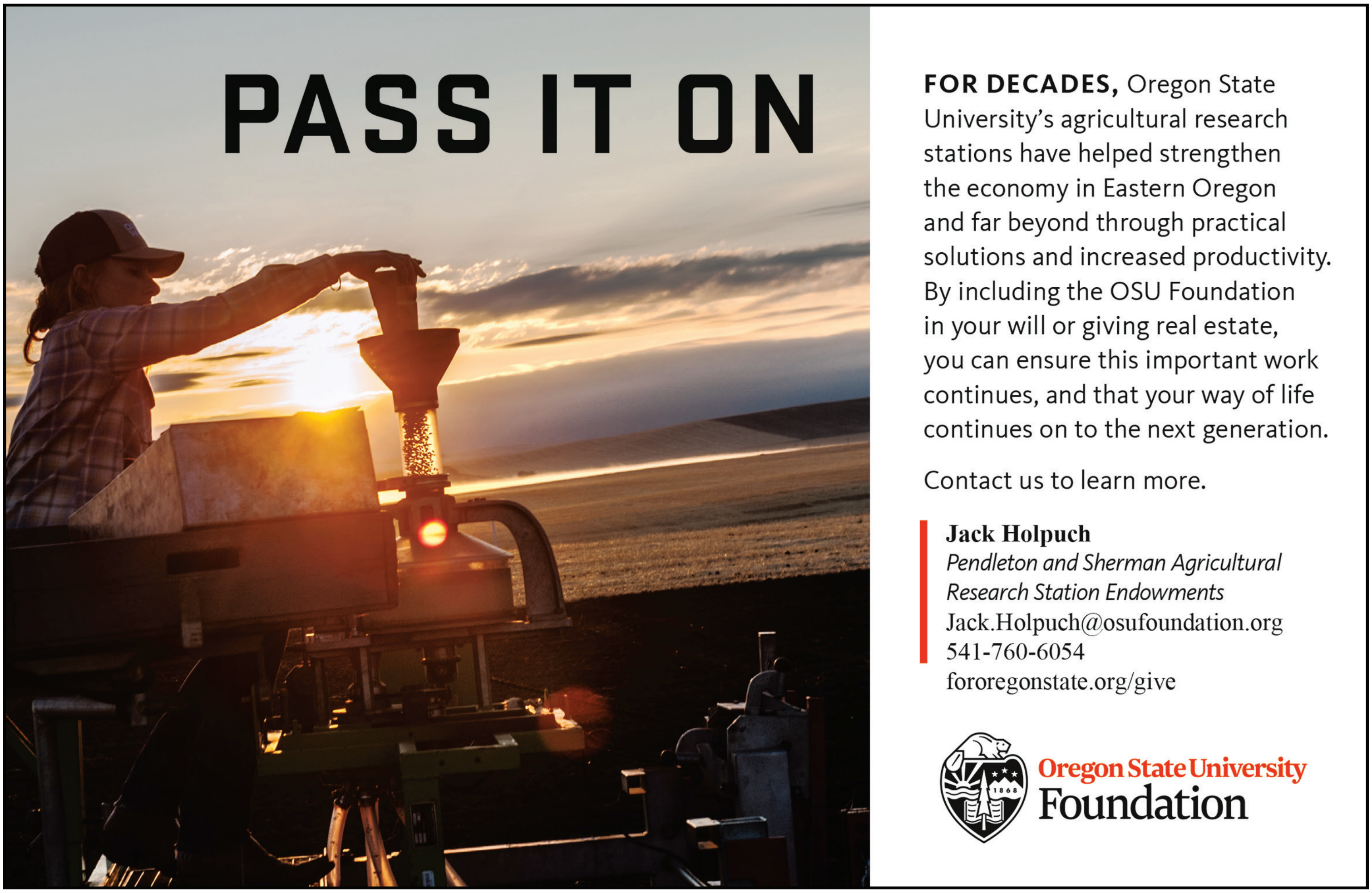
The results of this study indicate that the larger a winter canola plant is entering winter, the greater its prospects of winter survival. The survival model incorporates 2 years of observations and with both years having average to above average winter temperatures (NOAA National Centers for Environmental Information, 2023), it is difficult to estimate how a colder winter may affect the model's ability to predict. More years and observations would increase the understanding of how winter canola plant dimensions and environmental interactions affect winter survival probabilities. Collecting in-field weather observations along with plant measurements would also assist the advancement of understanding the interactions between canola plant size and temperature that result in plant mortality and damage. Future research within the iPNW should further explore the relationship between water use, drought stress, and winter survival of early seeded canola. This research would enable producers to maximize the fall growing period without excess soil water usage over the summer months and improve winter canola production across the region.

Table 1. Winter survival estimates of canola using a probability threshold (Very High >0.8, High >0.6, Medium >0.4, Low >0.2, Very Low<0.2). The associated average plant values for each predicted category are also included.

Observations	Probability Threshold	Crown Height (cm)	Crown Width (cm)	Canopy Width (cm)	Leaf Count	GDD	Precip (mm)	% Days Ncycle	% Days Minus15	% Days Delta10
	Very High									
931	TruPos	0.5	1.45	48.9	16.8	1048	23	17.2	3.6	16.9
51	FalsPos	0.4	1.42	46.4	14.1	989	23	18.2	3.6	16.2
	High									
165	TruPos	1.4	1.35	38.2	12.4	1206	22	19.0	2.4	18.4
57	FalsPos	1.6	1.51	38.7	15.1	1274	24	19.5	2.3	17.0
	Medium									
30	TruPos	2.0	1.50	42.9	11.7	1318	27	19.6	1.1	16.5
42	TruNeg	2.1	1.25	32.1	9.7	1179	27	19.1	1.4	16.1
29	FalsPos	1.8	1.40	40.2	10.5	1351	24	19.4	1.4	18.5
19	FalsNeg	2.6	1.35	40.1	8.9	1326	31	19.2	1.1	13.7
	Low									
63	TruNeg	2.5	1.18	33.5	7.4	1367	32	19.2	0.9	13.8
36	FalsNeg	2.6	1.27	33.1	9.0	1318	33	19.2	0.7	13.3
	Very Low									
41	TruNeg	3.3	1.08	26.1	7.0	1418	31	18.3	2.2	15.4
6	FalsNeg	1.8	1.69	38.0	12.0	1548	31	18.7	2.4	14.7

*Variable definitions are as follows: Crown.Height.cm-crown height of plant, Crown.Width.cm-crown width of plant, Canopy.Width.cm-canopy width at widest point of plant, Leaf.Count-number of true leaves on plant, GDD-growing degree days, Precip-precipitation from seeding to first frost, DeltaT-percentage of days during the cold period with an average daily temperature change greater than 10°C, DMFTeen-percentage of days.





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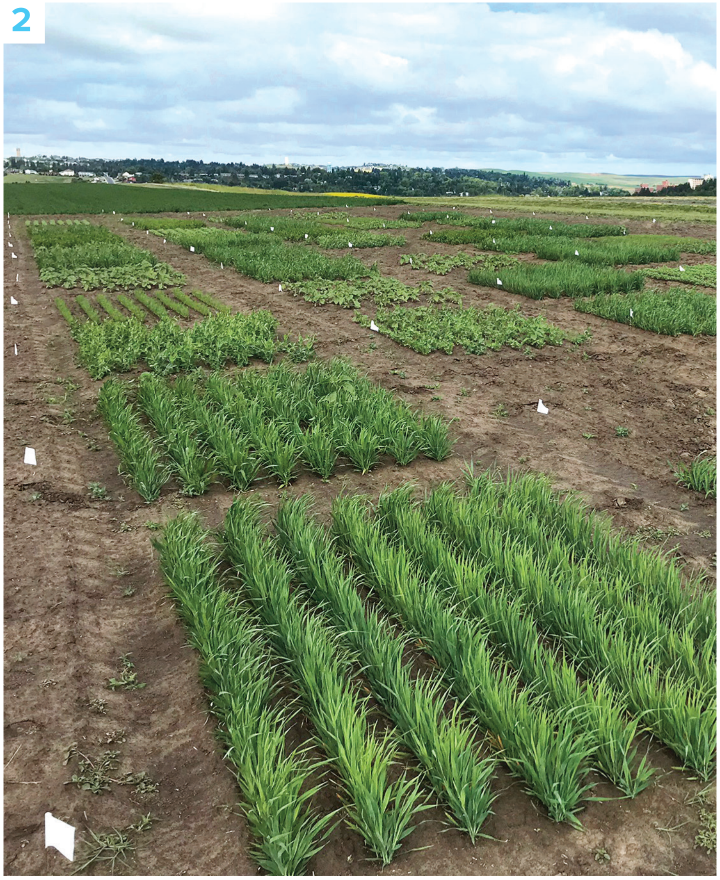

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