2021

Dryland Field Day Abstracts

Highlights of Research Progress

Oregon State University

Washington State University

University of Idaho

Photo by Kayla Yearout-Janowski

Editors:

WASHINGTON STATE UNIVERSITY
- Samantha Crow
- Bill Schillinger

UNIVERSITY OF IDAHO
- Kurt Schroeder
- Doug Finkelnburg
- Arash Rashed

OREGON STATE UNIVERSITY
- Susan Philips
- Debbie Sutor

Supporting Agriculture Research

For over a century, Washington State University has partnered with farmers to develop new crop varieties, solve problems from kernel to storage, and educate the next generation to be leaders. Please consider supporting one of our most important tools in supporting farmers—the Cook, Lind, and Spillman field research farms.

GIVING OPTIONS:

- **Consider a Gift of Land**

  The WSU Land Legacy program is committed to stewarding and managing gifts of agriculture land, in which the profits can go toward any area in the university.

  Learn more: **legacyofland.wsu.edu**

- **Make a Gift of Grain**

  You can direct the proceeds of a crop to area at WSU you would like to support. Significant tax benefits can be gained through gifts of grain instead of cash.

  Visit: **cahnrs.wsu.edu/alumni/giftsofgrain**

FOR MORE INFORMATION, CONTACT:

Office of Alumni and Development

College of Agricultural, Human, and Natural Resource Sciences

509-335-2243 | Donate online: give.wsu.edu

Welcome to our 2021 Field Day Abstracts!

2021 Dryland Field Day Abstracts:
Highlights of Research Progress

Washington State University
Department of Crop and Soil Sciences
Technical Report 21-1

Oregon State University
Department of Crop and Soil Science
Technical Report OSU-FDR-2021

University of Idaho
Idaho Agricultural Experiment Station
Technical Report UI-2021-1

Table of Contents

Part 1. Pathology, Weeds, and Insects

Part 2. Breeding, Genetic Improvement, and Variety Evaluation

Part 3. Agronomy and Soils

Part 4. Oilseeds and Other Alternative Crops

Washington State University
Cooperative Personnel and Area of Activity

Kirk H. Schulz	President, Washington State University
Richard T. Koenig	Interim Dean of College of Agricultural, Human, and Natural Resource Sciences
Drew Lyon	Interim Chair, Department of Crop & Soil Sciences
Scot H. Hulbert	Associate Dean for Research and Director, Agricultural Research Center
Vicki McCracken	Associate Dean and Director of Extension
Richard S. Zach	Associate Dean, Academic Programs

Agronomy, Conservation Systems, Soil Fertility, and Oilseeds

D. Brown .... 509-335-1859 .... dave.brown@wsu.edu
D. Crowder .... 509-335-7965 .... dcrowder@wsu.edu
A. Esser .... 509-659-3210 .... aarons@wsu.edu
S. Fransen .... 509-786-9266 .... fransen@wsu.edu
D. Huggins, USDA .... 509-335-3379 .... dhuggins@wsu.edu
R.T. Koenig .... 509-335-2726 .... richk@wsu.edu
D. Llewellyn .... 509-735-3551 .... don.llewellyn@wsu.edu
I. Madsen .... 360-448-9081 .... isaac_madsen@wsu.edu
C. Neely .... 509-335-1205 .... clark.neely@wsu.edu
H. Neely .... 509-335-0947 .... h.neely@wsu.edu
M.M. Neff .... 509-335-7705 .... mmneff@wsu.edu
W.F. Schillinger .... 509-235-1933 .... william.schillinger@wsu.edu
H. Tao .... 509-335-4389 .... haiying.tao@wsu.edu
D. Whaley .... 509-745-8531 .... dwhaley@wsu.edu

D. Appel, B. Barry, J. Braden, K. Curran, B. Gerrish, C. Hoffman, J. Jacobsen, J. Morse, E. Reardon, R. Rupp, S. Schofstoll, R. Sloot, E. Warner

Breeding, Variety Testing, and Culture of Legumes

DRY PEAS, LENTILS, CHICKPEAS

R. McGee, USDA .... 509-335-0300 .... rebecca.mcgee@usda.gov
G. Vandemark, USDA .... 509-335-7728 .... george.vandemark@usda.gov

T. Chen, J. Haines, M. Lauver, S.L. McGrew, J. Pfaff, N. Pierre-Pierre

DRY BEANS

P. Miklas, USDA .... 509-786-9258 .... phil.miklas@usda.gov

S. Swanson

Photo by Wilson Craine

Cereal Breeding, Genetics, and Physiology

WHEAT BREEDING & GENETICS

K. Garland-Campbell, USDA .... 509-335-0582 ....kim.garland-campbell@usda.gov
A.H. Carter .... 509-335-6198 ....ahcarter@wsu.edu
K.S. Gill.. 509-335-4666 ....ksgill@wsu.edu
S.S. Jones .... 360-416-5210 ....joness@wsu.edu
C.F. Morris, USDA .... 509-335-4062 ....craig.morris@usda.gov
M.M. Neff .... 509-335-7705 ....mmneff@wsu.edu
M.O. Pumphrey .... 509-335-0509 ....m.pumphrey@wsu.edu
K. Sanguinet.. 509-335-3662 ....karen.sanguinet@wsu.edu
D.R. See, USDA .... 509-335-3632 ....deven.see@wsu.edu
C. Steber, USDA .... 509-335-2887 ....camille.steber@usda.gov
M. Baldrige, K. Balow, B. Bellinger, R. Brew-Appiah, A. Burke, S. Conrad, J. DeMacon, P. DeMacon, V.L. DeMacon, D. Engle, K. Hagemeyer, T. Harris, V. Jitkov, B. Kelley, A. Kincaid, A. Kiszonas, E. Klarquist, M. Lenssen, K. Leonard, S. Lyon, W. Nyongesa, M. Russo, S. Rynearson, G.B. Shelton, R. Sloot, A. Stowe, E. Wegner, N. Wen, J. Worapong, D. Zborowski

BARLEY BREEDING & GENETICS

B. Brueggeman .... 509-335-5272 ....bob.brueggeman@wsu.edu
M. Wood

Crop Diseases

CEPHALOSPORIUM STRIPE, FOOT ROTS, SNOW MOLDS, AND VIRUS DISEASES

T.D. Murray .... 509-335-7515 ....tim.murray@wsu.edu
H. Sheng, M. Thorne

WHEAT HEALTH

P. Okubara, USDA .... 509-335-7824 ....patricia.okubara@usda.gov
T. Paulitz, USDA .... 509-335-7077 ....timothy.paulitz@usda.gov
L. Thomashow, USDA .... 509-335-0930 ....linda.thomashow@usda.gov
D. Weller, USDA... 509-335-6210 ....david.weller@usda.gov

RUSTS, SMUTS; FOLIAR, VIRUS AND BACTERIAL DISEASES

W. Chen, USDA .... 509-335-9178 ....weidong.chen@usda.gov
X.M. Chen, USDA .... 509-335-8086 ....xianming.chen@usda.gov
C.K. Evans, USDA .... 509-335-8715 ....kent.evans@usda.gov
Y. Liu .... 509-335-1596 ....y.liu@wsu.edu
J. Sprott, USDA... 509-335-4789 ....jason.sprott@usda.gov
M.N. Wang .... 509-335-1596 ....meinan_wang@wsu.edu

Soil Microbiology

L. Carpenter-Boggs .... 509-335-1533 ....lcboggs@wsu.edu
M. Friesen.. 509-335-5805 ....m.friesen@wsu.edu
J.C. Hansen, USDA .... 509-335-7028 ....jeremy.hansen@usda.gov
T. Sullivan .... 509-335-4837 ....t.sullivan@wsu.edu
R. Wieme

Weed Management

I.C. Burke .... 509-335-2858 ....icburke@wsu.edu
D.J. Lyon .... 509-335-2961 ....drew.lyon@wsu.edu
D. Appel, R. Sloot, M. Thorne, H. Wetzel

Wheat Quality and Variety Evaluation

WHEAT QUALITY

C.F. Morris, USDA .... 509-335-4062 ....craig.morris@usda.gov

M.L. Baldridge, D. Bolingbroke, S. Conrad, D.A. Engle, U. Ganjyal, W.J. Kelley, A.M. Kiszonas, S. Lenssen, K. Leonard, J. Luna, G. Mikhaylenko, C. Munoz, N. Ovetz, G.L. Peden, D. Power, M. Rauch, R. Saam, E. Stout, S. Sykes, Y. Thompson, S. Vogl, E. Wegner

WSU EXTENSION CEREAL VARIETY TESTING

C. Neely .... 509-335-1205 ....clark.neely@wsu.edu

B. Gerrish, A. Horton

WSCIA Foundation Seed Service & Certification

G. Becker 509-592-4515

L. Evans... 509-334-0461 ....lynae@washigtoncrop.com

D. Hilkin .... 509-592-4515 ....darlene@washingtoncrop.com

D. Krause .... 509-592-4515 ....darryl@washingtoncrop.com

K. Olstad .... 509-334-0461 ....karen@washingtoncrop.com

L. Port .... 509-334-0461 ....lauren@washingtoncrop.com

H. Sweet .... 509-334-0461 ....hannah@washingtoncrop.com

Field Stations

WSU LIND DRYLAND RESEARCH STATION

B.E. Sauer, Farm Manager .... 509-677-3671 ....sauerbe@wsu.edu

WSU PLANT PATHOLOGY FARM

F. Ankerson, Farm Manager .... 509-335-3081 ....fca@wsu.edu

WSU SPILLMAN FARM AND WSU COOK FARM

F. Ankerson, Farm Manager .... 509-335-3081 ....fca@wsu.edu

WSU/USDA-ARS PALOUSE CONSERVATION FIELD STATION

F. Ankerson, Farm Manager .... 509-335-3081 ....fca@wsu.edu

WSU WILKE FARM

A. Esser, Adams Co. Director .... 509-659-3210 ....aarons@wsu.edu

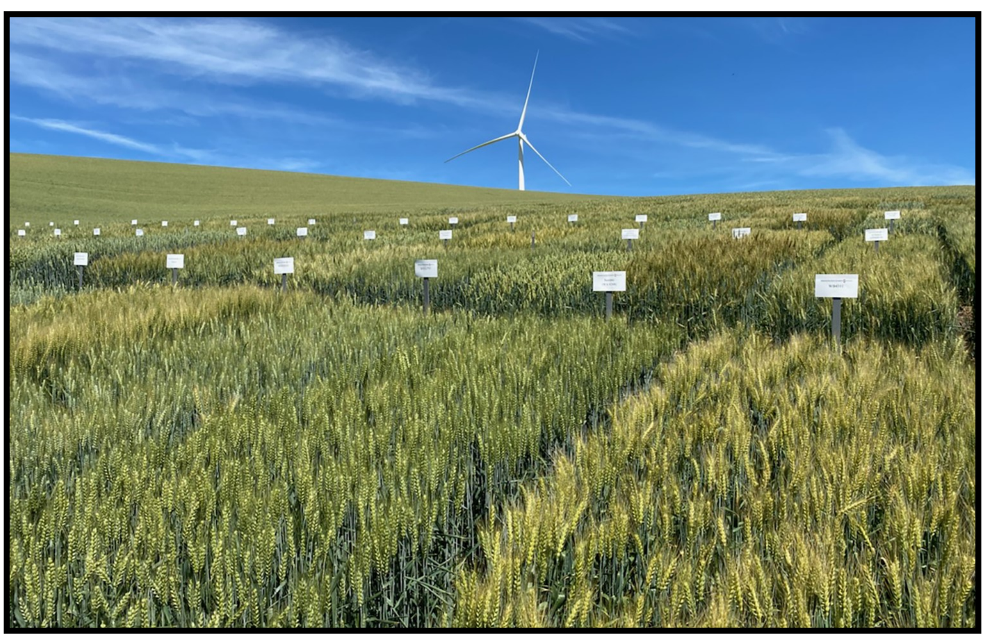


Photo by Clark Neely

University of Idaho
Cooperative Personnel and Area of Activity

C. Scott Green	President, University of Idaho
Michael P. Parrella	Dean, College of Agricultural and Life Sciences
Mark McGuire	Associate Dean of Research & Director of Idaho Agricultural Experiment Station
Barbara Petty	Associate Dean & Director of Extension

Agronomy and Cropping Systems

D. Finkelnburg........ 208-799-3096 .... dougf@uidaho.edu
X. Liang .... 208-397-7000 x110........ xliang@uidaho.edu
J. Marshall........ 208-529-8376 .... jmarshall@uidaho.edu
N. Olsen .... 208-423-6634 .... norao@uidaho.edu
K. Schroeder .... 208-885-5020 .... kschroeder@uidaho.edu
J. Spackman .... 208-844-6323 .... jspackman@uidaho.edu
R. Spear........ 208-397-7000 .... rhetts@uidaho.edu
M. Thornton........ 208-722-6701 x211........ miket@uidaho.edu
O. Walsh .... 208-722-6701 x218........ owalsh@uidaho.edu
K. Beck, J. Davis, L. Jones, C. Lowder, J. McClintick, M. Moll, R. Portenier, C. Poulson, L. Schroeder, T. Shelman, L. Woodell

Cereal Breeding, Genetics, and Variety Testing

J. Chen .... 208-397-4162 x229........ jchen@uidaho.edu
D. Fu........ 208-885-1542 .... dlfu@uidaho.edu
J. Marshall........ 208-529-8376 .... jmarshall@uidaho.edu
K. Schroeder .... 208-885-5020 .... kschroeder@uidaho.edu
Y. Wang........ 208-885-9110 .... ywang@uidaho.edu
J. Davis, N. Klassen, L. Jones, R. Lawrence, J. Wheeler, S. Windes, B. Yimer

Crop Diseases

L-M. Dandurand........ 208-885-6080 .... lmd@uidaho.edu
K. Duellman .... 208-529-8376 .... kduellman@uidaho.edu
A. Karasev .... 208-885-2350 .... akarasev@uidaho.edu
J. Kuhl........ 208-885-7123 .... jkuhl@uidaho.edu
J. Marshall........ 208-529-8376 .... jmarshall@uidaho.edu
B. Schroeder .... 208-339-5230 .... bschroeder@uidaho.edu
K. Schroeder .... 208-885-5020 .... kschroeder@uidaho.edu
P. Wharton........ 208-397-7000 x108........ pwharton@uidaho.edu
J. Woodhall .... 208-722-6701 .... jwoodhall@uidaho.edu
B. Amiri, A. Bates, W. Bills, M. Chikh Ali, J. Chojnacky, J. Dahan, M. Harrington, M. Haylett, L. Jones, S. Keith, A. Kud, M. Lent, A. Malek, K. Malek, M. Murdock, G. Orellana, C. Pizolotto, A. Poplawsky, B. Yimer

Integrated Pest Management

J. Clements .... 208-722-6701 .... justinclements@uidaho.edu
S. Eigenbrode .... 208-885-2972 .... sanforde@uidaho.edu
S. Hafez .... 208-722-6701 x237 .... shafez@uidaho.edu
A. Rashed .... 208-397-7000 x114 .... arashed@uidaho.edu
M. Schwarzläender .... 208-885-9319 .... markschw@uidaho.edu
E. Wenninger .... 208-423-6677 .... erik@uidaho.edu
S. Adhikari, D. Carmona, F. Garcia, B. Harmon, S. Odubiyi, A. Sadeghi, D. Sirengo, L. Standley, A. Stanzak

Soil Fertility and Management

J. Johnson-Maynard .... 208-885-9245 .... jmaynard@uidaho.edu
R. Mahler .... 208-885-7025 .... bmahler@uidaho.edu
I. Popova .... 208-885-4953 .... ipopova@uidaho.edu
D. Strawn .... 208-885-2713 .... dgstrawn@uidaho.edu
O. Walsh .... 208-722-6701 x218 .... owalsh@uidaho.edu
A. Crump, K. Kahl, J. McClintick

Weed Management

A. Adjesiwor .... 208-423-6616 .... aadjesiwor@uidaho.edu
J. Campbell .... 208-885-7730 .... jcampbel@uidaho.edu
P. Hutchinson .... 208-397-7000 x109 .... phutch@uidaho.edu
T. Prather .... 208-885-9246 .... tprather@uidaho.edu
B. Beutler, J. Gromm, L. Jones, T. Keeth, T. Rauch

Field Stations

UI PARKER FARM
R. Patten, Farm Manager .... 208-885-3276 .... royp@uidaho.edu
UI KAMBITSCH FARM
B. Bull, On-site Ag Mechanic .... 208-885-3276 .... bbull@uidaho.edu

Photo by Kate Painter

Oregon State University
Cooperative Personnel and Area of Activity

Rebecca Johnson	Interim President, Oregon State University
Alan Sams	Reub Long Dean & Director, College of Agricultural Sciences and Oregon Agricultural Experiment Station
Staci Simonich	Executive Associate Dean, College of Agricultural Sciences
Joyce Loper	Associate Dean of Research, College of Agricultural Sciences
John Talbott	Assistant Dean of Research & Assistant Director, College of Agricultural Sciences & Experiment Stations
Tom Chastain	Department Head, Crop and Soil Science
Joey Spatafora	Department Head, Botany and Plant Pathology
Francisco Calderon	Director, Columbia Basin Agricultural Research Center

Agronomy

D. Long, USDA (retired)........ 541-969-6122........ dan.long@usda.gov
S. Machado .... 541-278-4416........ stephen.machado@oregonstate.edu
L. Pritchett, S. Singh

Barley Breeding

P. Hayes .... 541-737-5878........ patrick.m.hayes@oregonstate.edu

Wheat Breeding

K. Garland Campbell .... 208-310-9876........ kim.garland-campbell@usda.gov
R. Zemetra .... 541-737-4278........ robert.zemetra@oregonstate.edu

Chemistry—Wheat

A. Ross .... 541-737-9149........ andrew.ross@oregonstate.edu

Extension

R. Graebner........ 541-278-4186........ graebner@oregonstate.edu
L. Lutcher .... 541-676-9642........ larry.lutcher@oregonstate.edu
J. Maley........ 541-384-2271........ jordan.maley@oregonstate.edu
D. Walenta .... 541-963-1010........ darrin.walenta@oregonstate.edu
D. Wysocki .... 541-969-2014........ dwysocki@oregonstate.edu
M. Hunt, D. Rudometkin Odell, A. Wernsing

Soil Microbiology

D. Myrold........ 541-737-5737........ david.myrold@oregonstate.edu
C. Reardon, USDA .... 541-278-4392........ catherine.reardon@usda.gov
E. Klarer

Soil Science

H. Gollany, USDA .... 541-278-4410........ hero.gollany@usda.gov
S. Wuest, USDA........ 541-278-4381........ stewart.wuest@usda.gov
W. Polumski, D. Robertson

Plant Pathology

C. Hagerty .... 541-278-4396........ christina.hagerty@oregonstate.edu
C. Mundt........ 541-737-5256........ mundtc@science.oregonstate.edu
R. Smiley, Emeritus Prof........ 541-278-4397........ richard.smiley@oregonstate.edu
D. Kroese

Weed Management

D. Ball, Emeritus Professor .... 541-354-1261........ daniel.ball@oregonstate.edu
J. Barroso .... 541-278-4394........ judit.barroso@oregonstate.edu
N. Genna, J. Gourlie

Part 1. Pathology, Weeds, and Insects

On Top of Soil Health: Cover Crops Support Bee Pollinators and Suppress Weeds

Subodh Adhikari[1], Ian Burke[2], and Sanford Eigenbrode[1]
[1]Dept. of Entomology, Plant Pathology and Nematology, UI; [2]Dept. of Crop and Soil Sciences, WSU

Cover crops are non-cash crops planted in rotation between any cash crops and provide a variety of ecosystem services. Cover cropping is gaining attention in recent years as it improves overall soil health, but the effects on beneficial insects and weeds are largely unknown. In 2019 and 2020, we conducted an on-farm study by sampling 52 fields (26 cover crops and 26 wheat) in low and high precipitation zones in the inland Pacific Northwest. We compared bee communities between wheat and cover crops and assessed weed suppression among various cover crop mixes currently used by growers in the region. Using blue vane traps and yellow bee bowls filled with diluted soapy water, we trapped bee pollinators from each field during the peak flowering of cover crops. We also assessed cover crop and weed biomass from three 1 m^2 frames per cover crop field.

A honeybee foraging on volunteer alfalfa flowers.

Preliminary results revealed that different growers in the region used at least 35 different cover crop cultivars during the study period, but the cover crop diversity varied from a single species to a mix of 20 species present during biomass sampling. Brassicas (81%), legumes (69%), grasses (65%), asters (46%), and others (19%) were most commonly used in cover crop mixes in the region. We found that cover crops increased bee abundance and number of bee taxa, but the bee community composition was not different between wheat and cover crops. Out of 3,201 bee specimens collected, 67% were from cover crops and 33% from wheat fields. We recorded 82 bee taxa from 22 genera and five families, including: sweat bees, bumblebees, honeybees, long-horned bees, mining bees, blue orchard bees, and cuckoo bees. The number of species used in the cover crop mixture was positively but weakly associated with bee abundance (Fig. 1). We also recorded a total of 45 weed species from 14 families. Volunteer alfalfa, lambsquarter, redroot pigweed, Mayweed chamomile, and cheatgrass were the five most dominant species that accounted for 78% of total weed biomass. Cover crop biomass was negatively associated with weed abundance (i.e., a good cover crop stand,

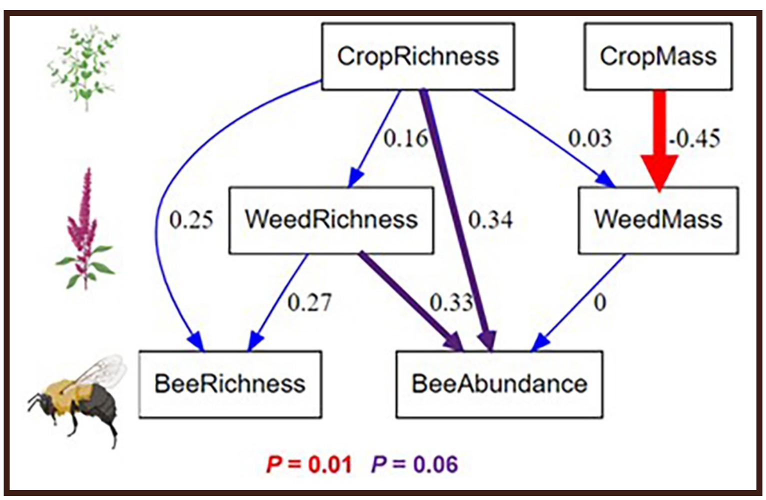


Figure 1. Associations of bee abundance and richness with cover crop biomass and weed biomass. Crop biomass was negatively associated with weed biomass. Crop diversity did not necessarily suppress weeds, but crop and weed richness were positively associated with bee abundance.

irrespective of cultivars used in the mixes, can suppress weeds). Similarly, the number of weed species found in cover crop fields had weak positive associations with bee abundance (Fig. 1).

Our results suggest that while alternative cereal-based production systems could increase certain metrics of pollinator communities, current cover crop adoption in the region is not yet sufficient to support significantly more diverse pollinators than business-as-usual production systems. Inland Pacific Northwest growers are in the early stages of adopting cover crops, and increased adoption is expected to help suppress weeds and support beneficial insects (Fig. 2). Cover crop performance could be affected by different edaphic and climatic conditions; hence their benefits may not be similar across regions or the mixes may need to be tailored to suit the local conditions. With a properly created mix of pollinator-friendly forbs, cover crops can increase cropping system diversification in the region, help adapt to climate change, and offset the negative effects of native prairie loss in the region by provisioning food and habitat to beneficial organisms.

"Landscapes in Transition" is funded through award #2017-68002-26819 from the National Institute of Food and Agriculture.

Figure 2. Cover crops (adjacent to a wheat field on the right), replacing a portion of a fallow field (on the left) in Asotin County, WA.

Responses of Soil Fungal Communities to Lime Application in Wheat Fields in the Pacific Northwest

CHUNTAO YIN[1,3], DANIEL C. SCHLATTER[2], DUNCAN R. KROESE[3], TIMOTHY C. PAULITZ[1,2], AND CHRISTINA H. HAGERTY[3]
[1]DEPT. OF PLANT PATHOLOGY, WSU; [2]WHEAT HEALTH, GENETICS AND QUALITY RESEARCH UNIT, USDA-ARS PULLMAN; [3]DEPT. OF BOTANY AND PLANT PATHOLOGY, OSU

Liming is an effective agricultural practice and broadly used to ameliorate soil acidification in agricultural ecosystems. Our understanding of the impacts of lime application on soil fungal communities is scarce. In this study, we explored the responses of fungal communities to liming at two locations with decreasing soil pH in Oregon in the Pacific Northwest using high-throughput sequencing (Illumina MiSeq). Our results revealed that the location and liming did not significantly affect soil fungal diversity and richness, and the impact of soil depth on fungal diversity varied among locations. In contrast, location and soil depth had a strong effect on the structure and composition of soil fungal communities, whereas the impact of liming was much smaller, and location- and depth- dependent. Interestingly, families Lasiosphaeriaceae, Piskurozymaceae, and Sordariaceae predominated in the surface soil (0-7.5 cm) and were positively correlated with soil OM and aluminum, and negatively correlated with pH. The family Kickxellaceae which predominated in deeper soil (15-22.5 cm) had an opposite response to soil OM. Furthermore, some taxa in Ascomycota, such as Hypocreales, *Peziza* and *Penicillium*, were increased by liming at one of the locations (Moro). In conclusion, these findings suggested that fungal community structure and composition rather than fungal diversity responded to location, soil depth and liming. Compared to liming, location and depth had a stronger effect on fungal communities, but some specific fungal taxa shifted with lime application.

A Rapid Greenhouse Screening Method for Cereal Cyst Nematode (CCN) Resistance in Wheat

NUAN WEN[1], NIKAYLA STRAUSS[1], KIMBERLY GARLAND-CAMPBELL[2], AND TIMOTHY PAULITZ[2]
[1]WASHINGTON STATE UNIVERSITY; [2]USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT

The cereal cyst nematodes (CCN, *Heterodera avenae* and *H. filipjevi*) cause substantial yield loss in wheat. In the Pacific Northwest (PNW) of the U.S., *H. avenae* was first detected in 1974 and *H. filipjevi* in 2008. CCN related annual yield loss has been estimated to be $78 billion globally and at least $3.4 million in the PNW. Control of CCN, including fallow and rotation, chemical nematicides, and environment-friendly biological control, are all infeasible while breeding for resistant cultivars is the most efficient and cost-effective approach. However, the breeding progress has been slow due to lack of a fast and convenient screening procedure. In this study, a dependable method for CCN resistance screening was developed, enabling the screening to be conducted under greenhouse conditions, within six weeks in limited space, using naturally infested soil collected from the field. With this method, we 1) screened over 1,000 wheat breeding lines and identified more than 200 with useful resistance; 2) discovered that the PNW *H. filipjevi* reacts differently to the CCN differential lines with the existing Ha23 and Ha33 pathotypes, indicating that the PNW *H. filipjevi* is likely to be a new pathotype; and 3) determine that none of the previously identified *Cre* genes confer full resistance to the PNW *H. filipjevi*, supporting new pathotype status for the PNW *H. filipjevi*. These results indicate that we must screen for CCN resistance using the PNW *H. filipjevi* pathotype and that we have useful levels of genetic resistance existing in adapted PNW wheat breeding lines.

Figure 1. Roots of Alpowa spring wheat with small white cysts (arrow). White cysts are young females that contain eggs, protruding from the feeding sites.

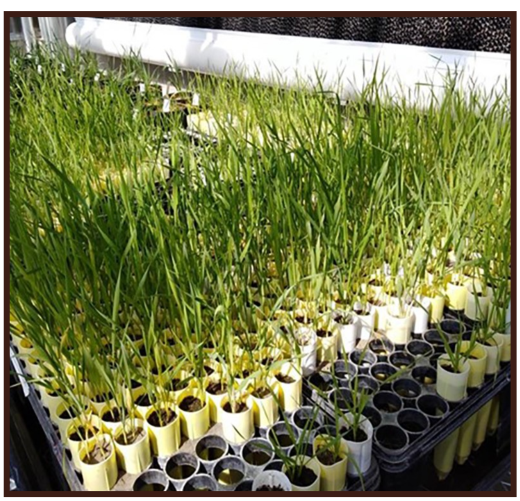


Figure 2. CCN screening trial in the growth chamber at the WSU Plant Growth Facility.

Key Words: Cereal Cyst Nematode (CCN), *Heterodera filipjevi*, Pacific Northwest (PNW), resistance screen, pathotype

Russian Thistle Control with Soil-Active Herbicides in No-Till Fallow

JUDIT BARROSO[1], DREW J. LYON[2], MARK E. THORNE[2], JENNIFER GOURLIE[1], AND LARRY K. LUTCHER[3]
[1]OREGON STATE UNIVERSITY, ADAMS, OR; [2]WASHINGTON STATE UNIVERSITY; [3]OSU, HEPPNER, OR

The benefits of no-till fallow, which include reduced soil erosion, improved soil health, and increased stored soil water, are in jeopardy due to the widespread development of glyphosate resistance in Russian thistle. The objective of this research was to evaluate the efficacy of soil-active, residual herbicides for Russian thistle control in no-till fallow. Spartan® Charge (sulfentrazone + carfentrazone) at 8 fluid ounces/acre, Fierce® (flumioxazin + pyroxasulfone) at 4.5 ounces/acre, and TriCor® DF or Metribuzin 75 (metribuzin) at 10.5 ounces/acre were each applied in late fall, late winter, and split-applied with 50% applied in late fall and the other 50% applied in late winter at multiple sites: Adams, OR in 2017-2018-2019-2020; Moro, OR in 2017-2018-2019; Ione, OR in 2019-2020, Lind, WA in 2018-2019; and Ralston, WA in 2019-2020. Russian thistle densities were sufficiently high for analysis at three sites: Adams, OR in 2018, Lind, WA in 2019, and Ralston, WA in 2020. All treatments provided good to excellent control of the initial flush of Russian thistle when assessed in mid-May, except the late fall application of metribuzin at all three sites, and the late fall application of Spartan Charge at Adams (Table 1).

Table 1. Russian thistle mean density in May of the fallow year at Adams, OR in 2018, Lind, WA in 2019, and Ralston, WA in 2020.

			Russian thistle density[a]		
Treatment	Rate	Timing	2018	2019	2020
	oz product/A		-------- plants/square yard --------		
Check			12.8 a	12.3 a	2.3 a
Spartan Charge	8	Late fall	4.5 b	0.0 c	0.0 c
Spartan Charge	8	Late winter	0.0 d	0.0 c	0.0 c
Spartan Charge +	4	Late fall	0.4 d	0.0 c	0.0 c
Spartan Charge	4	Late winter			
Fierce	4.5	Late fall	0.9 c	0.2 c	0.0 c
Fierce	4.5	Late winter	0.8 cd	0.3 c	0.2 c
Fierce +	2.25	Late fall	0.0 d	0.0 c	0.0 c
Fierce	2.25	Late winter			
TriCor DF	10	Late fall	14.1 a	3.3 b	1.0 b
TriCor DF	10	Late winter	0.0 d	0.2 c	0.0 c
TriCor DF +	5	Late fall	1.3 c	0.1 c	0.1 c
TriCor DF	5	Late winter			

[a]Within a column, means followed by the same letter are not significantly different at the 95% probability level.

Cumulative Russian thistle densities, evaluated monthly throughout the fallow season, were lowest for the Spartan Charge treatments, except for the late fall application at Adams (Figure 1). However, Fierce and metribuzin provided greater control of tumble mustard and prickly lettuce than Spartan Charge (data not shown). Spartan Charge, Fierce, and metribuzin can all be used for Russian thistle control in fallow. To reduce the risk for crop injury to subsequently planted winter wheat, a late fall application of Spartan Charge may be the preferred treatment in low rainfall regions where winter wheat-fallow is commonly practiced. A late winter application may be preferred in higher rainfall regions where a three-year rotation (e.g., winter wheat-spring wheat-fallow) is common. Fierce should be considered if other broadleaf weeds, such as tumble mustard or prickly lettuce, are of concern. The use of these soil-applied herbicides will reduce the need for the frequent application of glyphosate for Russian thistle control in no-till fallow.

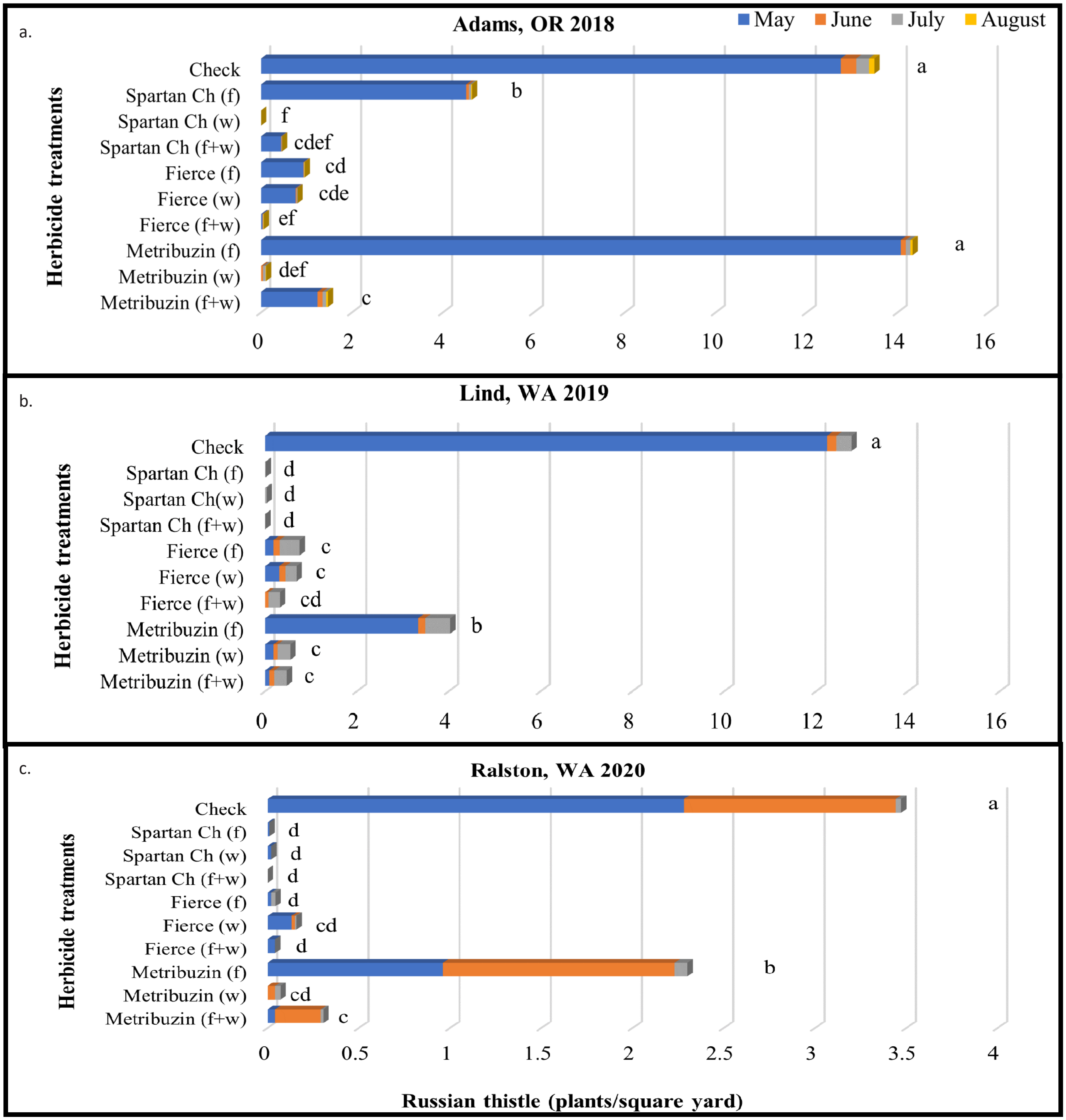


Figure 1. Cumulative Russian thistle density from May through August at (A) Adams, OR, in 2018; (B) Lind, WA, in 2019; and (C) Ralston, WA 2020. Bars followed by the same letter are not significantly different ($\alpha = 0.05$) according to the lsmeans function. Abbreviations: f, fall; w, winter, f+w, split-applied fall and winter.

Precision vs. Uniform Spraying to Control Broadleaf Weeds in Fallow and Post-Harvest

NICHOLAS G. GENNA, JENNIFER A. GOURLIE, AND JUDIT BARROSO
COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU

A no-till winter wheat-fallow rotation relies on herbicides to control weeds in fallow and post-harvest. Conventional herbicide applications are made uniformly to fields regardless of the presence of weeds or their density. On the other hand, real-time precision spraying systems are designed to differentiate weeds from soil with sensors that turn individual spray nozzles on and off to minimize coverage of weed-free soil without the need of a weed map. WEED-IT® and WeedSeeker® are two optical spot spraying systems that are currently marketed to farmers with the potential of reducing herbicide costs. However, their efficacy is unknown. We conducted three experiments in 2019 and 2020 to compare WEED-IT and WeedSeeker precision spraying systems to uniform spraying in fallow and post-harvest (Image 1).

Image 1. Example of the WEED-IT precision sprayer in operation during fallow and postharvest.

Experiment 1 and 2 compared precision spraying systems to uniform spraying in fallow and post-harvest using Gly Star® Plus at 32 fl oz/A (a.i. glyphosate) and Huskie® at 15 fl oz/A (a.i. bromoxynil + pyrasulfotole), while experiment 3 compared precision spraying systems to uniform spraying with differing residue management treatments. Those treatments included short stubble (~4 in) with residue, tall stubble (~10 in) with residue, and medium stubble (~8 in) without residue where the chaff and straw were removed at harvest with a tarp behind the combine. Experiment 3 was post-harvest in 2019 and fallow in 2020. Deadbolt® (a.i. bromoxynil + 2,4-D) was applied at 40 fl oz/A in 2019 and a tank-mix of Huskie at 14 fl oz/A with Gly Star Plus at 32 fl oz/A was used in 2020. Herbicide rates were the same for uniform and precision applications. Weed density was assessed before herbicide applications and at three and six weeks thereafter. Herbicide efficacy was determined as the percentage reduction in weed density after herbicide applications.

Results from experiment 1 in fallow demonstrated overall higher efficacy for uniform spraying compared to precision spraying with Gly Star Plus and Huskie. For instance, across 2019 and 2020, uniform spraying provided 63% efficacy while precision spraying systems provided an average of only 41%. In experiment 2 at post-harvest, uniform spraying provided 1.7 times greater efficacy with Huskie in 2019 compared to precision spraying, while efficacy was similar for Gly Star Plus in 2019 and both herbicides in 2020. When comparing experiment 1 to experiment 2, overall herbicide efficacy was two times higher in fallow (41%) compared to post-harvest (20%), indicating that stubble or the larger size of weeds in post-harvest reduced efficacy. Experiment 3 showed no significant effect of residue management treatments in either year. Similar to experiments 1 and 2, herbicide efficacy was higher for uniform spraying in 2019 while efficacy with WEED-IT was higher in 2020 due to an unintentional higher application rate.

Results from experiments 1, 2, and 3 indicate that uniform spraying might provide greater herbicide efficacy than precision spraying systems when applying similar herbicide rates. However, using higher herbicide rates with precision sprayers may improve their efficacy by overcoming issues related to suboptimal weed detection or herbicide coverage. This possibility should be explored in future research.

Sugar Beet Wireworm (*Limonius californicus*) Mortality in Response to Yellow and Brown Mustard Green Manure

Atoosa Nikoukar[1], Inna Popova[2], and Arash Rashed[1]
[1]Dept. of Entomology, Plant Pathology and Nematology, UI; [2]Dept. of Soil and Water Systems, UI

In recent years, crop production in the Pacific Northwest (PNW) region of the USA has been threatened by the re-emergence of a damaging pest, known as wireworm. The term 'wireworm' refers to the larval stage of click beetle (Coleptera: Elateridae) species. Until 2021, neonicotinoid seed treatments were the only group of insecticides registered for application in small grains. The neonicotinoid seed treatments, however, do not reduce wireworm populations and in many cases failed to provide an acceptable level of protection. In a search for identifying an effective alternative control method, we conducted a greenhouse study to evaluate the efficacy of different mustard species and their products against the most damaging wireworm species in the PNW, the sugar beet wireworm *Limonius californicus*. Mustard species belong to the family Brassicaceae and are known for their biocidal effects on a wide range of pests, due to their glucosinolate contents. Yellow mustard (*Sinapis alba*) and brown mustard (*Brassica juncea*) contain different glucosinolates. Yellow mustard contains sinalbin with mostly herbicidal effects, whereas sinigrin in brown mustard is known to have insecticidal effects on various insect pests. In a series of greenhouse experiments we evaluated the effects of soil-incorporated brown and yellow mustard plants, seed meal, and concentrated seed meal extracts from each of the two plant species against sugar beet wireworm. The experiment was conducted in two time-blocks with 10 replicates per treatment in each time-block. There was a total of 13 treatments which are listed in Fig. 1. Each replicate was conducted in a small pot containing a single wireworm. All pots were arranged in a completely randomized design within each time-block. After incorporating plant tissues, or applying each product, the pots were covered with plastic and sealed with parafilm (individually) for a 24-hr period (Fig. 2). Four wheat seeds were planted in each pot two weeks after treatment application. A significant variation was reported among treatments (F = 3.145, df = 12, 192, $P < 0.001$). The brown mustard concentrated seed meal extracts, applied at the rates of 3.3 and 4.5 t/ha, caused 56.3% and 64.3% wireworm mortality, respectively. Yellow mustard seed

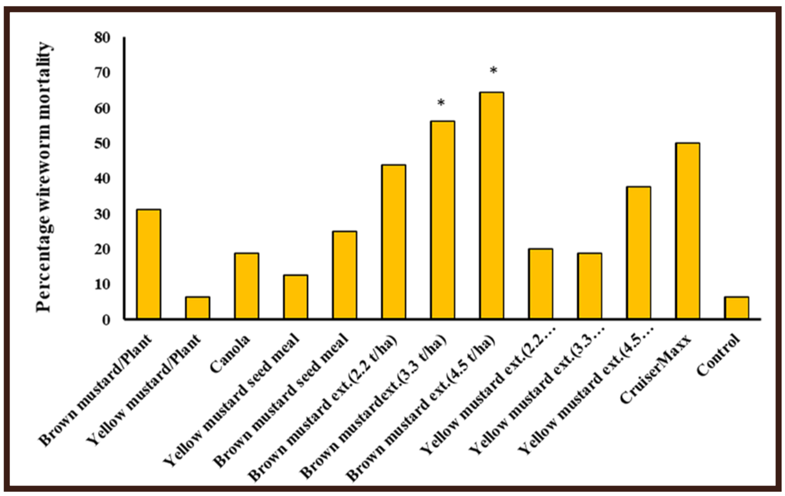


Figure 1. Percentage mortality caused by each treatment in sugar beet wireworm. A total of 13 treatments in two time blocks were evaluated: 1) brown mustard soil-incorporated plant tissue; 2) yellow mustard soil-incorporated plant tissue; 3) canola soil-incorporated plant tissue as control; 4) yellow mustard seed meal applied at the rate of 8.9 tons/ha ; 5) brown mustard seed meal applied at the rate of 8.9 tons/ha; 6) brown mustard concentrated seed meal extract applied at the rate of 2.2 tons/ha; 7) brown mustard concentrated seed meal extract applied at the rate of 3.3 tons/ha; 8) brown mustard concentrated seed meal extract applied at the rate of 4.5 tons/ha; 9) yellow mustard concentrated seed meal extract applied at the rate of 2.2 tons/ha; 10) yellow mustard concentrated seed meal extract applied at the rate of 3.3 tons/ha; 11) yellow mustard concentrated seed meal extract applied at the rate of 4.5 tons/ha; 12) neonicotinoid seed treatment (Cruiser Maxx) applied at the rate of 325 ml/ 100 kg seeds; 13) non-treated control. Asterisks indicate significant difference with the untreated control.

meal and concentrated seed meal extract were not as effective in reducing wireworm numbers. Germination rate was not significantly different among treatments. Seed meal concentrated extract from brown mustard appeared to be a promising product in reducing wireworm numbers in the greenhouse. A field trial is ongoing to confirm their efficacy in uncontrolled conditions.

Figure 2. All pots were covered with plastic bag and parafilm after incorporating mustard plant tissues, seed meal and concentrated seed meal extract.

Postharvest Control of Russian-thistle with Herbicides

HENRY WETZEL, DREW LYON, AND MARK THORNE
DEPT. OF CROP AND SOIL SCIENCES, WSU

A study was conducted at the Lind Dryland Research Station near Lind, WA to evaluate herbicides for the control of Russian-thistle following the harvest of spring wheat. The objective was to evaluate three herbicide application timings, one, two and three weeks after harvest to determine when would be the best time to apply herbicides to get the best control of Russian-thistle, postharvest.

Postemergence herbicides were applied on 8/4, 8/11 and 8/18/2020, which corresponded to one, two and three weeks after harvest. RT 3® (glyphosate) plus ammonium sulfate (64 fl oz/A + 17 lb/100 gal) were applied at 10 GPA, whereas Maestro® 4EC + TriCor® 75DF (16 fl oz + 10.67 oz/A) and Gramoxone® SL 2.0 + NIS (48 fl oz/A + 0.25% v/v) were applied at 20 GPA. Environmental conditions for the 8/4 application were an air temperature of 86°F, relative humidity 26% and the wind was out of the west at 6 mph. There was an average of 2.5 Russian-thistle plants per square yard in the nontreated check plots. Plants were 13.5-in-diameter and 12-in-height. The wheat stubble height (10.5 in) was uniform across the trial area. As noted in the height of the Russian-thistle, the plants were beginning to grow above the height of the wheat stubble. Environmental conditions for the 8/11 application were an air temperature of 74°F, relative humidity 28% and the wind was out of the southwest at 6 mph. Environmental conditions for the 8/18 application were an air temperature of 87°F, relative humidity 36% and the wind was out of the southwest at 4 mph.

The last time it rained prior to the trial initiation (8/4) was July 1st when the trial area received 0.36 inches of rain. It did not rain again until September 19th, when the trial area received 0.05 inches or rainfall. This was 2 days after the final rating was taken. During this time period, the lack of rainfall is not uncommon in this area of eastern WA. Air temperatures were average to below average during the trial period.

When RT 3 was applied one-week (8/4) after harvest, plants did not exhibit injury symptoms until 14 days after treatment (DAT) (Table 1). However, by 21 DAT, plants were almost completely killed with RT 3. Plants treated with either Maestro 4EC + TriCor 75DF or Gramoxone SL 2.0, exhibited injury symptoms 7 DAT (Table 1). By the last rating date, Gramoxone SL 2.0 provided better Russian-thistle control than Maestro 4EC + TriCor 75DF, but neither of these treatments provided the level of control that RT 3 did.

The Maestro 4EC + TriCor 75DF and Gramoxone SL 2.0 provided quick activity on Russian-thistle when they were applied 14 or 21 days after harvest (Table 1), which was similar to what they did when applied 7 days after harvest (Table 1). RT 3 applied two or three weeks after harvest acted more slowly than when it was applied one week after harvest, and by the last rating date, control with RT 3 was not greater than with the other herbicide treatments (Table 1). These results suggest that glyphosate should be applied within a week after harvest, before plant growth slows as a result of drought stress. However, contact herbicides such as Gramoxone SL 2.0 and Maestro 4EC + TriCor 75DF worked better when applied two and three weeks after harvest, when drought stress likely limited regrowth. We plan to repeat this trial in 2021.

Table 1. Evaluation of Herbicides to Control Russian-thistle Postharvest at the Lind Dryland Research Station, 2020.

		Treatments were applied 1 week after harvest (8/4)					
		8/11	8/18	8/25	8/31	9/9	9/17
Treatment	Rate	----------------Russian-thistle control-------------------					
	fl oz/A	----------------------------%-----------------------------					
Maestro® 4EC + TriCor® DF	16 + 10.67 oz	85 b[1]	86 a	89 b	79 c	75 c	74 c
RT 3® + AMS	64 + 17 lb/100 gal	0 c	75 a	99 a	100 a	100 a	100 a
Gramoxone® SL 2.0	48 + 0.125% v/v	91 a	85 a	91 b	86 b	94 b	91 b
		Treatments were applied 2 weeks after harvest (8/11)					
Maestro® 4EC + TriCor® DF	16 + 10.67 oz	--	76 b	91 a	84 b	83 a	80 a
RT 3® + AMS	64 + 17 lb/100 gal	--	0 c	15 b	45 c	90 a	95 a
Gramoxone® SL 2.0	48 + 0.125% v/v	--	94a	98 a	95 a	95 a	95 a
		Treatments were applied 3 weeks after harvest (8/18)					
Maestro® 4EC + TriCor® DF	16 + 10.67 oz	--	--	91 a	84 b	83 a	80 a
RT 3® + AMS	64 + 17 lb/100 gal	--	--	15 b	45 c	90 a	95 a
Gramoxone® SL 2.0	48 + 0.125% v/v	--	--	98 a	95 a	95 a	95 a

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.

Cereal Rust Management and Research in 2020

X.M. CHEN[1,2], K.C. EVANS[1], M.N. WANG[2], J. SPROTT[1], Q. BAI[2], L. LIU[2], Y.X. LI[2], J.M. MU[2], AND A.M. KUDSK
[1]USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT; [2]DEPT. OF PLANT PATHOLOGY, WSU

In 2020, wheat stripe rust was accurately forecasted at severe levels for the eastern Pacific Northwest (PNW) using our prediction models and monitored in fields throughout the crop season. Rust updates and advises were provided in a timely manner to growers based on the forecasts and field surveys. In our experimental fields under the natural infection of the stripe rust pathogen, yield losses of 62.4 bushels per acre (48.6 percent) were observed on the susceptible check and 1.2-52.4 bushels per acre (0.7-35.7 percent) with an average of 17.4 bushels per acre (11.6 percent) on commercial varieties of winter wheat; and of 93.9 bushels per acre (83.8 percent) on the susceptible check and 0-62.8 bushels per acre (0-57.7 percent) with an average of 11.9 bushels per acre (10.7 percent) on commercial varieties of spring wheat without fungicide application. Fungicide application increased grain yield by 14.3 percent on winter wheat and 13.1 percent on spring wheat of commercial varieties on average. Timely application of fungicides in commercial wheat fields prevented yield loss of more than 20 million bushels, worthying more than $100 million in Washington state alone. Nationally, wheat stripe rust occurred in 17 states in 2020. Barley stripe rust occurred in California, Oregon, Idaho, and Washington. In Washington, barley stripe rust was severe in western Washington, but low in eastern Washington. In 2020, leaf rusts of wheat and barley occurred in our experimental fields in western Washington, but rarely found in eastern Washington. Stem rust of wheat and barley was found in experimental fields in Pullman with some germplasm lines had severe levels. From stripe rust samples collected throughout the country, we identified 19 races (including 2 new races) of the wheat stripe rust pathogen and 10 races (including 1 new race) of the barley stripe rust pathogen. In Washington state alone, all 19 races of the wheat stripe rust pathogen and 8 races (including the new one) of the barley stripe rust pathogen were detected. We characterized the US stripe rust collections from 2010 to 2017 using 14 SSR markers. From 2,414 isolates, we identified 1,599 multi-locus genotypes and studied the genetic diversity and population differentiation. The results improve the understanding of stripe rust epidemiology and spore movement among different regions in the US. We completed a study of whole genome sequencing for a sexual population of the wheat stripe rust pathogen and identified candidate genes for avirulence. Using the gene sequences, we are developing virulence-specific markers for monitoring race changes in the pathogen population. We evaluated more than 25,000 wheat, barley, and triticale entries for resistance to stripe rust in fields and about 3,000 of them also in the greenhouse and provided the data to breeding and other related programs. We collaborated with breeders in pre-releasing, releasing, and registering 19 wheat and 1 barley varieties. The germplasm evaluation data were also used to update the Seed-Buying Guide for growers to choose resistant varieties to grow. We completed genome-wide association studies and mapped 37 genes in a spring wheat panel and 51 genes in a winter panel for stripe rust resistance. These results provide information on which genes are effective and used in breeding programs in various regions in the US, especially the Pacific Northwest. The resistance genes and their markers are useful in breeding stripe rust resistant wheat varieties. We tested 19 fungicide treatments in fields for control of stripe rust on both winter and spring wheat and tested 24 winter and 24 spring wheat varieties for their yield loss and fungicide response. The data of the fungicides and varieties are used for guiding the integrated control of stripe rust.

Part 2. Breeding, Genetic Improvement, and Variety Evaluation

Washington State University Extension Cereal Variety Testing Program

CLARK NEELY[1], BRANDON GERRISH[2], AND ANDREW HORTON[2]
[1]WSU EXTENSION; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

The WSU Extension Cereal Variety Testing Program conducts variety trials at 31 physical locations throughout eastern Washington. In total, the program conducts 24 soft white winter, 18 hard winter, 18 soft white spring, and 20 hard spring wheat trials in addition to 12 spring barley trials. Four 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.

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 dryland precipitation zones, plus irrigated sites, and span from the Highway 2 corridor in the north to the Walla Walla Valley in the south in order to capture the diverse climates found in the state.

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. In-person field days will resume in 2021, however "Virtual" field days will again be recorded at select locations and posted on the College of Agriculture, Human, and Natural Resources YouTube Channel (https://www.youtube.com/user/WSUCAHNRS/).

Clientele can also utilize the "Variety Selection Tool" at https://varietyselection.cahnrs.wsu.edu/ or utilize the new mobile app version of this tool (search for 'WSU Variety Selection' in the app store). Once the class of wheat and precipitation zone have been selected, this interactive tool allows users to sort and select varieties based on multiple traits and thresholds in order to find a variety that meets their needs. Data provided on the tool includes two- and three-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 and physical copies are mounted on signs at each location in the spring.

Three Soft White Winter Wheat Cultivars -- VI Shock, VI Voodoo CL+, and VI Presto CL+

YUEGUANG WANG[1] AND JAY KALOUS[2]
[1]DEPT. OF PLANT SCIENCES, UI; [2]LIMAGRAIN CEREAL SEEDS

In 2020, the three common soft white winter wheat (SWWW) cultivars VI Shock, VI Voodoo CL+ and VI Presto CL+ were co-released by the University of Idaho (UI) and Limagrain Cereal Seeds (LCS). The Double Haploid (DH) breeding method was used in developing these three varieties.

VI Shock (UIL15-72223) is a common SWWW (*Triticum aestivum* L.) cultivar. It was derived from the cross of "01-10704A/99-06202A", which was made in 2013 by UI. 01-10704A and 99-06202A were UI advanced breeding lines. It has awned heads. Its plants are blue-green at boot stage. VI Shock is well-adapted to the irrigated production areas of southern Idaho. It is released for its high yield potential, high test weight, excellent stripe rust resistance, high flour yield, high break flour yield, and excellent end-use quality. It is released specifically for southern Idaho irrigated acres and is a promising replacement for SY Assure and SY Ovation.

VI Voodoo CL+ (UIL17-6268 CL+) is a 2-gene Clearfield SWWW (*T. aestivum* L.) cultivar. It is derived from the cross 'LCS Artdeco/UI Magic CL+', which was made in 2013 by LCS. It has awned heads. Its plants are gray-blue at boot stage. It is best adapted to intermediate to high rainfall conditions and areas where LCS Artdeco has performed well. VI Voodoo CL+ has high yield potential. Its yield is higher than UI Magic CL+. However, it is slightly lower in test weight as compared to UI Magic CL+ in dryland conditions. VI Voodoo CL+ is 1-2 days later in heading and 1-2 cm shorter than Magic CL+ and has superior resistance to stripe rust. It is susceptible to Cephalosporium stripe, similar to the variety Stephens. It has superior end-use quality as compared with UI Magic CL+, in terms of break flour yield and cookie diameter.

VI Presto CL+ (UIL17-6451 CL+) is a 2-gene Clearfield SWWW (*T. aestivum* L.) cultivar. It is derived from the cross 'UI Palouse CL+/Norwest Duet', which was made in 2013 by LCS. It has awned heads. Its plants are gray-blue at boot stage. It is adapted to lower rainfall areas of southeastern Washington and Oregon, including drier areas of the Palouse, as is suggested by its parentage. VI Presto CL+ has shown higher yield potential, higher test weight, and improved stripe rust resistance when compared to UI Magic CL+. It has taller plant height and is photoperiod insensitive, suggesting it is better for later, dryland seedings. It has shown MS/MR response to Cephalosporium stripe, similar to the variety Madsen. End-use quality is similar to UI Magic CL+ in terms of break flour yield and cookie diameter.

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 Elite Yield Trial or OWEYT; the Hard Winter Elite Yield Trial or HWEYT; the Oregon Soft Spring Elite Yield Trial or OSSYT; and the Oregon Hard Spring Elite Yield Trials or OHSYT) while barley varieties are evaluated in two trials (the Oregon Spring Barley Variety Trial or OSBVT and the Oregon Winter Barley Variety Trial or OWBVT). 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://agsci.oregonstate.edu/wheat/osu-wheat-variety-trials, so that variety testing data may 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 build an understanding of their performance before they are released.

The Washington State University Winter Wheat Breeding and Genetics Program Update

A. CARTER, K. BALOW, A. BURKE, K. HAGEMEYER, G. SHELTON, A. STOWE, AND J. WORAPONG
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 for release to maintain sustainability of production. We use tools such as genomic selection and high-throughput phenotyping to accomplish this task and are excited about the breeding lines under evaluation and their release potential. About 200 populations each year are selected with molecular markers for important genes for disease resistance and end-use quality. Genomic selection efforts, which use the entire genome instead of one or two markers, have recently included models for traits such as snow mold, stripe rust, and emergence. Collaboratively with the Spring Wheat and USDA Wheat breeding programs, and groups in Biological Systems Engineering and Statistical Genomics, we are expanding our systems of high-throughput phenotyping, looking for ways we can use data collected for indirect predictions of breeding line performance. In collaboration with the Weed Science program, we are expanding our efforts to develop herbicide tolerance in winter wheat to benefit the growers of the state, as well as finding ways to make the wheat plant more competitive with weeds. Selection under field conditions continues for emergence from deep planting, grain yield and other agronomic characteristics, end-use quality, tolerance to low pH soils and cold temperatures, and diseases such as stripe rust, snow mold, eyespot foot rot, Cephalosporium, stripe, SBWMV, Fusarium crown rot, nematodes, Hessian fly, and many more too numerous to list! 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.

Figure 1. Breeding plots near Pullman, WA.

Figure 2. Breeding line showing high yield potential.

Releases from the WSU winter wheat program include **Otto**, **Puma**, **Jasper**, **Purl, Sequoia, Earl,** and **Sprinter**. We also participated in the collaborative release of **Curiosity CL+**, **Mela CL+**, **Resilience CL+**, **ARS-Pritchett,** and **ARS-Castella**. Lines released are well adapted for production in Washington and the Pacific Northwest, are high yielding, have good test weight, good cold tolerance, and have a combination of tolerance/resistance to stripe rust, eyespot foot rot, snow mold, nematodes, and low pH soils as needed. Recent released include the following:

Stingray CL+ which is a two-gene imazamox resistant line broadly adapted to both Washington and Oregon. It has high -yielding in many trials it has been in when compared to other two-gene lines. It has good stripe rust resistance, eyespot resistance, and cold tolerance.

Piranha CL+ is a soft white winter wheat with two-gene resistance to imazamox. This line is broadly adapted to many rainfall zones of Washington and does particularly well in the higher stress environments. Piranha CL+ has high grain yield potential, high test weight, stiff straw, and very good end-use quality. It has tolerance to cold temperatures, snow mold, eyespot, and resistance to stripe rust.

Sockeye CL+ is a soft white winter wheat with two-gene resistance to imazamox. This line is broadly adapted to many rainfall zones of Washington and does particularly well in the intermediate and high production environments. Sockeye CL+ has very high grain yield potential, high test weight, stiff straw, and excellent end-use quality. It has tolerance to cold temperatures, snow mold, eyespot, and resistance to stripe rust.

Devote is a soft white winter wheat with excellent yield potential in the less than 12-inch rainfall zones, where it has excellent emergence from deep planting. It has high test weight, excellent tolerance to snow mold and cold temperatures, stripe rust resistance, eyespot resistance, and Fusarium crown rot resistance.

Scorpio is a hard red winter wheat developed for the intermediate and high rainfall areas targeted to replace Keldin and LCS Jet. It has high yield potential and maintains a high grain protein content even with that high yield. It has stiff straw that withstands lodging, stripe rust resistance, cold tolerance, and very good end-use quality attributes. It has tolerance to Hessian fly and to low pH soil conditions, making it an ideal cultivar for conventional and no-till planting applications.

There are many additional lines in the 2021 Variety Testing program to watch. WA8290 and WA8307 are two soft white lines which have been in the trial for a couple of years and have been performing very well. New soft white and hard red lines have also been added which have performed well in the breeding program and are being evaluated for final release. 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.

Figure 3. New SWW release Devote near Waterville, WA after severe snow mold, amongst other lines within the WSU Variety Testing trials. Devote was a standout here with very good tolerance to snow mold.

USDA-ARS Club Wheat Breeding: Are you in the Club?

KIM GARLAND-CAMPBELL[1], PATRICIA DEMACON[2], EMILY KLARQUIST[2], NUAN WEN[2], BRIAN BELLINGER[1], NIKAYLA STRAUSS[2], CASSIDY SHAMSELDIN[2], AND AICHA DJIBO WAZIR[2]
[1]USDA-ARS; [2]WASHINGTON STATE UNIVERSITY

The focus of the USDA breeding program is to develop high quality club wheat and soft white cultivars, and to incorporate germplasm for disease resistance into adapted wheat germplasm. The breeding program has yield trials in 12 locations across eastern Washington, Idaho, and Oregon that allow us to test our cultivars in a variety of different climates and disease nurseries so we can release high-performing varieties adapted to specific PNW climates. Several of these trials are planted as collaborations with the WSU Winter Wheat and the Washington Cereal Grain Variety testing programs.

The top goals for 2021-2022 are to; 1) to develop earlier maturing club wheat varieties with better emergence and snow mold tolerance 2) utilize new freeze test chambers to increase cold tolerance screening in the greenhouse; 3) increase the size of our early generation populations through 'mini-bulking'; 4) screen our club

ARS09X492-6CBW at Spillman Farm 2020.

material in the field and greenhouse for resistance to Beyond®; 5) identify novel sources of Fusarium and stripe rust resistance from synthetic wheat and selected landraces, respectively ; 6) implement greenhouse screening for stem rust; 7) develop knowledge of resistance against the PNW local cereal cyst nematode (*Heterodera filipjevi* and *H. avenae*) species and pathotypes using previously identified resistant wheat lines; 8) screen segregating populations for aluminum tolerance.

We evaluate cultivars and breeding lines for cold tolerance using freezing trials conducted at the WSU Plant Growth Facility. Data is provided to the WSU Cereal Variety Testing program, and regional winter wheat breeders. A new technique from a rapid breeding method known as 'mini-bulking' will allow us to rapidly advance early generation nurseries and get them to the field sooner. This allows us to reduce the breeding time it takes for variety release. We currently have new populations with two-gene resistance to Beyond® herbicide in the field. Several of these populations are also segregating for snow mold resistance. We are continually screening the Western Regionals, Variety Trials, and our own breeding nurseries for resistance to stripe rust. As of this year, we are now screening both the winter and spring variety trials for Fusarium resistance in the greenhouse using an updated protocol developed by PhD candidate, Nikayla Strauss. Stem rust has been present in winter wheat in the field in 2019 and 2020, so we are initiating seeding and field resistance screening for this disease in collaboration with the Bruggeman lab. We have initiated a collaboration with the Schroder Lab at the Univ. of Idaho to evaluate early populations for tolerance to toxic levels of exchangeable aluminum.

The field crew snapping heads at Central Ferry in August 2020.

ARS09X492-6CBW is the latest variety to be released by the USDA-ARS. It has combined seedling and adult plant resistance to stripe rust, it carries the PCH1 gene for resistance to eyespot, and has excellent club wheat quality. The performance of ARS09X492 is superior to other club wheat cultivars in the high rainfall region, especially on the Palouse. It is targeted to replace Cara and Coda on the Palouse. ARS09X492-6CBW is on breeder seed increase in Othello.

Breeding with Major and Minor Genes: Genomic Selection for Stripe Rust Resistance

LANCE F. MERRICK[1], ADRIENNE B. BURKE[1], XIANMING CHEN[2], AND ARRON H. CARTER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS WHEAT HEALTH, GENETICS AND QUALITY RESEARCH UNIT AND DEPT. OF PLANT PATHOLOGY, WSU

Stripe rust is one of the most damaging wheat diseases and has resulted in a massive reduction in yield and economic losses globally. Stripe rust is usually screened for two disease traits, infection type and disease severity. Stripe rust resistance is categorized into single gene all-stage resistance (ASR) and multi-gene adult-plant resistance (APR). APR is detected in adult plants, associated with resistance usually to all stripe rust races, and considered a durable form of resistance controlled by many minor effect genes. ASR is conferred by race-specific major effect genes that only have a life span of around 3.5 years per gene. Most disease resistance in plants is multi-gene, meaning both major and minor genes control resistance. It is recommended to combine both ASR and APR genes by taking advantage of both types of resistance and overcoming their limitations. The lack of ASR durability coupled with the challenge in identifying and breeding APR creates a unique opportunity for genomic selection. Genomic selection (GS) allows us to create a statistical model using past trait data to predict future breeding lines using genetic data. In addition, accounting for major genes for ASR in our models can increase prediction accuracy. This research aimed to compare GS models in breeding programs needing to select for both major and minor genes for resistance.

We used many breeding lines with both phenotypic data for APR and genetic data to develop our GS models. These groups of breeding lines are called training populations. The training population was composed of 2,630 breeding lines screened in four years (2016-2020) in two locations. The models used genetic data called genotype-by-sequencing single -nucleotide polymorphism markers, which allow us to collect many genetic markers to account for all of the genes that control APR. We also used four DNA markers for resistance genes, *Yr10*, *Yr17*, *Lr68*, and *IWB12603*. These markers are the most common disease resistance genes in our germplasm and allow us to account for this resistance in our genomic selection model. We then compared the use of the major markers to a base model called rrBLUP in individual and across years.

The base GS model had a high accuracy of 0.65 within 2018 and 2020 for infection type and 0.68 within 2018 for disease severity. The accuracy of our models is a measure of the genomic selection model to predict the phenotypic observation of a breeding line and ranges from 0 to 1, with 1 being a perfect prediction. The major markers' effects varied from year to year, but only a had small increase in prediction accuracy. The largest differences within a single year were seen in 2016 for the GS models (Fig. 1). Within 2016, both *Yr10* and *Yr17* increased accuracy with the combination of markers increasing accuracy by 0.06 for disease severity. Only *Yr17* and the combination of markers slightly increased accuracy across environments with an increase in infection type of 0.01 (Fig. 2). Our results indicate that GS can accurately predict multi-gene disease resistance in the presence of major and minor genes. This allows us to still make selections and progress based on the genetic information of the lines, even when we do not have the actual disease present to make those selections. The breeding lines selected will have a more durable stripe rust resistance that will have a better ability to exhibit resistance even with new races of the stripe rust pathogen from year to year.

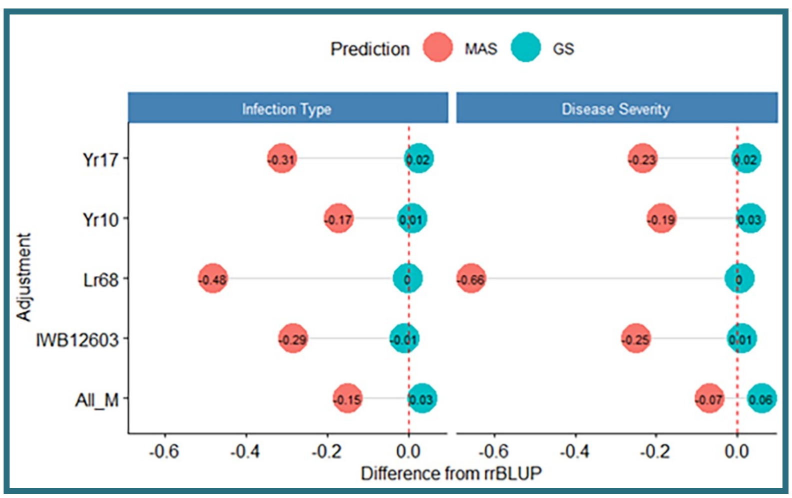


Figure 1. Change in accuracy from the base rrBLUP model for major markers in genomic selection (GS) and marker-assisted selection (MAS) in the breeding lines in 2016. Adjustments: ALL_M: IWB12603, Lr68, Yr10, and Yr17 combined.

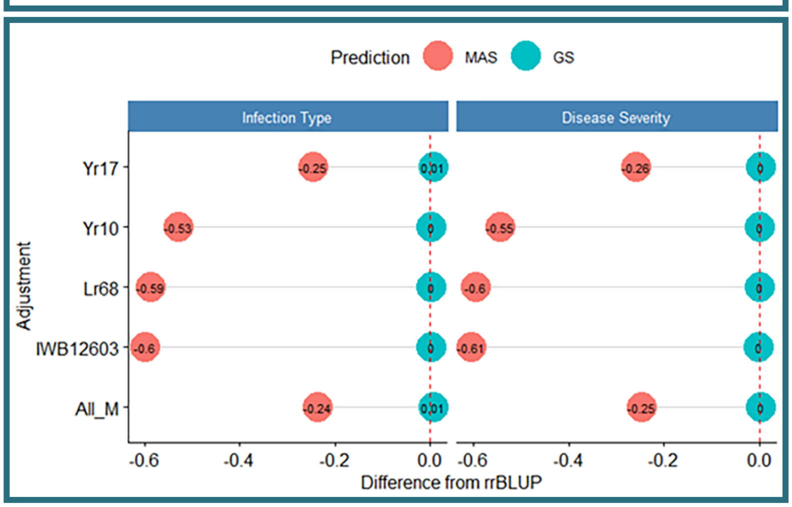


Figure 2. Change in accuracy from the base rrBLUP model for major markers genomic selection (GS) and marker-assisted selection (MAS) in the breeding lines across 2016-2020. Adjustments: ALL_M: IWB12603, Lr68, Yr10, and Yr17 combined.

Genomic Regions Controlling Wheat Coleoptile Length and Seedling Emergence

ALEX BLACKBURN, GAGANJOT SIDHU, BILL SCHILLINGER, AND KULVINDER GILL
DEPT. OF CROP AND SOIL SCIENCES, WSU

Seedling emergence (SE) is an essential trait in wheat that allows desirable stand establishment even when adequate seed-zone soil moisture is present at depths of four inches or greater. The SE trait bestows several other advantages, including lodging resistance and improved water use efficiency. The aim of this study was to understand the genetic basis of SE. It has previously been reported that the wheat variety *Spinkcota* has a high rate of SE and *Bounty 309* has a slow rate of SE. An F_2 population of 190 plants from a cross between these two parents was developed and evaluated for coleoptile length (CL) and in a specialized field SE test conducted at Lind, WA. The population was genotyped by simple sequence repeat (SSR) and genotyping-by-sequencing (GBS) for genetic mapping and marker discovery of the two traits. The GBS analysis was performed using 128,848,348 sequence reads with an average of 671,085 per F_2 plant. From a total of 2,639 raw SNPs discovered in the F2 population, 243 high-quality SNPs along with 68 SSR markers were utilized to construct a genetic linkage map of wheat spanning 5,532.9 cM on the 21 chromosomes. Using this map, eight QTLs linked to CL and SE were detected on chromosomes 1A, 1B, 2B, 3A, and 7D. Bioinformatic dissection of the intervals under these QTLs on the wheat whole-genome sequence led to the identification of ~ 60 genes. Validated markers may enhance the understanding of this critical trait and provide a basis for marker-assisted selection.

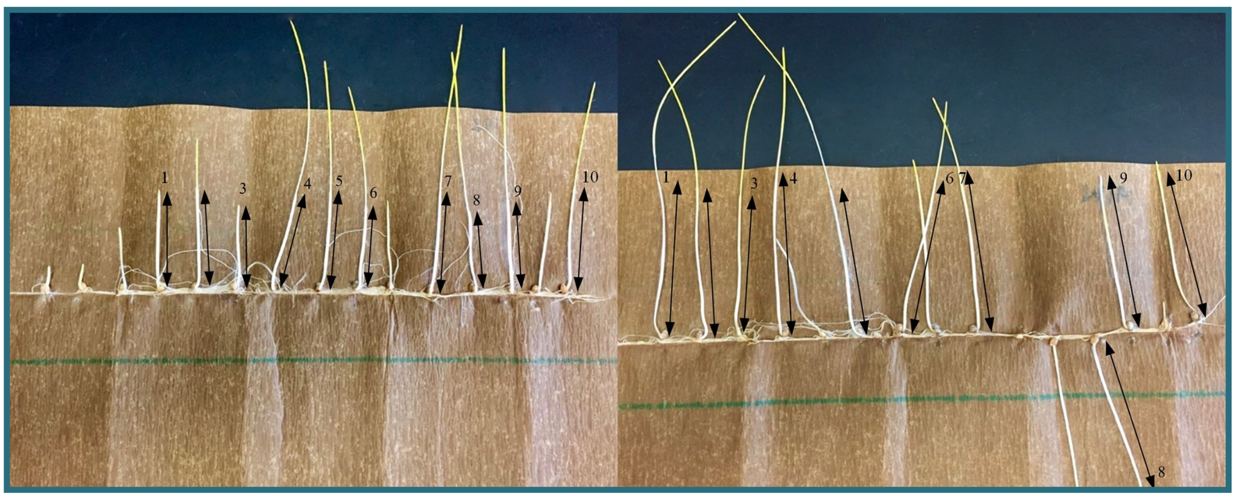


Figure 1. Coleoptiles of Bounty 209 and Spinkcota on day10 of the laboratory experiment. Lines with double arrows represent the height of the coleoptile measured and the numbers (1-10) represent the number of plants.

Potential of Deep Learning for Predicting Complex Traits in Wheat Breeding Programs

KARANSHER SANDHU, ZHIWU ZHANG, MICHAEL PUMPHREY, AND ARRON CARTER
DEPT. OF CROP AND SOIL SCIENCES, WSU

Plant breeders are rapidly adopting genomic selection (GS) to predict genomic estimated breeding values (GEBVs) using genome-wide markers. GS uses the previous year's phenotypic and genotypic data to train models to predict the performance of new line. GS is transforming plant breeding, and implementing models that improve prediction accuracy for complex traits is needed. Analytical methods traditionally used in other disciplines for complex datasets represent an opportunity for improving prediction accuracy in plant breeding. Machine and deep learning have come as an alternative to traditional statistical methods. Deep learning (DL) is a branch of machine learning focusing on densely connected networks using artificial neural networks for prediction. The concept of DL is based on biological networks of brain neurons. DL uses a different combination of layers where data is transformed across each layer to obtain better accuracy. DL employs multiple neurons with proposed models such as multilayer perceptron (MLP), recurrent neural network (RNN), and convolutional neural network (CNN) and has the potential for application in plant breeding. Implementation of DL algorithms is straightforward, but the optimum model performance depends on hyperparameter selection, which is not trivial and computationally intensive. This study aimed to optimize the DL models for predicting five different complex traits in the wheat breeding programs and compared their performances with the traditional ridge regression best linear unbiased predictor (rrBLUP) model.

To assess DL models potential in the wheat breeding program, phenotypic data for five agronomic traits were collected from 650 recombinant inbred lines (RILs) of wheat grown for three years (2014-16) at Spillman Agronomy Farm, Pullman, WA. These five agronomic traits were grain yield, grain protein content, test weight, days to heading, and plant height. The whole population was genotyped using genotyping by sequencing and a 90 K SNP chip; after running different filtering pipelines, we were left with 40,005 polymorphic markers for GS. We explored two DL models, namely MLP and CNN. Different hyperparameters, including activation function, solver, number of hidden layers, number of neurons, filter size, learning rate, and regularization, were optimized for both models using grid search cross-validation function. The best hyperparameters were selected that gave the least mean square error on the inner testing population; later, these parameters were used for the individual traits. Model performances were assessed using five-fold cross-validation, where 80% of the data was used for model training, and the remaining 20% of the data was used for model testing. Model performances were assessed as the Pearson correlation coefficient between the actual phenotypic value and predicted GEBVs.

We observed that DL models gave 0-5% higher prediction accuracy than rrBLUP for all five traits evaluated in this study (Fig. 1). Overall, MLP performed best, followed by CNN, due to the ability to deal better with one-dimensional data. The highest improvement in prediction accuracy with DL models was observed for grain yield and grain protein content, demonstrating their superiority over rrBLUP to predict quantitative traits. This study showed the potential of using the DL model in the breeding program and suggested that these should be explored on bigger datasets for multiple traits. Higher accuracies observed in this study could aid the breeding program to use the historical datasets of wheat with weather parameters to predict the performance of wheat varieties across different locations and environments. This will ultimately help shorten the time required to release a variety and cut the cost required to perform multi-location and multi-environment trials before releasing a variety to the farmers.

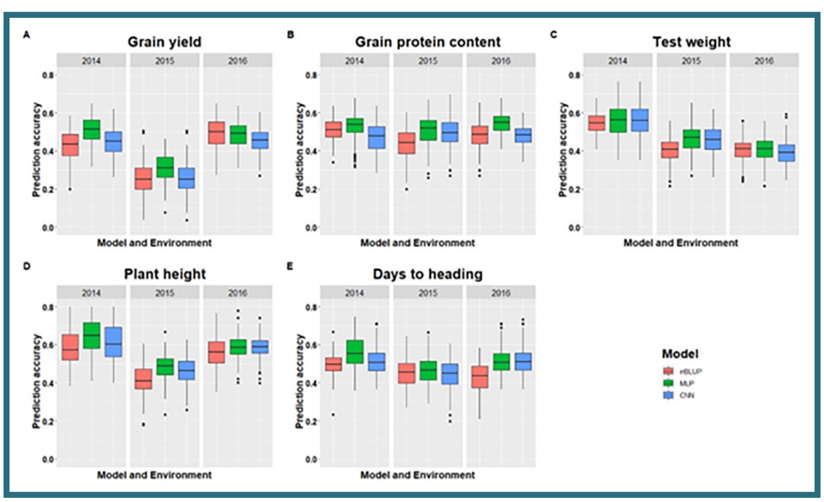


Figure 1. Comparison of model performance for five different traits used in this study. Figure A, B, C, D, and E represents the model's performance for grain yield, grain protein content, test weight, plant height, and days to heading, for each trait under each environment using fivefold cross-validation and 40,005 SNP markers. The x-axis represents the environment, and the y-axis represents the prediction accuracy for the model.

Determining Genomic Regions Associated with Snow Mold Tolerance in a Winter Wheat Landrace

SAVANNAH PHIPPS[1], TIMOTHY MURRAY[2], AND ARRON CARTER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]DEPT. OF PLANT PATHOLOGY, WSU

Improving snow mold tolerance in Washington winter wheat varieties has proven challenging as there are multiple genes with each one playing small roles in contributing to this trait. Due to this complexity, there has been an increased effort to understand the genetics behind snow mold tolerance as this information can be utilized to improve the efficiency of selecting for snow mold tolerant lines and reduce the time it takes to release a variety using modern breeding techniques. There was additional interest in finding sources such as landraces or wheat relatives that possess new genes for snow mold tolerance that were not already present in released varieties. The landrace wheat PI173438 is a hard red wheat originating from Turkey and has been observed to have excellent snow mold tolerance making it an ideal candidate for this research and is subsequently being assessed for novel genetics related to snow mold tolerance.

Figure 1. Dark colored sclerotia of speckled snow mold on wheat leaves induced by Typhula spp. Photo by Savannah Phipps.

To investigate the presence of such genes, three double haploid populations were developed from a cross between PI173438 and three snow mold susceptible winter wheat varieties adapted to the PNW. These populations were then scored for snow mold tolerance and snow mold recovery in Waterville and Mansfield, WA in the 2017 and 2018 growing seasons. Genetic information on one of the populations, PI173438/WA8137, was gathered through a genotype-by-sequencing analysis pipeline developed by the USDA. The genetic data was used to construct linkage maps in which we were able to establish distances between each of the molecular markers from the prior analysis and their order. The field, genetic, and map information gathered on PI173438/WA8137 was then used to analyze and identify genomic regions associated with snow mold tolerance.

Figure 2. Photo of a PI173438/WA8137 progeny line and its parents in the field, four weeks after snow melt. From left to right, PI173438, WA8137, and a PI173438/WA8137 progeny line. Photo by Timothy Murray.

The results of this analysis thus far suggest that PI173438 does appear to have genomic regions associated with snow mold tolerance and recovery traits. There were six tentative genes found, of which five were contributed by PI173438. Currently, these initial results are being validated in the other two populations to confirm that these genes are truly present in this landrace and that they can be tracked reliably in future breeding efforts.

The USDA-ARS Western Wheat Quality Laboratory

CRAIG F. MORRIS[1], ALECIA M. KISZONAS[2], AND DOUGLAS A. ENGLE[2]
[1]USDA-ARS WESTERN WHEAT QUALITY LABORATORY; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

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' wheat, arabinoxylans, puroindolines, polyphenol oxidase (PPO), and waxy wheat. Our recent publications include a review of the Poeae and Triticeae indolines and a suggested system for harmonization of nomenclature published in the Journal of Cereal Science. Research on soft durum wheat as a potential ingredient for direct expanded extruded products was published in the Journal of Cereal Science. An 18-year retrospective on sponge cake baking quality was published in Cereal Chemistry. The roller milling performance of dry yellow split peas: mill stream composition and functional characteristics was published in Cereal Chemistry. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Scorpio, Devote, Stingray CL+, Resilience CL+, ARS-Crescent, Castella, and USDA Lori.

Genomic Selection of Seedling Emergence in a Wheat Breeding Program

LANCE F. MERRICK AND ARRON H. CARTER
DEPT. OF CROP AND SOIL SCIENCES, WSU

In low-precipitation dryland areas, fast-emerging varieties from deep planting are most desirable because rain events before emergence create soil crusting and decrease seedling emergence. Seedling emergence is a vital factor affecting stand establishment and grain yield and has a poorly understood genetic architecture, which presents a unique opportunity for genomic selection. Genomic selection allows us to create a statistical model using past trait data to predict performance of future breeding lines using genetic data. Seedling emergence relies on environmental influences such as soil moisture, deep planting, and soil crusting, to create differences in breeding lines for selection purposes. Since these conditions are not present every year at our field screening sites, some years we cannot get good screening for emergence. Using genomic selection to predict and select breeding lines is helpful in years when field observations (called phenotypes) or adequate screening conditions are not possible. The goal of this research is to compare genomic selection models to predict and identify breeding lines with better seedling emergence in our winter wheat breeding program.

In order to create a genomic selection model, we need to use many breeding lines with both phenotypic data for seedling emergence and genetic data. These groups of breeding lines are called training populations. We used two training populations, one consisting of 473 varieties from a diverse quality association mapping panel consisting of varieties from various breeding programs and screened from 2015-2019. The other training population consists of 643 breeding lines from the Washington State University breeding program from the years in 2015 and 2020. The different populations will be used to compare the diversity panel to the breeding lines for prediction purposes, and to compare whether it would be beneficial to grow independent populations outside of the breeding program for genomic selection purposes. The models use genetic data called genotype-by-sequencing single-nucleotide polymorphism markers, which allow us to collect a large number of genetic markers to account for all of the genes that control seedling emergence.

The accuracy of our models is a measure of the genomic selection model to predict the phenotypic observation of a breeding line and ranges from 0 to 1, with 1 being a perfect prediction. Our results showed that the prediction model with the highest accuracy was a machine learning model that accounts for both genetic and non-genetic factors in breeding lines and reached an accuracy of 0.56. Figure 1 shows the results in the diversity panel, which reached an

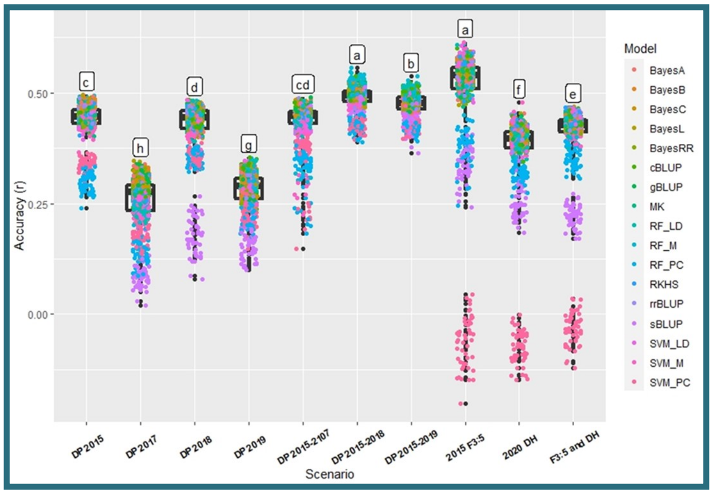


Figure 1. Comparison of accuracy and pairwise comparisons between cross-validation scenarios across all genomic selection models for deep-sowing seedling emergence for Pacific Northwest winter wheat diversity panel lines and breeding lines phenotyped across 2015 to 2020 in Lind, WA. Models labeled with the same letter are not significantly different (P-value =0.05).

accuracy of 0.43 in a single year and 0.49 across multiple years across all models. Within the breeding lines, the accuracy reached a high of 0.49 in a single year and 0.39 across years for all models.

Overall, predicting seedling emergence in a single year can be high or low, depending on the year we use. However, as we combine years, we gradually increase our accuracy and have a more consistent prediction. The moderate accuracy of the genomic selection models will aid breeders in identifying breeding lines with better seedling emergence in low rainfall environments and select seedling emergence even in years with little difference between breeding lines due to good field conditions. The breeding lines selected will show better seedling emergence and stand establishment, which will result in higher yield potential.

QTL Analysis and Mapping of Preharvest Sprouting Resistance in a Biparental Population

JASON WIGEN[1], ARRON CARTER[1], AND CAMILLE M. STEBER[1,2]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS, WHEAT HEALTH, GENETICS AND QUALITY UNIT, PULLMAN

Preharvest sprouting (PHS) is the germination of grain on the mother plant prior to harvest. PHS is one of the causes of low falling numbers, of poor end-use quality in the grain. Preharvest sprouting has the potential to cost farmers in the Pacific Northwest (PNW) millions of dollars due to price dockages due to the low falling numbers associated with PHS. In recent studies of PNW winter wheat, we mapped increased PHS resistance to chromosome 2D (Martinez et al., 2018; Sjoberg, 2020). This QTL is associated with the gene responsible for the club head type (Fig. 1). A biparental population of 130 individuals with the two parents having the club head type (Cara) and lax head type (Xerpha) is being used to explore whether PHS tolerance comes from the club gene itself or from a neighboring gene. If it is the club gene itself, then we will expect PHS tolerance to be associated club head type in spike-wetting tests. Spike wetting test consists of misting wheat spikes for 6 seconds every minute for 24 hours for 7 days. Ever 24 hours, the spikes are scored for visible signs of sprouting on a scale of 1-10 (Fig. 2). Germination assays should detect PHS tolerance resulting from grain dormancy rather than spike shape. So PHS tolerance from a gene near the club gene might give lower germination rates on a petri dish. Data from the 2019 and 2020 field season have been collected and a third year of data collection for 2021 will be done. Correlations between germination assays and spike wetting tests from the 2019 and 2020 data show correlations of 0.45 and 0.31, respectively. While weak, these correlations show a relatedness between the two tests. The QTL analysis will help better determine the underlying reason for the increased resistance to PHS in club wheat. PHS can be devastating to the value of the wheat crop in the Pacific

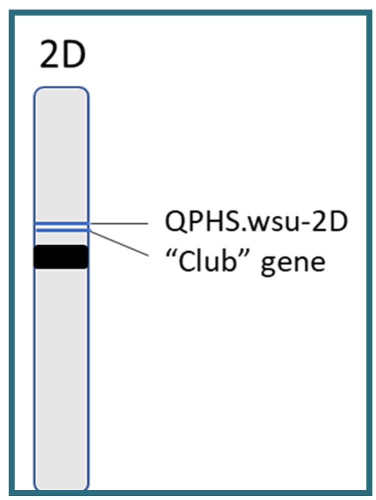


Figure 1. Illustrates the relative locations of QPHS.wsu-2D, found to be associated with PHS resistance in prior studies, and the "Club" gene, the gene responsible for the club head phenotype.

Northwest and it is important to further explore the genetics of why it happens. Better understanding can better equip breeders to continue to incorporate PHS resistance into new varieties.

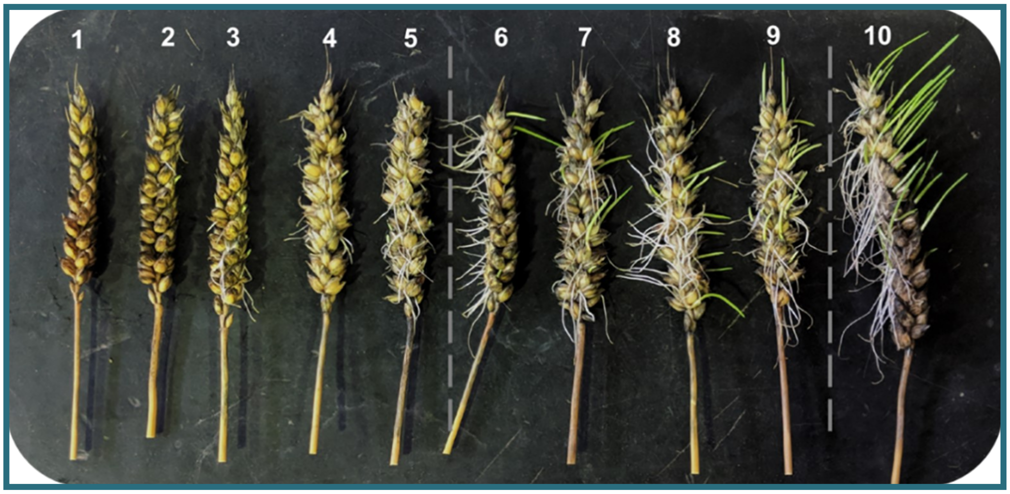


Figure 2. Scoring scale for Spike wetting tests. 1 – No visible spouting, 2-5 – Radicle emergence/elongation, 6-9 – Coleoptile emergence/elongation, 10 – First leaf emerges.

Deciphering Genetic Architecture of Grain Protein Content Stability Using Nested Association Mapping Population of Wheat

KARANSHER SANDHU, MICHAEL PUMPHREY, AND ARRON CARTER
DEPT. OF CROP AND SOIL SCIENCES, WSU

Grain protein content (GPC) is an important end-use quality determinant of hard red spring wheat (*Triticum aestivum* L.). GPC is controlled by a complex genetic system and is strongly influenced by environmental factors, making it hard for selection by the breeders. Furthermore, a hindrance to increasing GPC in wheat is imposed by its negative correlation with grain yield, making it hard to improve both traits simultaneously in a wheat breeding program. Several studies have identified various small-effect genes which control GPC and demonstrate its complex nature. Previous studies suggested that it is hard to increase GPC using marker-assisted selection due to many small-effect genes and negative correlation with grain yield. Hence, we investigated breeding for GPC stability using a nested association mapping (NAM) population of spring wheat. NAM populations provide high statistical power and resolution for identifying genes that are rarely found in the breeding population. Genome-wide association studies have shown tremendous potential during the last decade for identifying genes in all crop species.

This study's NAM population consisted of 26 founder parents selected from different countries and were crossed the common parent 'Berkut' to generate a population of 650 recombinant inbred lines with 26 NAM families. For three years (2014-16), the whole population was planted at Spillman Agronomy Farm, Pullman, WA. GPC was indirectly estimated using near-infrared spectroscopy using the Perten DA analyzer. The standard deviation of GPC within the NAM families was used to select NAM families having less variation. Genotyping was performed using genotyping by sequencing and 90 K Illumina SNP chip assay. Genotyping data were filtered to remove monomorphic markers, markers with allele frequency less than 0.05, and markers missing more than 20%, and these procedures are required for removing the false positives in the results. Our aim was to identify the stability index of each line, demonstrating its performance for the next year. If a line is having a stability index of 0, it means the same amount of GPC will be observed for the next year;

however, values above and less than zero suggest that there will either increase or decrease in GPC for next year. The magnitude of each will depend upon the stability index value. We used Finlay Wilkinson regression analysis to calculate the stability index. Stability index and GPC information were used to perform the analysis for identifying genes controlling GPC stability and GPC.

The GPC varied from 11.2-18.0%, 8.7-16.8%, and 9.7-17.0% in 2014, 2015 and 2016 (Fig. 1). Environment 2015 had the lowest GPC, followed by 2016 and 2014. Broad sense heritability for GPC varied from 0.62 in 2014, 0.36 in 2015 and 0.68 in 2016. Seven families having 175 RILs were selected to obtain the stability index for utilization in the GWAS. Marker trait association for GPC stability and GPC was performed with bayesian information and linkage-disequilibrium iteratively nested keyway model using 175 RILs and 38,588 markers in R studio. We identified seven small effect genes controlling GPC stability and three controlling GPC in the selected NAM panel. Manhattan plots representing the positions for the identified association are provided in Figure 2 for both traits. We concluded that GPC and its stability are controlled by different gene regions and could be improved simultaneously in the breeding program. This study will help us release wheat varieties with higher and more stable GPC across the years and locations.

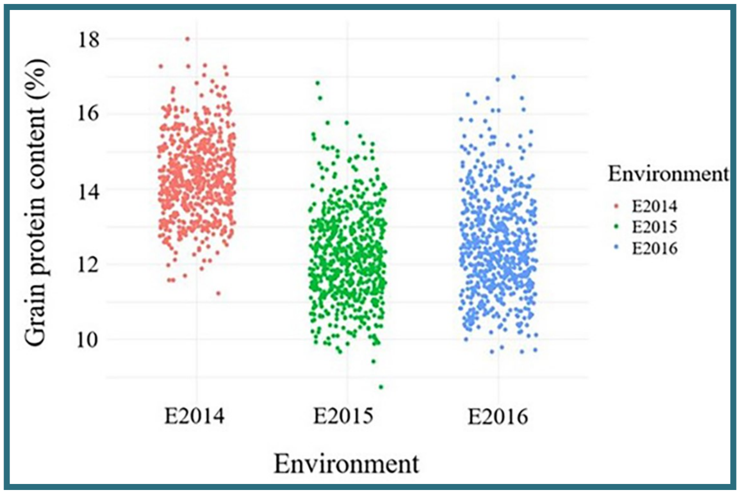


Figure 1. Variation in the grain protein content in the nested association mapping population of spring wheat evaluated for three years (2014-16) at Spillman Agronomy Farm, Pullman, WA.

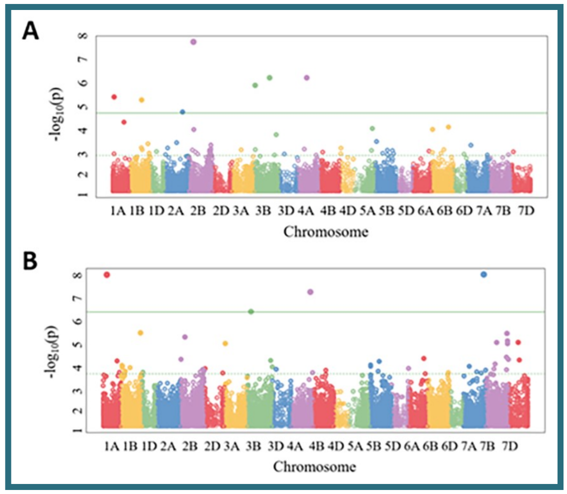


Figure 2. Manhattan plots representing marker-trait association for grain protein stability (A) and grain protein content (B) in the selected nested association mapping panel. This figures shows the small effect genes which we identified for grain protein content stability (A) and grain protein content. The X-axis shows the location on the chromosomes where those genes are located.

Picture This: Using a Bird's-Eye View to Improve Cultivar Development in a Wheat Breeding Program

ANDREW HERR AND ARRON CARTER
DEPT. OF CROP AND SOIL SCIENCES, WSU

Multispectral imaging with unmanned aerial vehicles is a promising high-throughput phenotyping technology that has shown to help understand the mechanisms associated with crop productivity. With multispectral imaging, we can evaluate the relationship between plant health and plant reflectance values. This established relationship allows us to accurately predict complex agronomic traits like grain yield by precisely identifying the health of the plant through the use of indices. Multispectral imaging creates the potential for accelerated variety selection in a breeding program.

Unfortunately, multispectral imaging has not been validated as a suitable breeding tool for predicting crop performance across years. The WSU winter wheat breeding program has set out to determine the effectiveness and efficiency in prediction across years and locations within the existing breeding pipeline. Breeding lines have been evaluated with this new phenotyping method across the state of Washington since 2018, with plans to continue evaluations through 2022. Data is being collected at heading with a DJI Inspire 1 drone, equipped with a Sentera quad-camera obtaining eight multispectral bands. Reflectance data collected at heading has shown, in previous research, to have the highest correlation with important agronomic traits in soft white wheat. Lines are observed from single location, single replication preliminary yield trials to multi-location, replicated advanced yield trials.

Our preliminary results validate that predictions within a single generation have a high correlation to grain yield within a trial year, indicating that plant health at heading has a direct influence on grain yield. Figure 1 shows the variation and detail that can be obtained with the collection of multispectral reflectance image data in the form of NDVI, a reflectance index that focuses on key wavelengths important for crop health. Furthermore, we can use these indices to improve our ability to predict winter wheat performance across Washington. Figure 2 show how much we can improve our ability to predict yield when we include an index like NDVI as a secondary trait.

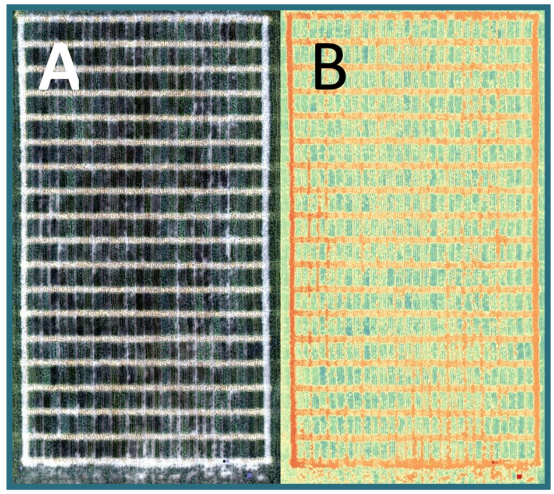


Figure 1. Image A shows a traditional RGB image of our 2020 Ritzville yield trial plots. Image B is a show NDVI of the same plot, showing a much clearer image of environmental variation and crop performance.

Moving forward, reflectance values can be used to help improve genomic prediction, thereby allowing us to better select breeding lines before field trials. We are also working to identify the usefulness reflectance data to account for environmental variation on the field scale to improve yield trial accuracy. This research will be vital for plant breeders to understand the value of multispectral imaging to improve winter wheat varieties while using fewer resources and insuring high performance in cultivar release.

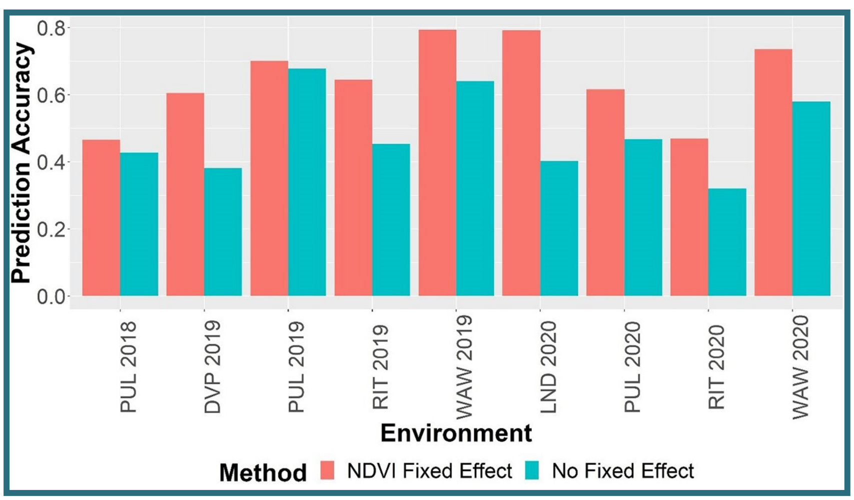


Figure 2. Prediction accuracy of a linear mixed model with and without using NDVI as a fixed effect across years and locations in Washington state.

Utilizing Spectral Information in Multi-Trait Machine and Deep Learning Models for Predicting Grain Yield and Grain Protein Content in Wheat

KARANSHER SANDHU[1], SHRUTI PATIL[2], MICHAEL PUMPHREY[1], AND ARRON CARTER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]SCHOOL OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE, WSU

Increasing grain yield and grain protein content (GPC) is the most important objective for hard red wheat. However, improvement for these two traits is difficult due to the negative correlation between them, low heritability, and high genotype by environment interaction. Spectral reflectance information collected from the plant provides information about various physiological processes, correlated with primary traits of interests (grain yield and GPC), and has high heritability. Due to these characteristics, spectral reflectance can be incorporated into multi-trait models for predicting grain yield and GPC. Multi-trait (MT-GS) models are designed to predict more than one trait and use shared genetic information between those traits. The increasing adoption of high throughput genotyping and phenotyping tools by plant breeders has increased data generation tremendously, which requires the adoption of analytical methods used in other disciplines for complex datasets. Machine and deep learning models have been explored in previous studies to predict one trait at a time and demonstrated exciting results. This study aims to explore the potential of MT-GS machine and deep learning models for predicting grain yield and GPC using spectral reflectance indices (SRI) derived from reflectance information.

The population used in this study consisted of 650 recombinant inbred lines (RILs) planted for three years (2014-16) at Spillman Agronomy Farm, Pullman, WA and spectral data was collected at heading and grain filling stages using the handheld CROPSCAN. Six different vegetation indices, namely, normalized difference vegetation index (NDVI), green NDVI (GNDVI), photochemical reflectance index, normalized water index, anthocyanin reflectance index, and normalized chlorophyll pigment ratio index were used in the MT-GS models. We explored two machine learning models (random forest and support vector machine), two deep learning models (multilayer perceptron and convolutional neural network), and their performances were compared with five traditional models (GBLUP, Bayes A, Bayes B, Bayes Lasso, and Bayes Cpi). MT-GS models for all the above nine models were used to make predictions for grain yield and GPC with individual SRI inclusion. Five-fold cross-validation was used where 80% of the data was used for model training, and remaining 20% of the data was used for testing. The model's performance was evaluated as the Pearson correlation between the actual phenotypic value and model-predicted values.

We observed significant phenotypic and genetic correlation between the primary traits (grain yield and GPC) and each SRI at both stages (heading and grain filling) (Table 1). However, due to the high correlation with grain yield at grain filling and with GPC at heading, SRI extracted from those two stages were separately used for both traits.

Table 1. Genetic correlation of six different spectral reflectance indices with grain yield and grain protein content.

Trait	NDVI[a]	PRI[b]	NWI[c]	ARI[d]	NCPI[e]	GNDVI[f]
Grain yield	0.73	0.52	0.65	0.59	0.56	0.65
Grain protein content	0.61	0.48	0.65	0.55	0.53	0.70

[a] NDVI, Normalized difference vegetation index; [b] PRI, Photochemical reflectance index; [c] NWI, Normalized water index; [d] ARI, Anthocyanin reflectance index; [e] NCPI, Normalized chlorophyll pigment ratio index; [f] GNDVI, Green normalized difference vegetation index; all genetic correlations are significant at $p < 0.05$

Figure 1 shows the prediction accuracy for grain yield using five-fold cross-validation under the single and multi-trait model. MT-GS models perform superior to their single-trait counterparts. Furthermore, random forest and multilayer perceptron were the best performing machine learning and deep learning model for predicting grain yield. Similar results were obtained to predict GPC, where MT-GS models result in better prediction accuracy with random forest and multilayer perceptron. We observed that GNDVI resulted in the greatest improvement in prediction for GPC when included in the MT-GS model, while for grain yield, we were not able to identify single SRI, which can perform better under all the scenarios. This study concluded that with the inclusion of spectral information in the machine and deep learning models, we could improve prediction accuracy. The high prediction accuracy will help the plant breeder select the best performing variety earlier in the breeding pipeline and with high efficiency. The models explored in this study will assist in predicting the performance of a variety across location and environment which will lower the cost of conducting those trials.

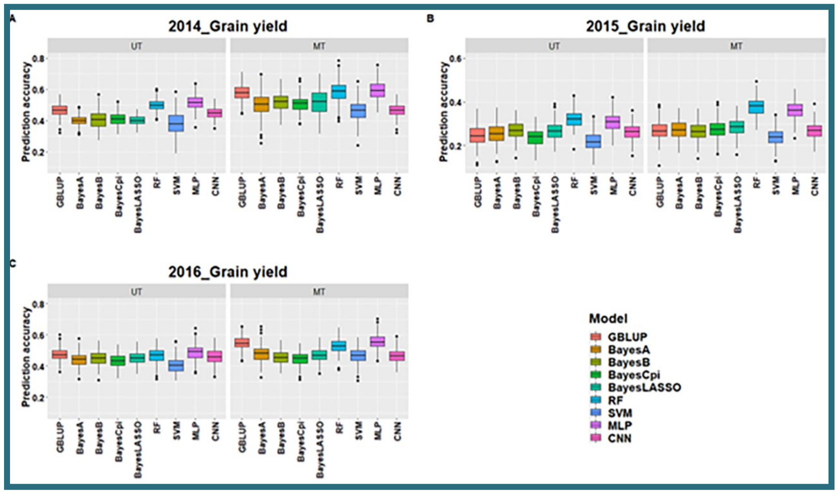


Figure 1. Prediction accuracies for grain yield with nine different single and multi-trait genomic selection models under the three different environments (2014-16) (A-C) using five -fold cross-validation. The x-axis represents the nine genomic selection models, with faceting separating the single and multi-trait models.

Characterizing Reduced Height Wheat Mutants for Traits Affecting Abiotic Stress and Photosynthesis During Seedling Growth

AMITA MOHAN, NATHAN GRANT, BILL SCHILLINGER, AND KULVINDER GILL
DEPT. OF CROP AND SOIL SCIENCES, WSU

We characterized reduced height wheat mutants during seedling growth for photosynthetic traits and traits critical for improving grain yield under marginal growing conditions. Most high-yielding, semi-dwarf wheat grown around the world contains either *Rht1* or *Rht2* genes. The success of these high-yielding cultivars is greatest in the most productive farming environments but provide marginal benefits in less favorable growing conditions such as shallow soils and low-precipitation dryland farming. Further, growing evidence suggests semi-dwarf genes not only affect early seedling growth but limit grain yield, especially under abiotic stress conditions. There are 23 other reduced-height mutants reported in wheat, most of which have not been functionally characterized. We evaluated these mutants along with their parents for several traits affecting seedling emergence, early seedling growth, and photosynthetic efficiency. Two- to seven-fold differences in coleoptile length, first leaf length, root length, and root angle were observed among the genotypes. Most of the mutations had a positive effect on root length, while the root angle narrowed. Coleoptile and first leaf lengths were strongly correlated with emergence. In a specialized deep planting experiment conducted at Lind, WA, we identified *Rht5*, *Rht6, Rht8,* and *Rht13* as having significantly improved seedling emergence compared to the parent. Among the mutants, *Rht4, Rht19* and *Rht12* ranked highest for photosynthetic traits while *Rht9, Rht16* and *Rht15* performed best for early seedling growth parameters. Considering all traits collectively, *Rht15* showed the most promise for utilization in marginal environments followed by *Rht19* and *Rht16*. These wheat mutants may be useful for deciphering the underlying molecular mechanisms of understudied traits in breeding programs in arid and semi-arid regions where deep planting is practiced. We reported significant variation for different traits in the present study. We found first leaf length strongly correlated with emergence from deep planting depths. Thus, while selecting for emergence from deep planting depths, considering both the coleoptile and first leaf length could be the best strategy. The identified germplasm could be utilized in breeding programs to improve traits not only for abiotic stress tolerance but also to improve photosynthetic capacity. Most of the traits we report here are not well characterized and the genes controlling the traits are not identified. Hence, the contrasting lines could also be a valuable resource to dissect the molecular and physiological mechanism underlying the studied traits.

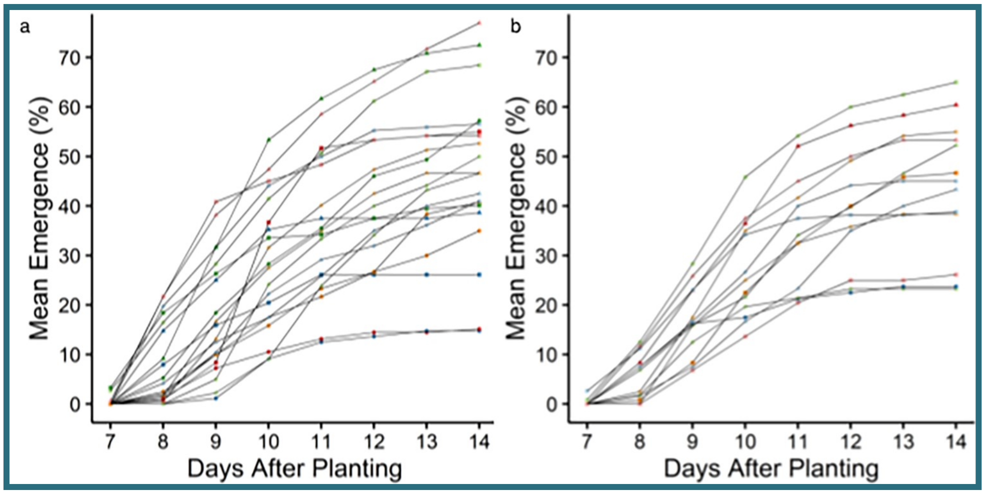


Figure 1. Mean percent seedling emergence from deep planting depths of a) reduced height mutants and b) standard height parent genotypes. Color and symbols represent respective mutant (a) and parent (b) in the figure are as follows:

Rht1, Rht14, Rht18, Rht20, Rht6, Rht11, Rht15, Rht19, Rht3, Rht7, Rht12, Rht16, Rht1Rht2, Rht4, Rht8, Rht13, Rht17, Rht2, Rht5, Rht9

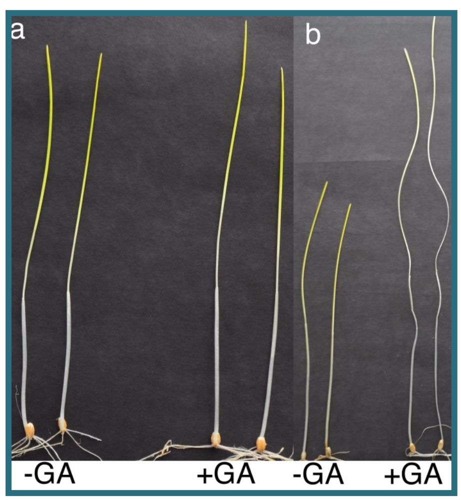


Figure 2. Representative genotype coleoptile growth response a) no response b) positive response to exogenous GA compared to control.

Part 3. Agronomy and Soils

Soil Health and Grain Yields Under Different Residue Management Practices

FRANCISCO CALDERÓN AND STEPHEN MACHADO
COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU

The long-term experiments at the Columbia Basin Agricultural Research Center include a Crop Residue Management experiment that originated in 1931. This experiment compares several treatments that include three wheat straw managements (incorporated, fall burned or spring burned), three N rates (0, 40 and 80 lbs per acre), a manure treatment or a pea vine amendment. All of the treatments are applied to a wheat fallow rotation. The length of the experiment and the diversity of treatments makes the Residue Management experiment an ideal field laboratory to test the relationship between soil attributes and crop performance. The residue treatments and amendments have, after decades of management, created a variety of soil conditions, which in turn could affect the wheat grain yields and quality. Previous studies have shown that the long history of repeated manure amendments can result in increased soil organic matter, phosphorus, and micronutrients. However, nitrogen fertilizer has resulted in soil acidification near the soil surface in many areas of the PNW. In this study, we evaluate the relationship between two measures of soil quality (penetrometer resistance, and electrical conductivity (Ec)), and two measures of crop performance (current season NDVI, and previous grain yields). Penetrometers are useful for measuring the compaction of soil at different depths throughout the profile. The bulk Ec of a soil is a measure of the soils capacity to transmit an electric current, which is very sensitive to changes in soil salinity and soil spatial variability. Due to its relatively ease of measurement, Ec has been used to develop management zones for precision farming operations in different regions. In Figure 1 we show the wheat grain yields for the last two harvests in the Crop Residue Management plots.

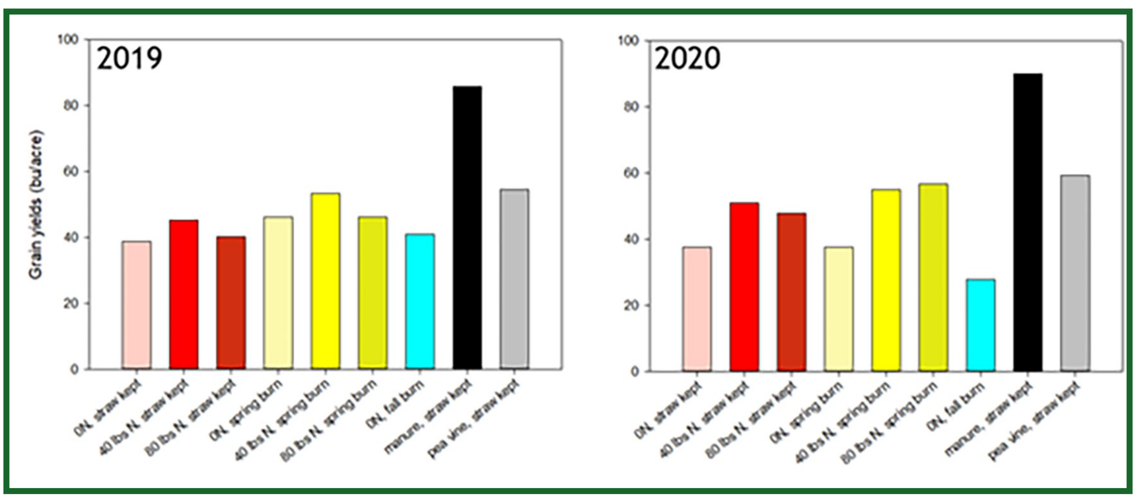


Figure 1. Winter wheat grain yields from the different treatments in the Crop Residue Management experiment at the Columbia Basin Agricultural Research Center, Adams, Oregon.

Results show that the manure treatment had the highest grain yields in the 2019 and 2020 seasons relative to all the fertilizer and the pea vine treatments. Fertilizer nitrogen rates saw a yield increase between the control (0 lbs N/ac) and the 40 lbs N/ac treatment, but there was no clear difference between the 40 lbs N/ac and 80 lbs N/ac rates. The NDVI data from the spring 2021 shows a very similar pattern as the previous two year grain yields, with manured plots having the highest NDVI, and the zero fertilizer N controls having the lowest values (not shown). Soil Ec showed low sensitivity to fertilizer N treatments, but manured soils did have higher values than the rest of the treatments (Fig. 2). The figure shows the relationship between Ec and the previous crop's grain yield for soils last harvested in 2020 and 2021. Because of this lack of response to N fertilizers, Ec is marginally effective in identifying high productivity soils in Walla Walla silt loam soil. The Ec, does respond to manure, possibly due to the additional salts added with the manure.

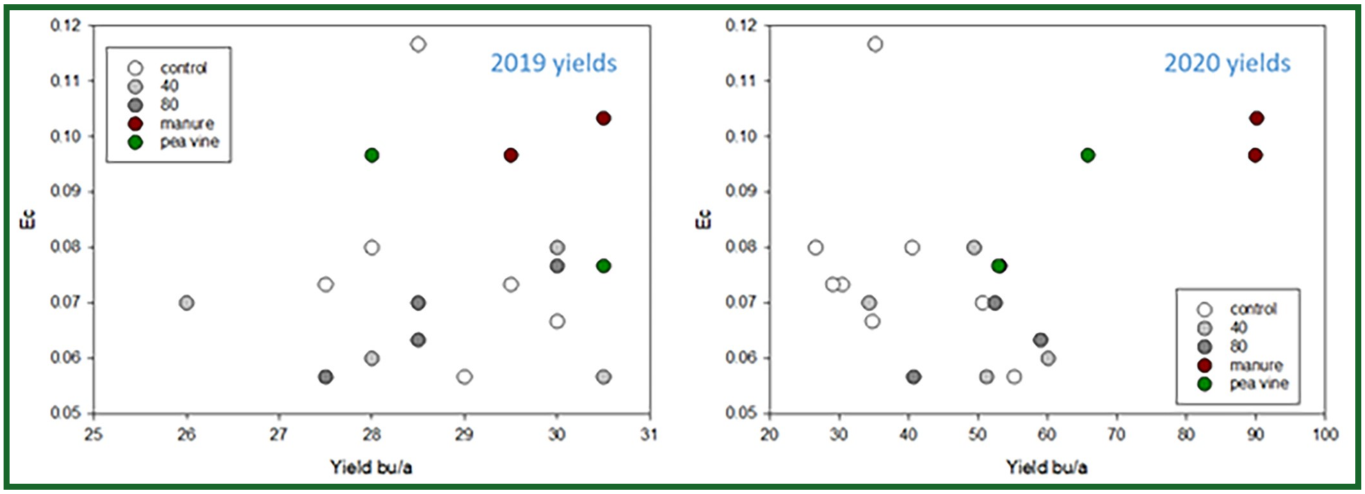


Figure 2. Soil bulk electrical conductivity vs. wheat grain yields at the Crop Residue Management experiment at the Columbia Basin Agricultural Research Center, Adams, Oregon.

Penetrometer resistance turned out to be a very useful indicator of management effects. Figure 3 shows the results for the different fertilizer and amendment treatments. The graphs show a hard layer between 15-30 cm (6-12 inches). The data, however, shows that the soils that have a history of receiving manure and pea vine have reduced compaction in that depth range. We hypothesize that organic amendments could be fostering more root growth and have favored better soil structure and lower bulk density due to the added organic material.

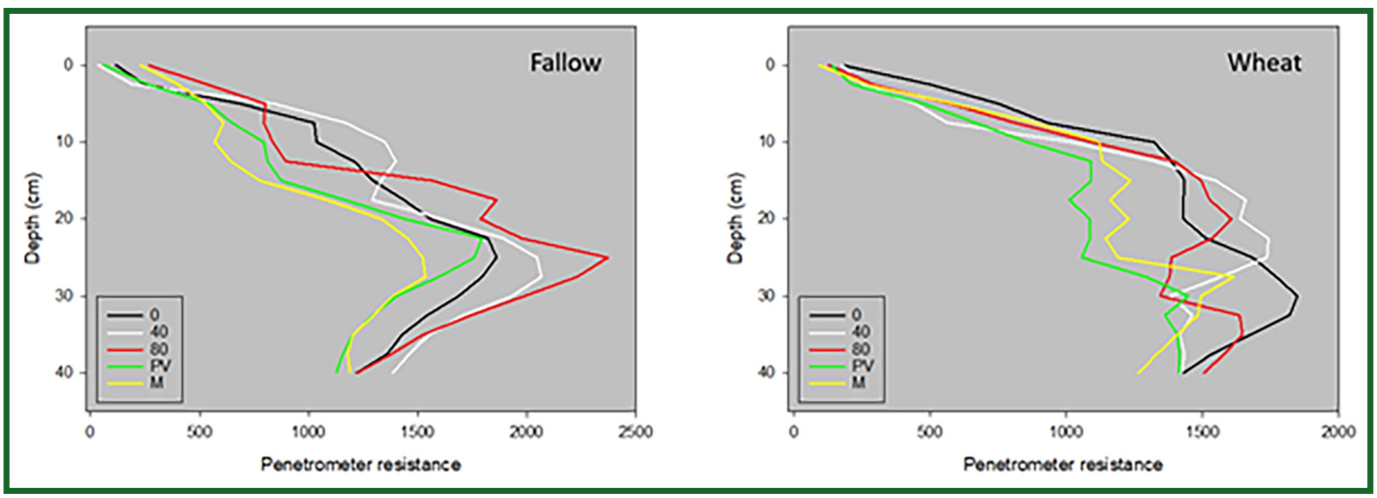


Figure 3. Penetrometer resistance (kPa), measured in the spring of 2021 at the Crop Residue Management experiment at the Columbia Basin Agricultural Research Center, Adams, Oregon. Pv is pea vine amendment, and M is manure amendment. The 0, 40, and 80 refer to nitrogen fertilizer rates in lbs/acre.

In summary, we show that NDVI and penetrometer resistance are sensitive measures of crop performance and soil physical health in these soils. The good news is that these measurements come from field ready instruments, so they are relatively easy to obtain, and could thus become part of long term data sets to monitor these soils and to determine the effects of common agricultural practices.

Spring Cereal & Cereal-Pea Forage Hay Productivity and Nutrition

DOUG FINKELNBURG, JIM CHURCH, AND KEN HART
UI EXTENSION

Cattle producers in Northern Idaho need high quality forage for optimal animal health and growth. Farmers in the region face challenging returns on spring grain or grain-legume crops. In other regions of the country with cattle and uncertain returns on small-grains, ground is frequently converted to single-season forage production. This work explores the performance of spring cereal and cereal-pea forages in two location on the Camas Prairie in North-Central Idaho conducted at the request of area cattle-producers.

Forage oats, barley, and cereal-forage pea mixes were trialed in Idaho and Lewis Counties in 2018-2020 (Fig. 1). A randomized complete block design with four replications of small plots was used. Quality samples were analyzed at Northwest Labs in Jerome, ID. Plots were seeded at 28 seeds/sq-ft for cereals and cereal-legume mixed plots at 20 cereal seeds and 3 forage pea seeds/sq ft respectively. Fertility was added based on soil tests to provide 80-90 lbs/acre plant available N. Swathing was targeted during the flowering stage with the intent to capture the maximum tonnage before quality decline, typically the 2nd to 3rd week of July. Weeds were controlled with 2, 4-D amine and hand weeding in the cereal-pea plots. Yields were between 2.4 – 3.2 dry tons/acre with protein content lowest in "Stockford" barley and highest in the "Proleaf 234/Flex Pea" mix (Table 1). Average protein contents, relative feed values (RFV) and total digestible nutrients (TDN) of these annual forages were higher than found in average grass hay produced in the region (1% higher protein, 10% higher TDN, RFV quality grade "Fair" vs "Poor").

Figure 1. Proleaf 234 & Flex Pea forage plot near Nezperce, ID 2020.

Table 1. Hay Yields & Quality Results for 5 Site-Years (2018-2020).

Entry	Forage Type	Yield Dry Ton/Acre		Protein %		TDN** %		RFV***	
Otanas	Oats	3.17	a*	9.1	abc	55.9	de	90	cd
Proleaf 234	Oats	3.04	a	9.0	bc	55.0	e	87	d
Everleaf 114	Oats	2.85	ab	9.5	ab	57.6	abc	97	b
Proleaf 234/Flex	Oats/Pea	2.84	ab	9.8	a	57.7	abc	86	d
Everleaf 126	Oats	2.82	ab	9.1	bc	56.6	cd	94	bc
Stockford	Barley	2.53	bc	8.8	c	57.1	bc	106	a
NZA 4.14	Oats	2.49	bc	9.3	abc	58.1	ab	98	b
Stockford/Flex	Barley/Pea	2.40	c	9.1	bc	58.4	a	105	a
Average		2.77		9.2		57.1		95	
LSD (.05)		0.37		0.7		1.1		6.2	
CV (%)		20		11		3		9	

* Results with different letters are significantly different.
**Total Digestible Nutrients
***Relative Feed Value

Annual crop rotations in North Central Idaho tend to be dominated by winter and spring wheat production. Including a cool season forage oat or barley crop can benefit these rotations by breaking up wheat-disease and pest cycles. The comparatively early harvest of cool season forages allows for additional weed control opportunities not possible in spring grain crops. Additionally, these results show that spring planted forage crops can provide an increase in forage quality while maintaining yield per acre compared to locally grown grass hay.

Diversification of Inland Pacific Northwest Wheat-Based Systems

JODI JOHNSON-MAYNARD[1], SUBODH ADHIKARI[2], SAUGAT BASKOTA[3], ERIN BROOKS[1], IAN BURKE[4], SANFORD EIGENBRODE[2], DANE ELMQUIST[2], ZHONGMING GAO[5], DAVID HUGGINS[6], KENDALL KAHL[1], REBECCA MCGEE[6], DANIEL NESSLY[1], SHELLEY PRESSLEY[5], ERIC RUSSELL[5], KURTIS SCHROEDER[3], AND CLARK SEAVERT[7]
[1]DEPT. OF SOIL AND WATER SYSTEMS, UI; [2]DEPT. OF ENTOMOLOGY, PLANT PATHOLOGY AND NEMATOLOGY, UI; [3]DEPT. OF PLANT SCIENCES, UI; [4]DEPT. OF CROP AND SOIL SCIENCES, WSU; [5]DEPT. OF CIVIL AND ENVIRONMENTAL ENGINEERING, WSU; [6]USDA-ARS PULLMAN; [7]DEPT. OF APPLIED ECONOMICS, OSU

Limited crop options reduce the ability of farmers in the highly productive wheat-production region of the inland Pacific Northwest (iPNW) to respond to climatic variability and may result in the expansion of fallow within the region. To address this, the Landscapes in Transition project is conducting a comprehensive assessment of two alternative crops (winter pea and cover crops) in replicated trials in two agroclimatic zones (annual and transition). Fallow is common in the transition zone, but largely restricted to wet springs that preclude the timely seeding of spring crops in the annual zone. Diversified rotations are compared to business-as-usual rotations (spring pulse-winter wheat-spring wheat in the annual zone and fallow-winter wheat-spring wheat in the transition zone). Biological indicators of soil health (earthworms and Solvita-CO_2) were similar between the two sites, despite differences in annual precipitation and soil moisture. Soil arthropods reflect the crop being grown and are more abundant under winter pea than in other crops in the annual zone. The Haney Soil Health test ranged from 9 to 12.5 across sites and years and does not appear to reflect treatments at this point in the study. Water lost under fallow in the transition site was about half of that used by winter pea and wheat in the transition zone. Winter wheat yields were similar for each rotation in the annual zone, but were reduced when winter wheat followed winter pea or cover crop in the transition zone. Carbon uptake (assessed by flux towers) was generally positive, except for fallow (-105 g C/m^2) at the transition site. Additional data is currently being analyzed, and modeling of rotational effects and economic/supply chain analysis have been initiated. Overall, the combined LIT data set will allow a comprehensive assessment of the impact of crop diversification and allow farmers to better deal with climate variability.

"Landscapes in Transition" is funded through award #2017-68002-26819 from the National Institute of Food and Agriculture.

Nitrogen Stabilizers to Improve Nitrogen Application Efficiency in Winter Wheat in High Rainfall Zones of Northern Idaho

SARAH SEUBERT[1], HAIYING TAO[2], AND KURTIS SCHROEDER[1]
[1]DEPT. OF PLANT SCIENCES, UI; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Nitrogen can be prone to leaching from winter wheat fields in the higher rainfall zones of northern Idaho. One possible solution is to use nitrogen stabilizers at the time of planting to slow the conversion of nitrogen to a leachable nitrate form. However, the effectiveness of these products and their potential impacts on soil microbes are not well studied in the region. Two research trials were established at Cottonwood and Cavendish, Idaho during the 2019-2020 and 2020-2021 growing seasons. A nitrogen stabilizer (Instinct® II) was applied to portions of the plots and two separate trials were conducted at each location using the soft white winter wheat LCS Hulk or the hard red winter wheat LCS Jet. There were five nitrogen, UAN 32, treatment levels (0, 50, 100, 150 and 200 lb N/A), each with and without Instinct® II. Trials were seeded into 100 ft long strips using a custom AgPro direct seed drill equipped with Bourgault paired-row openers on 12" spacing, with fertilizer banded between and below the paired-row. Four soil samples were collected to test for nitrate and ammonia concentrations. Two sampling dates occurred in the late fall and early spring when the soil is between 0 and 4°C at the depth of one foot divided in 6-inch increments. The other two samplings occurred in the spring, when fields are accessible with a tractor mounted Giddings soil corer, and the fall after harvest at five increments (0-6, 6-12, 12-24, 24-36, 36-48 inches). Other agronomic data collected during the growing season included winter kill, stand establishment, plant height, number of reproductive tillers, NDVI (green reflectance), grain yield, test weight, and grain protein. Microbial quantification will also be conducted on the late fall and early spring soil samples to test the effect of the nitrification inhibitor on the abundance of the ammonia-oxidizing bacteria responsible for nitrification, *Nitrosomonas* sp. and *Nitrosospira* sp. Preliminary data has been collected and analyzed from the 2019-2020 crop year.

The nitrogen concentration data from the first sampling date in late fall indicated that nitrogen stabilizer helped retain ammonium and decreased the concentration of nitrate at the Cavendish location only in the top 6 inches where the fertilizer was applied (Fig. 1). Similarly in the early spring samples at both sites, significantly more ammonium was retained in the plots treated with Instinct® II compared to plots without stabilizer. Likewise, the Instinct® II treated plots had significantly less nitrate. Late spring sampling showed slightly higher ammonium retention and decreased nitrate concentrations for both sites. Differences in the concentration of ammonia were only detectable in the top 12 inches while nitrate concentrations were easy to detect across all the depths. Soil samples collected after harvest did not show any significant differences between stabilizer treatments.

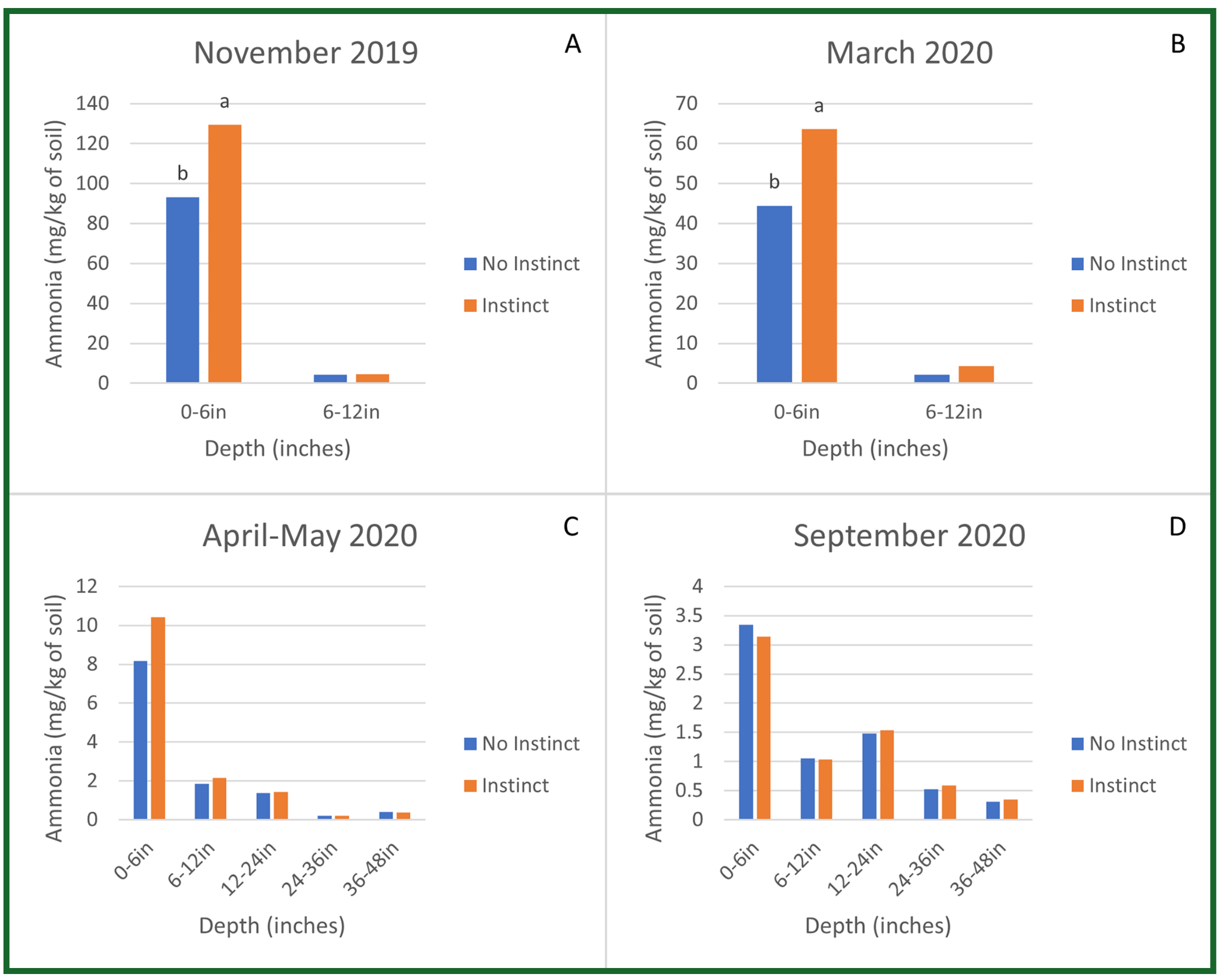


Figure 1. Ammonia concentrations in LCS Jet plots at Cavendish from soil samples collected in November 2019 (A), March 2020 (B), April-May 2020 (C) and September 2020 (D). Values with different letters were significantly different.

Average wheat yield across all nitrogen treatments did not show a significant difference between plots treated with and without stabilizer (Table 1). There also was not a difference in test weight, grain protein, NDVI, and reproductive tiller counts. However, in Cavendish there was, albeit non-significant, a slightly higher yield in plots with Instinct® II. This preliminary study using UAN as the source of nitrogen fertilizer does not support the use of nitrogen stabilizer in winter wheat production in northern Idaho. Field trials are currently underway to confirm these findings.

Table 1. Yield of soft white winter wheat and hard red winter wheat at test sites in Cavendish and Cottonwood to evaluate the effectiveness o f a nitrogen stabilizer.

Treatment	Cottonwood SWWW	Cottonwood HRW	Cavendish SWWW	Cavendish HRW
	------------------ Yield (bu/A) ------------------			
Instinct	127	83	75	84
No instinct	128	83	74	81
LSD (0.05)	ns	ns	ns	ns

Impact of Biochar and Fly Ash Application to Agricultural Soils on Soil Health and Crop Productivity

Timothy D. Murray[1], Haiying Tao[2], Stephen Van Vleet[3], and Hongyan Sheng[1]
[1]Dept. of Plant Pathology, WSU; [2]Dept. of Crop and Soil Sciences, WSU; [3]WSU Extension

Soil acidification is a widely occurring problem in the PNW, especially in areas with higher precipitation and those soils that were historically forested. Soil acidification alters soil chemistry, fertility, and soil microbes, which in turn, can have major negative effects on soil health and crop production. The overall objective of this project was to determine whether the non-traditional soil amendments biochar (BC) and fly ash (FA), applied alone or in combination, can improve wheat productivity under field conditions.

Liming study trial in Palouse Conservation Field Station farm. Photo taken by Keith M. Curran in spring, 2020.

The experiment was conducted in two winter wheat fields located in Pullman and Rockford for two crop years of 2019-2020 and 2020-2021. The initial soil pH and exchangeable aluminum in the top 6 inch soil profile were pH<5.3 and [Al^{3+}] <10 ppm in Pullman and pH<4.6 and [Al^{3+}]>140 ppm in Rockford. Nine treatments (agricultural lime, fly ash, two different types of biochar, mixture of agricultural lime or fly ash with each type of biochar, as well as a control) were applied at both locations. Amendments were incorporated to a 6-inch depth immediately after spreading. Biochar was applied at a rate of 600lbs/acre at both locations and rates of lime materials were determined to raise soil pH to the targeted pH of 5.7. The research conducted in Pullman had four winter wheat varieties and all varieties were inoculated with oat kernels colonized by Cephalosporium gramineum on October 4, 2019.

Preliminary data collected in the first crop season showed that soil pH at 0–3-inch depth increased significantly in all soils amended comparing with unamended control, except for the soils amended with the two types of biochar, 10 months after application of amendments in both locations (Figs 1 & 2). Application of soil amendments resulted in significant yield benefits in both sites. In Rockford site, yields in the plots amended with agricultural lime, and agricultural lime mixed with either type of biochar was highest, followed by the yields in the plots amended with fly ash and fly ash mixed with either type of biochar. Similarly, agricultural lime and agricultural lime mixed with wheat residue-based biochar applications resulted in the best yield, followed by fly ash mixed with wood-based biochar in Pullman site (Table 1).

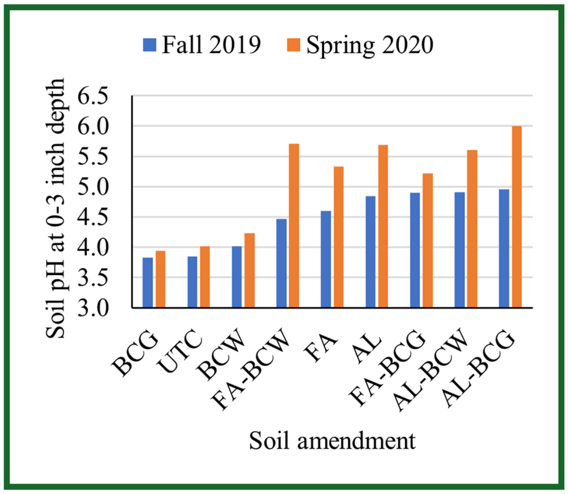


Figure 1. Soil pH at 0-3 inch depth measured 3 and 10 months after application of soil amendments in Rockford site.

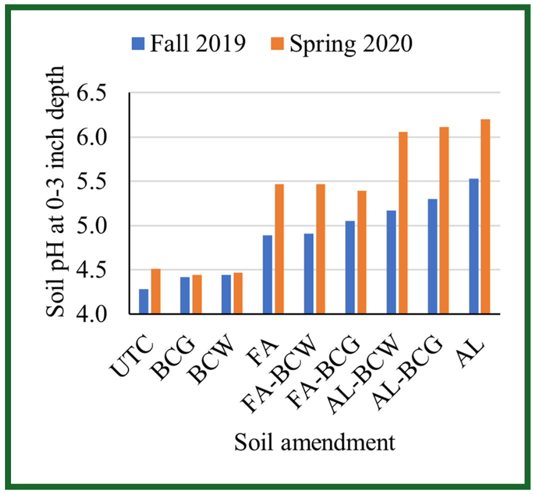


Figure 2. Soil pH at 0-3 inch depth measured 3 and 10 months after application of soil amendments in Pullman site.

Table 1. Impact of soil amendments on winter wheat yield and test weight in Rockford site in 2019-2020 crop season.

Rockford, 2019-2020			Pullman, 2019-2020		
Treatment	Yield, bu/ac		Treatment	Yield, bu/ac	
AL-BCG	63.5	AB	FA-BCW	106.8	AB
AL	75.6	A	AL	112.7	A
AL-BCW	70.0	AB	AL-BCW	106.4	AB
FA	56.5	B	AL-BCG	108.4	A
FA-BCG	59.5	AB	FA	99.9	B
FA-BCW	59.5	AB	FA-BCG	99.9	B
BCG	37.0	C	BCG	89.6	C
BCW	34.1	C	BCW	86.4	C
UTC	24.3	C	UTC	84.9	C

Note: AL=agricultural lime; FA=fly ash; BCG & BCW=two types of biochar; UTC=control.

Variation in Soil Carbon Over Short Time Periods

STEWART WUEST
USDA-ARS PENDLETON, OR

No doubt you have been hearing about various efforts to make farming eligible to be a player in the carbon credit market. The concept is that certain farming practices cause a net release of soil carbon back to the atmosphere, and other practices cause a net increase in soil carbon. Getting paid to sequester carbon in the soil is an attractive idea, as increasing soil carbon also makes soil perform better in almost every way. I am not going to discuss the effects of farming practices on soil carbon, but I want to share data on one aspect of measuring soil carbon that is commonly ignored.

Trading carbon credits requires a way to measure the quantity of carbon a soil contains at different time points. Every advertisement or research effort into developing carbon credits that I have seen either does not discuss measurement methods or says that the methods are currently being developed. It happens that I have relatively rare data on how soil carbon changes from month-to-month, and I thought this would be of interest to anyone developing protocols for soil sampling, or anyone signing up to be subject to sampling protocols.

In a research effort several years ago (Wuest, 2014) I found that taking samples over a period of 39 months from large replicated plots indicated about 0.15% soil carbon content variability month-to-month (compared to an average of about 1% total soil carbon). There seemed to be trends, that is neighboring months were likely to be more similar than months far apart, but the pattern was not tied to the time of year.

Since that initial work, I have collected additional data and present it here. Figure 1 shows three years of monthly sampling from a single acre of land divided into 12 plots. There were three residue treatments that may have had minor influences, but all the samples were combined for this graph. Three cores were analyzed from each plot in a narrow transect across all 12 plots, so each data point represents 36 samples taken on a particular day. The core depth was 0 to 12 inches (measured by dry soil weight to avoid errors due to seasonal soil bulk density fluctuation). As much particulate organic matter as possible was removed before analysis. The variation over time has a range of 0.15% soil carbon, which would be about 2.5 tons of carbon per acre.

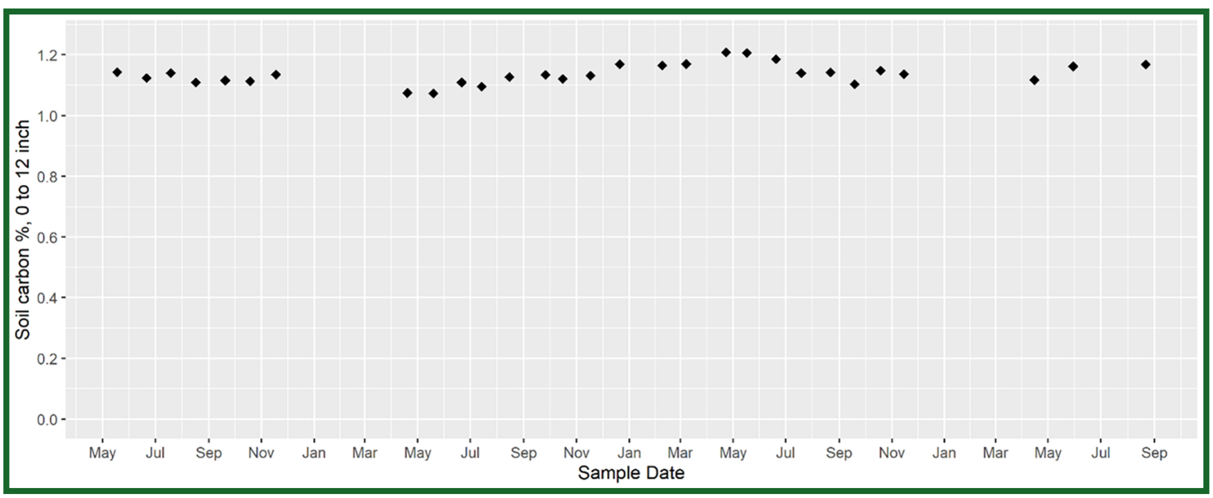


Figure 1. Soil organic carbon measured in test plots at the Columbia Basin Agricultural Research Center. Twelve plots were sampled with three cores each, for a total of 36 samples averaged per data point.

Figure 2 shows the results of single cores taken twice a year from 12 fields in a winter wheat—pea rotation (except "Kahler", which was annual recrop winter wheat). The range at each location, including both sample depths, averaged

0.32% soil carbon, which would be about 5 tons of carbon per acre. You can see that it would be difficult to choose a starting soil carbon level, and equally difficult to confidently measure the change years from now.

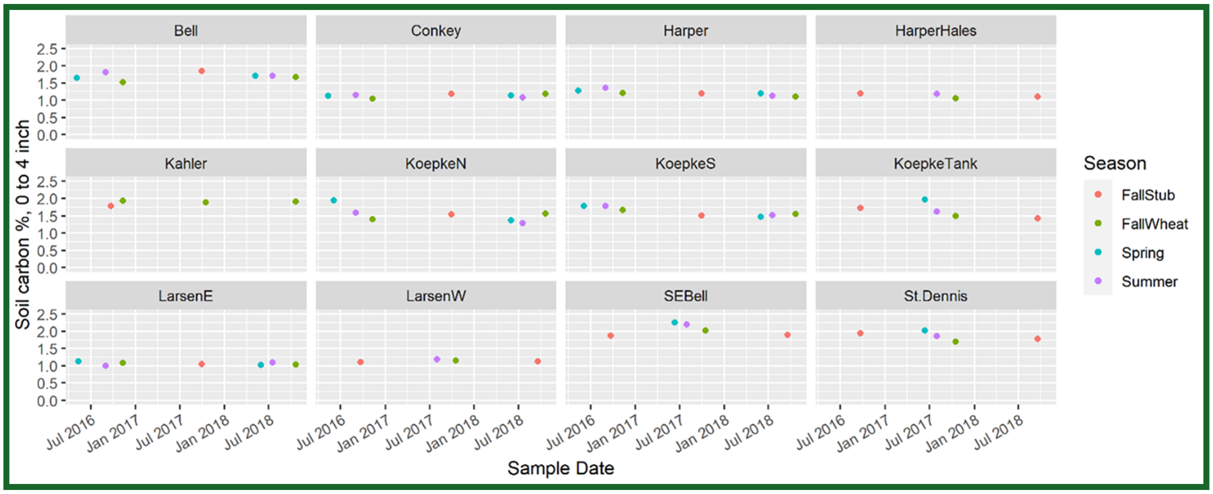


Figure 2. Soil organic carbon measured from 0- to 4-inch depth in twelve fields near Athena, OR over a three-year period. FallStub = fall after wheat harvest, FallWheat = after winter wheat planting, Spring = at time of pea planting, Summer = after fresh pea harvest.

The problem of variation in soil carbon over time is invisible when only one sample is taken. Looking at the data, it appears that weather or the stage in the crop cycle can influence results, but not predictably from one year to the next. Also note that the variation over time is significant even with samples taken in the same way, by the same person and analyzed in the same lab using techniques believed to minimize variance. My hope is that this data will help explain some of the challenges in verifying soil carbon quantities and developing accurate models of soil carbon trends, especially when looking for small changes.

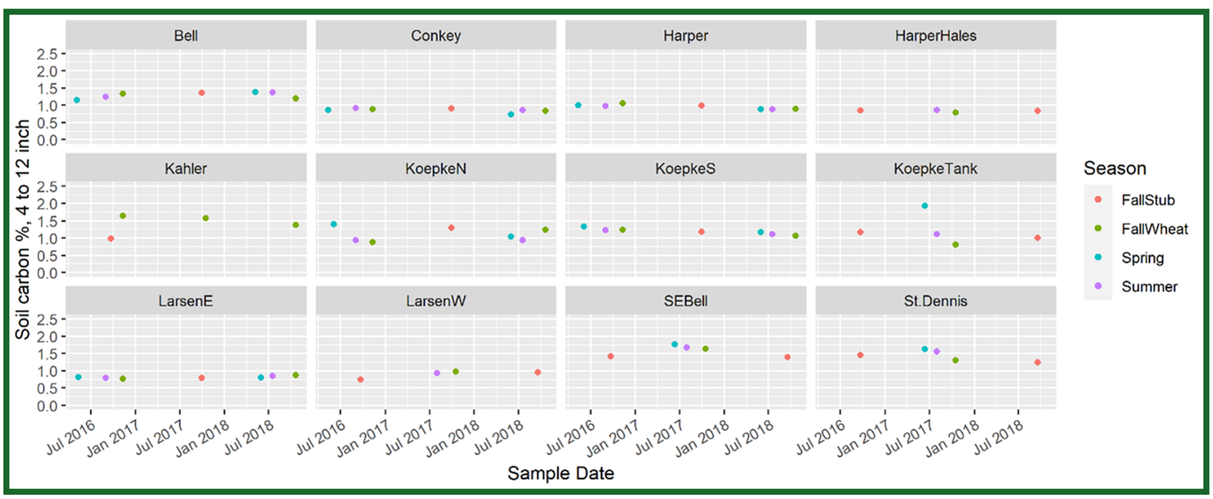


Figure 3. Soil organic carbon measured from 4- to 12-inch depth in twelve fields near Athena, OR over a three-year period. FallStub = fall after wheat harvest, FallWheat = after winter wheat planting, Spring = at time of pea planting, Summer = after fresh pea harvest.

Reference

Wuest, S. 2014. Seasonal variation in soil organic carbon. Soil Sci. Soc. Am. J. 78: 1442-1447. doi:10.2136/sssaj2013.10.0447.

Inland Pacific Northwest Wheat-Based Systems: Landscapes in Transition

JODI JOHNSON-MAYNARD[1], SUBODH ADHIKARI[2], SAUGAT BASKOTA[3], ERIN BROOKS[1], IAN BURKE[4], SANFORD EIGENBRODE[2], DANE ELMQUIST[2], ZHONGMING GAO[5], DAVID HUGGINS[6], KENDALL KAHL[1], REBECCA MCGEE[6], DANIEL NESSLY[1], SHELLEY PRESSLEY[5], ERIC RUSSELL[5], KURTIS SCHROEDER[3], AND CLARK SEAVERT[7]
[1]DEPT. OF SOIL AND WATER SYSTEMS, UI; [2]DEPT. OF ENTOMOLOGY, PLANT PATHOLOGY AND NEMATOLOGY, UI; [3]DEPT. OF PLANT SCIENCES, UI; [4]DEPT. OF CROP AND SOIL SCIENCES, WSU; [5]DEPT. OF CIVIL AND ENVIRONMENTAL ENGINEERING, WSU; [6]USDA-ARS PULLMAN; [7]DEPT. OF APPLIED ECONOMICS, OSU

Greater variability in weather patterns may lead to an increase in fallow and associated declines in organic matter inputs and soil health within the dryland wheat production region of the inland Pacific Northwest (iPNW). The overall goal of this USDA-funded project is to guide ongoing land use change in the iPNW towards sustainable, resilient agricultural landscapes and food systems. The project includes four research objectives that: employ field-based measurements to optimize agronomic practices for current and alternative diversified rotations; measure the impact of adoption of alternative systems on soil health, biogeochemical fluxes and greenhouse gas emissions; and quantify impacts of potential shifts in land use change on profitability. Three extension-based objectives employ stakeholder input to develop a supply chain vulnerability matrix; identify critical leverage points for adaption and mitigation; carryout targeted training on climate vulnerability assessment and application; and develop tools and educational products aimed at reducing barriers. This integrated project approach will assess biophysical and economic factors in terms of the entire supply chain. The combination of field studies and modeling will directly address knowledge gaps in agronomic practices, profitability, and environmental outcomes of two alternative rotations.

"Landscapes in Transition" is funded through award #2017-68002-26819 from the National Institute of Food and Agriculture.

Figure 1. A combination of replicated strip crop and small-plot trials studies are being conducted as part of LIT.

Table 1. Business as usual (BAU) and diversified crop rotations under study.

Genesee, ID	St. John, WA
Chickpea-winter wheat-spring wheat (BAU)	Fallow-winter wheat-spring wheat (BAU)
Chickpea-winter wheat-winter cover crop	Spring cover crop-winter wheat-spring wheat
Winter pea-winter wheat-spring wheat	Winter pea-winter wheat-spring wheat

Relative Profitability Estimates by Crop and Rotation for Dryland Grain Producers in 2021

KATHLEEN PAINTER AND SHELLEY JONES
NORTHERN DISTRICT, UNIVERSITY OF IDAHO EXTENSION

A volatile year makes crop decisions challenging but tracking expenses and prices by crop can help with planning. Detailed cost spreadsheets created for the UI Extension Ag Biz website provide an excellent starting point for tracking expected returns by crop and rotation.

Crop returns for rotational crops including garbanzos, canola, lentils and peas can hurt overall profitability of a typical 3-year rotation of winter wheat, spring grain, and a non-grain crop. Volatile prices for these crops in recent years have changed relative profitability dramatically. At the time of this analysis, estimated net returns for spring canola are highest for the annual cropping region, at $48 per acre. None of the other rotational crops have positive returns over total production costs (see Fig. 1). Estimated net returns for winter wheat are highest, at $57 per acre, assuming a farmgate price of $5.50 per bushel (see Table 1) and an average yield of 90 bu per acre. Returns for both soft white spring and hard red spring wheat crops are also positive, at $23 and $13 per acre, respectively. The most profitable 3-year rotations, in terms of average net returns over three years (or, assuming 1/3 of each crop is grown across the farm), would be soft white winter wheat, soft white spring wheat, and spring canola, at $43 per acre (Fig. 2).

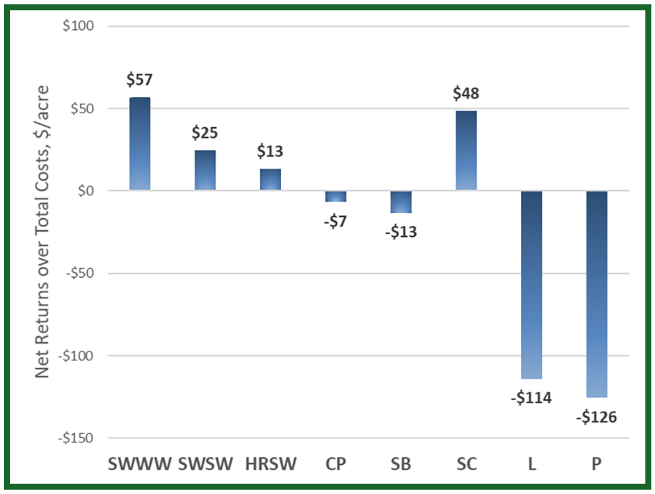


Figure 1. Estimated net returns over total costs by crop, 2021 farmgate crop price estimates ($/acre).

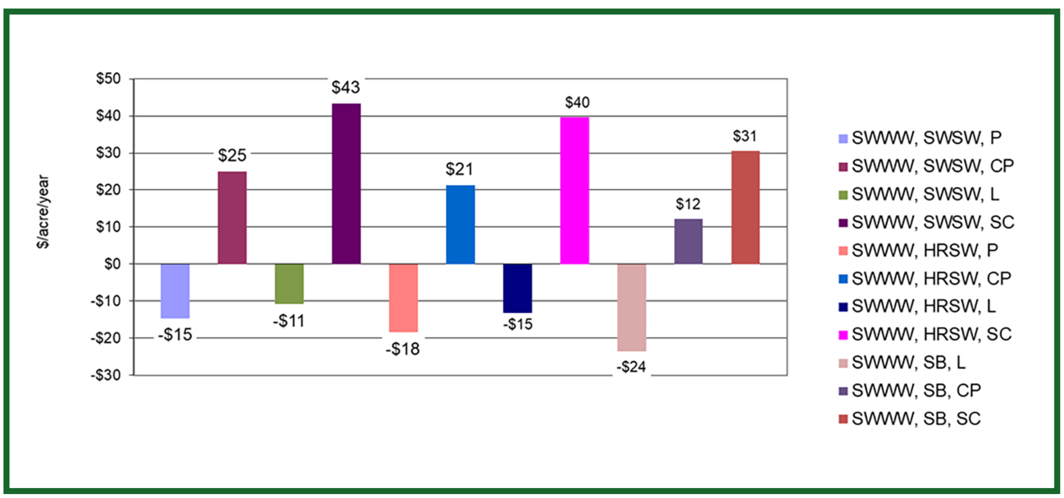


Figure 2. Estimated net returns over total costs by rotation, 2021 farmgate crop price estimates ($/acre).

The average farm size for this region is assumed to be 2500 acres, and uses a three-year rotation of winter wheat followed by a spring grain and then a "break crop," which is a grain alternative such as peas, chickpeas, lentils or spring canola. Precipitation for the annual cropping region is approximately 18 inches or more per year. The farming practices are assumed to use conservation tillage methods in this region characterized by highly erodible soils. Input prices for this study are based on 2020-2021 cost assumptions for fuel, fertilizer, agricultural chemicals, and application costs for

Northern Idaho. Crop prices represent current farmgate price estimates for the 2021 harvests in this three-state dryland cropping region (Table 1). Crop yields are based on data from the USDA National Agricultural Statistics Service (NASS) database for this region.

Table 1. Crop yield and 2021 farmgate price estimates by crop.

Crop	Unit	Price ($/unit)
Soft White Winter Wheat (SWWW)	bu	$5.50
Soft White Spring Wheat (SWSW)	bu	$5.50
Hard Red Spring Wheat (HRSW)	bu	$6.75
Spring Barley (SB)	ton	$150.00
Lentils (L)	lb	$0.20
Spring Canola (SC)	lb	$0.25
Peas (P)	lb	$0.11
Chickpeas (CP)	lb	$0.28

Farm operators are assumed to pay land rent based on a traditional cost-share arrangement, in which the landlord receives one-third of the crop and pays for one-third of the fertilizer and crop insurance premiums. The tenant covers all other production expenses.

An easily adaptable, detailed spreadsheet with cost and returns for each crop is available at https://www.uidaho.edu/cals/idaho-agbiz/crop-budgets or by request (kpainter@uidaho.edu). Additional cost-and-returns estimates for North Idaho are also available at this website, including cost and returns estimates using direct seed tillage methods, as well as cover crop budgets for this region.

Intercropping of Pulse Crops with Barley Improves Crop Productivity and Soil Health

XI LIANG[1], ZACHARY KAYLER[2], TORREY STEPHENSON[2], ISABELL VON REIN[2], AND BALA RAM SAPKOTA[1]
[1]DEPT. OF PLANT SCIENCES, UI; [2]DEPT. OF SOIL AND WATER SYSTEMS, UI

Pulse crops can biologically fix atmospheric nitrogen through symbiotic relationships, increasing nitrogen availability to the cropping system. This can also support a diverse microbial community, increasing the availability of soil water and nutrients to plants. We hypothesize that intercropping pulse crops with barley can enhance crop productivity, soil health, and water use efficiency of the cropping system. The objective of the current study was to quantify the potential benefits of incorporating pulse crops into barley cropping systems in terms of crop yield and quality, soil health, and water use efficiency. A four-year field experiment was initiated at the Aberdeen Research & Extension Center, the University of Idaho in the spring of 2020. It included seven cropping systems: continuous barley, barley rotating with lentil, chickpea, and dry pea, and barley intercropping with lentil, chickpea, and dry pea (Fig. 1). Two irrigation treatments (i.e., 100 and 50% crop evapotranspiration (ET) throughout the growing season) were also included to represent full and deficit irrigation conditions. During the growing season of 2020, the full irrigation treatment (100% ET) received irrigation of 283 mm, and the deficit irrigation treatment (50% ET) received 142 mm. Our first-year results indicated that deficit irrigation slightly decreased pulse crop biomass, but lentil grain yield was higher under deficit irrigation (Fig. 2 and 3). Barley-pulse intercropping produced barley grain yield similar to monoculture barley under deficit irrigation (Fig. 3), suggesting that individual barley plants in intercropping compensated for the low plant density. Root distributions of all plants were primarily located at deeper depths (>15 cm) within the soil profile, reflecting the sandy-loam soil characteristics and the impact of irrigation at the site. We observed a small increase (approx. 20 mg C/kg soil) in permanganate-oxidizable carbon (POX-C) across all cropping systems under fully irrigated conditions; except for the pea intercrop plots. Under reduced irrigation, POX-C slightly increased at depths below 40 cm, above these depths, there was not an increase or available carbon was mineralized. From these initial results, we infer that pulse crop species matter when considering intercropping and that samples from deeper soils are necessary to see the full impact of growing crops simultaneously. These results also suggest that pulse-barley intercropping systems could be suitable for dryland areas with limited water availability.

Figure 1. Barley-pea (left) and barley-lentil (middle) intercropping and monoculture barley (right).

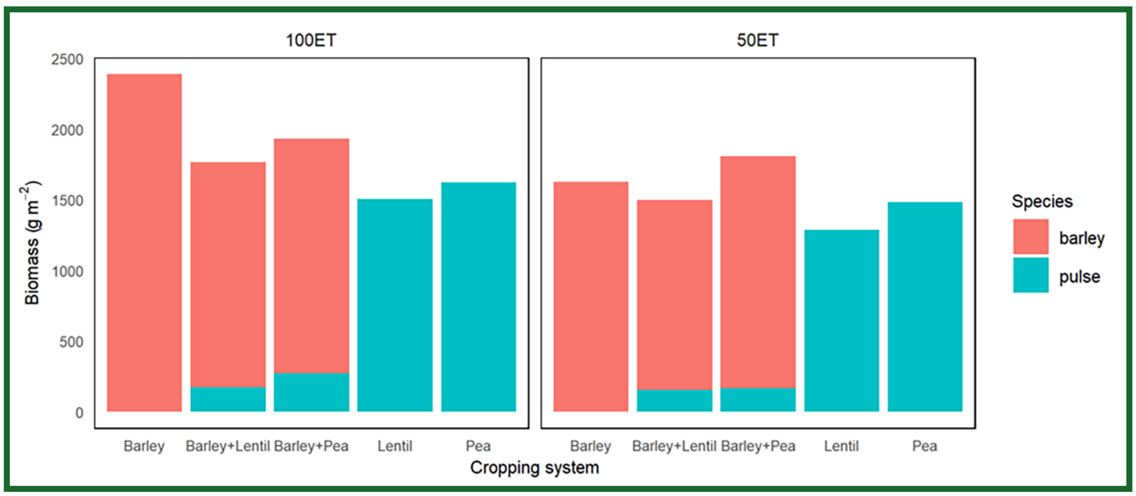


Figure 2. Biomass yield in response to cropping systems and irrigation treatments (i.e., 100 and 50% ET). The seeding rate of monoculture barley was 198 seeds/m^2 and 99 seeds/m^2 for intercropping barley. The seeding rate of monoculture pea was 86 seeds/m^2 and 43 seeds/m^2 for intercropping pea. The seeding rate of monoculture lentil was 129 seeds/m^2 and 65 seeds/m^2 for intercropping lentil.

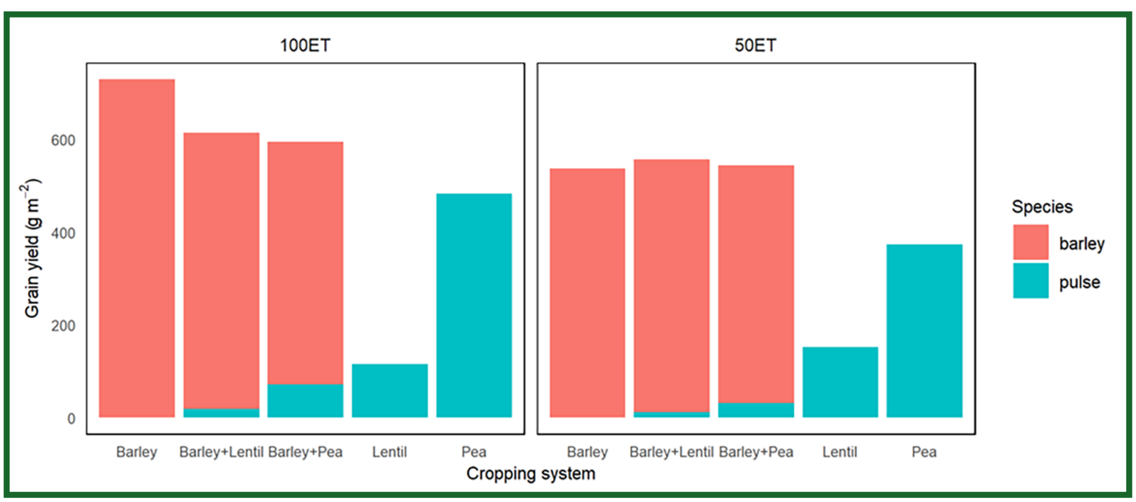


Figure 3. Grain yield in response to cropping systems and irrigation treatments (i.e., 100 and 50% ET). The treatment of barley-pulse intercropping produced barley grain yield similar to monoculture barley under deficit irrigation (50% ET) ($P > 0.05$).

Part 4. Oilseeds and Other Alternative Crops

Impact of Flea Beetle Damage, Insecticide Application, and Delayed Seeding Dates in Spring Brassica Crops – 2021 Update

JIM B. DAVIS, JONAH E. KAYA, ASHLEY JOB, MEGAN WINGERSON, AND JACK BROWN
DEPT. OF PLANT SCIENCES, UI

Flea beetle is a major pest of canola and mustard, and yield losses of 7% and 35% from flea beetle feeding have been documented in north-central Idaho. Control strategies for flea beetle are based primarily on the use of insecticidal seed treatments such as Helix Vibrance or Prosper EverGol. This study examines the efficacy of a post-emergence, foliar spray to supplement seed treatments.

Four spring canola/rapeseed cultivars (*B. napus*) with differing maturities and an Indian mustard (*B. juncea*) were used in this three-year study at Moscow, Idaho. The seed of all cultivars was treated with Helix Vibrance at the label rate. Each cultivar was seeded at three different seeding dates at two-week intervals: April 25/May 1/April 28, May 8/May14/May 14, and May 23/May 28/May 28 in 2018/2019/2020, respectively. At each seeding date, the plots were arranged in blocks that would be sprayed or not sprayed with a foliar insecticide (Warrior II and R56 adjuvant).

Flea beetle damage was low to intermediate during the study, with an average rating of 7.2 (on a scale of 1 to 9, with 9 being no damage). Data for each of the cultivars tested are shown in Table 1. Seed yield was significantly and dramatically affected by seeding date (Table 2). The seed yields from the three seeding dates, early to late, were 2,470, 1,964, and 1,086 lb. per acre; delaying seeding for four weeks in May resulted in a 56% yield loss.

Table 1. Average flea beetle damage score (scale of 1 to 9 with 9 being no damage), days from seeding to 50% flowering, and seed yield of five canola, rapeseed, and mustard cultivars grown near Moscow, Idaho in 2018, 2019, and 2020.

Cultivars	Flea Beetle Damage (1-9 score, higher is better)	Days to 50% Flower	Seed Yield (lb./acre)
Pacific Gold Mustard	6.7 [a]	42 [a]	1,774 [b]
Industrious Rapeseed	7.1 [b]	44 [b]	1,639 [a]
HyCLASS 930 RR	7.3 [b]	46 [c]	2,019 [c]
Star 402 RR	7.4 [c]	47 [d]	1,976 [c]
DynaGro 200 CL	7.6 [c]	51 [e]	1,791 [b]
Mean	7.2	46	1840
LSD (p=0.05)	0.2	0.3	92

Means within columns with different superscript letters are significantly different ($P<0.05$).

The effect of the foliar insecticide varied across planting dates and years. Averaged across the trial, a foliar insecticide spray improved flea beetle damage scores from 6.9 to 7.5, while seed yield improved from 1,734 lbs. per acre to 1,946 lbs. per acre. The greatest difference in yield due to insecticide spray treatment was seen at the intermediate seeding date in 2020 when spraying a foliar insecticide increased yield by 491 lb. per acre from 1,907 to 2,398 lb. per acre.

Each two-week delay in seeding delayed flowering by 10 to 11 days (Table 3). This pushed flowering and seed filling later in the summer to a time with higher temperatures and lower relative humidity, which would increase the environmental stress on the crop. The time from seeding to flowering decreased as seeding was delayed. This likely reduced the amount of above and below ground vegetative growth of the crop prior to flowering. A five-inch reduction in plant canopy height at the late seeding date shows the reduced growth. This means that in addition to the seed fill period occurring in a more stressful environment, the plants were smaller and could not produce the same resources for seed set. These factors likely are responsible for the yield losses with delayed seeding.

Table 2. Average flea beetle damage score (scale of 1 to 9 with 9 being no damage), seed yield (lb. per acre), and oil content (%) of five canola, rapeseed, and mustard cultivars with three seeding dates when grown near Moscow, Idaho in 2018, 2019 and 2020.

Seeding Dates	Flea Beetle Damage (1-9 score, higher is better)	Seed Yield (lb./acre)	Oil Content (percent)
Early	7.2 [b]	2,470 [a]	42.9 [a]
Intermediate	7.0 [a]	1,964 [b]	42.2 [a]
Late	7.5 [c]	1,086 [c]	39.7 [b]
LSD (p=0.05)	0.2	186	1.0

Means within columns with different superscript letters are significantly different (*P*<0.05).

This study showed that delaying planting until late May resulted in a slight decrease in flea beetle damage, perhaps due to a cessation of feeding as the adult flea beetles completed their life cycle and died, but any positive effect was far outweighed by yield losses associated with delayed planting. The study also showed that even with relatively low flea beetle pressure, a foliar application of insecticide can be justified and will increase seed yields of spring canola. At a canola price of 20 cents per pound, the average seed yield increase of 212 lb. per acre observed in the trial has a value of $42 per acre, which should cover the cost of insecticide and application. With higher flea beetle pressure and the current higher prices, the economic return of an insecticide application would be greater.

Table 3. Average flower date, days from seeding to 50% flowering, and plant canopy height of five canola, rapeseed, and mustard cultivars with three seeding dates when grown near Moscow, Idaho in 2018, 2019, and 2020.

Seeding Dates	50% Flower Date	Days to 50% Flower	Plant Height (inches)
Early	June 17 [a]	51 [a]	44 [a]
Intermediate	June 27 [b]	45 [b]	42 [b]
Late	July 8 [c]	43 [c]	39 [c]
LSD (p=0.05)	0.3	0.3	1.8

Means within columns with different superscript letters are significantly different (*P*<0.05).

Use of Agronomic Approaches to Improve Stand Establishment in Winter Canola

SHAHBAZ AHMED AND MICHAEL M. NEFF
DEPT. OF CROP AND SOIL SCIENCES, WSU

Expanding oilseed cultivation in the Pacific Northwest (PNW) is important not only for the edible oil production for human consumption but also as a rotation crop with winter wheat. Both winter and spring canola are being grown in the PNW, but winter canola has more yield potential compared to spring canola in this region. Winter survival of canola depends on many factors including the planting date, seeding depth, seeding rate, plant stature, and cultivar genetics. Our lab is using a combination of molecular and agronomic approaches to study and improve the winter survivability of winter canola in the inland PNW.

Improved stand establishment via early planting results in an increase in plant size. This increase in plant size, however, can favor winter kill. We are using the plant growth inhibitor paclobutrazol to manipulate plant growth of early planted winter canola. We have carried out experiment to determine the optimum concentration of paclobutrazol for reducing plant height in early seeded canola. Due to the unavailability of commercial paclobutrazol for canola, we chose to make our own product in-lab to determine the working solution for controlling plant height at seedling stages. Paclobutrazol powder from PhytoTechnology Laboratories was used to make spray solutions. The following rates were used to determine the optimum dose and study its effect on canola seedling growth: 150mg/200ml, 300 mg/200ml, and 400 mg/200ml. A series of greenhouse experiment showed that the 150mg/200ml rate effectively reduced seedling growth (Fig 1).

Figure 1. Control (left) vs. Paclobutrazol (right) (150mg/200ml) in greenhouse trials.

Based on our greenhouse trials, a rate of 150mg/200ml was also used in field experiments at the Washington State University Grass Breeding and Ecology Farm in Pullman, WA. Paclobutrazol was applied early in the day to avoid transpiration of the chemical solution and to enable the maximum absorption of solution in plant leaves. Plants treated with chemicals showed reduced height with leaves appearing to spread around the crown and no upward growth for the first two weeks (Fig. 2). Spreading of leaves around the crown may provide protection against frost and low winter temperatures. The same experiment will be repeated this year on early planted canola to study the winter survival of treated and untreated plots.

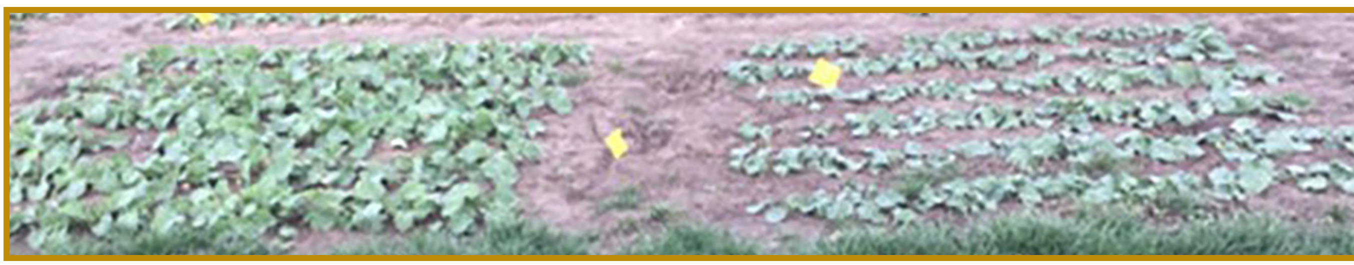


Figure 2. Control (left) vs. Paclobutrazol (right) (150mg/200ml) in field trials.

Our lab is also carrying out a winter tolerance screen on a collection of *Brassica napus* germplasm grown in the inland PNW region. A collection of 144 winter *Brassica napus* accessions is being screened at the Washington State University Grass Breeding and Ecology Farm in Pullman, WA for yield and winter survivability (Fig 3). A multi-year trial of this experiment is being conducted to understand the genetics of winter tolerance, as well as identify lines with better winter survival and yield to incorporate in future winter canola breeding programs at Washington State University.

Together, these agronomic approaches should help us develope new agronomic practices and germplasm with better stand establishment and winter-kill tolerance. As a result, these studies may help farmers in the inland PNW plant more acres of winter canola.

Figure 3. Screening of Brassica napus accession in the field for yield and winter tolerance.

Plant Density and Pod Count Variation Within Large-Scale Variety Trials

ISAAC J. MADSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU

In addition to yield data, large-scale variety trials can be utilized to improve out understanding on a variety of other yield related variables. During the summers of 2019 or 2020 plant counts were collected at all the large-scale variety trial locations for a total of five site years. Additionally, pod counts were collected at two locations in 2019 and two locations in 2020 for a total of four site years of data. The importance of stand and pod count have been discussed previously and various research has sought to form connections between stand count and yield as well as the pod count and yield. In five site years stand count data was not correlated with yield at the field scale (figure 1). The average stand count within each strip ranged from 1-7 plants ft^{-2}. These results indicate that spring canola yield is stable over a wide range of stand densities. The branching architecture of canola allows it to develop a full canopy when plant density is low. A clear example of this is in the Cloverland 2020 data. Over the five stie years Cloverland was among the lowest plant densities and had the highest yield. Untimely frost, inappropriate nitrogen applications, low moisture, and insect pressure may all result in poor stands. However, no clear guidance for replant decisions can be found in the regional literature. Our future research will focus on developing decision support for replant. In light of the weak correlation between stand count and yield, some have hypothesized a correlation between pod count and yield. However, in our research no inter year correlations between pod count and yield have been achieved. Future research will focus on a more robust spatial analysis of plant density and pod count.

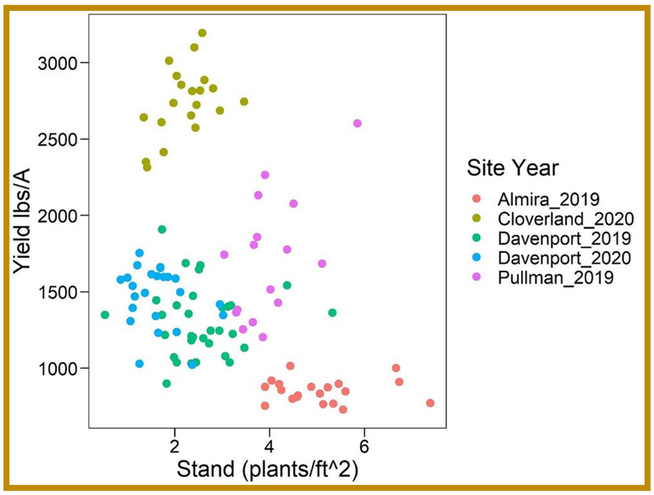


Figure 1. Stand count and yield from five site years of spring canola data. It appears that no relationship between stand count and yield exists even at low stand densities < 2 plants ft^{-2} high yields can be achieved as is seen in Cloverland 2020.

Spring and Winter Canola Large-Scale Variety Trials

ISAAC J. MADSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU

Small plot variety trials serve to assess the relative yields and traits of varieties. However, small plots do not capture the effect of landscape on different varieties. In order to assess the effect of landscape on yield and other important agronomic variables it is important to test varieties on a larger scale (Fig. 1). The large-scale variety trials are planted with a production scale drill and range from 400-600 ft in length. Each variety was replicated four times to allow for statistical comparisons of yield, stand counts, and pod counts. During the 2019-2020 growing season two large scale winter variety trials were established at Cloverland and Ralston. The Cloverland trial was sprayed out in the spring of 2020 due to severe winter kill which had reduced the stand by greater than 95%. The Ralston location was taken to harvest and the results are presented here. Mercedes was the highest yielding variety followed by Surefire, Phoenix, Claremore, and Griffin. Falstaff had the lowest yield. Two spring canola trials were established near Davenport and Cloverland. Liberty Link (InVigor L233P), Roundup ready (BY6080, HC930, HC9919), Clearfield (BY5545), and non-resistant (NCC101s) varieties were entered into the trial. At the Davenport location, herbicide drift between the plots resulted in convoluted yield data with no significant differences between varieties. However, at Cloverland there were significant differences between yield with NCC101s and InVigor L233P having significantly higher yields than the BY5455 and HC9919. HC930 was not significantly lower than InVigor L233P and NCC101s, but was not significantly higher than BY5545. When selecting varieties, it is important to consider the herbicide history, weed pressure, and economics as well as the yield. Non-GMO varieties offer a premium while the GMO varieties offer more in crop weed control options.

Figure 1. Strip trials near Pullman, WA demonstrate the landscape variability which can be captured with large scale trials.

	Spring Canola				**Winter Canola**		
	Davenport		Cloverland			Ralston	
BY5545 CL	1547.75	a	2647.75	b	Mercedes	2478.16	a
BY6080	1392.5	ab	-	-	Surefire	1978.58	b
HC930	1558	a	2805.25	ab	Phoenix	1879.89	b
HC9919	1629	a	2429.75	c	Claremore	1726.07	bc
InVigor L233 P	1280.5	b	2893.75	a	Griffin	1650.52	bc
NCC 101 s	1401.25	ab	2940	a	Falstaff	1461.98	c
Mean	1468		2743		Mean	1862	
CV (%)	11.8		5.22		CV(%)	14.6	
LSD	257		216		LSD	404	

Washington Oilseed Cropping System Extension and Outreach

ISAAC J. MADSEN AND IAN BURKE
DEPT. OF CROP AND SOIL SCIENCES, WSU

The Washington Oilseed Cropping System (WOCS) project focuses on conducting research and extension to improve oilseed production in Washington. Over the past 14 years, the WOCS project has conducted research on safflower, sunflowers, flax, camelina, and canola. The WOCS research program has focused a range of research areas including but not limited to fertility, oil quality, weed management, crop density, planting date, and crop rotation. Effectively disseminating the information generated from this research is also in the purview of the WOCS project. The COVID-19 pandemic stalled many of the WOCS extension plans for the year 2020. However, webinars, podcasts, and videos were disseminated via web platforms. WOCS extension personal presented on Zoom webinars to more than 500 growers across the Pacific Northwest in the winter of 2020. The topics covered in these webinars included the most innovative research conducted as part of the WOCS project as well as important information regarding herbicide carryover. While it was disappointing to not meet with growers in person, webinars successfully reached a wider audience the previous years in person extension events. We will likely continue webinars as a core part of our extension program for the foreseeable future. In addition to webinars, three field day videos focused on canola production were recorded in collaboration with the Small Grains Extension Team. The videos focus on information regarding canola varieties, production practices, and rotations. The videos can be found in on the Small Grains website in the video library (https://smallgrains.wsu.edu/additional-resources/video-resource-library/). Three canola production podcasts were also recorded and can be found on the small grains podcast page. (https://smallgrains.wsu.edu/category/podcast/). During the 2021 growing season, the WOCS extension team will be posting weekly or bi-weekly photos of our field operations the WOCS Facebook page (https://www.facebook.com/WSUOilseeds/). For more information on canola varieties and production methods you can go to the WOCS website (www.css.wsu.edu/oilseeds). In the fall of 2021 and the spring of 2022 we hope to resume in person events.

Determining Optimal Foliar Fungicide Application Timing for Control of Blackleg Disease of Winter Canola and Tracking *Leptosphaeria maculans* Spore Release in Northern Idaho

KAYLA M. YEAROUT-JANOWSKI, JIM B. DAVIS, AND KURTIS L. SCHROEDER
DEPT. OF PLANT SCIENCES, UI

Blackleg disease of canola (*Brassica napus*) is caused by the fungal pathogen *Leptosphaeria maculans*. Worldwide, blackleg is one of the most destructive canola diseases, and it is an emerging problem in seed production for the Idaho oilseed industry. Researchers and growers have limited knowledge of how environmental conditions impact the pathogen's development and distribution in northern Idaho and elsewhere in the Inland Pacific Northwest.

Figure 1. Burkard volumetric spore trap.

Blackleg infection is caused by wind-blown spores (ascospores), rain-splashed spores (conidia), and infected seed, however the source of initial disease infection for the region and spore movement is unknown. Therefore, Burkard volumetric spore traps (Fig. 1) have been placed adjacent to winter canola fields to identify the main source of inoculum and weather conditions associated with spore release. These traps pump air through an orifice and deposit any particles on a piece of tape that is then used for direct visualization of spores under a microscope. Ascospores were detected between April and June 2020 at average monthly temperatures of 44 to 57°F (Fig. 2), suggesting that the initial infection may be caused by ascospores, with secondary infections during the same growing season caused by conidia. Further research will be conducted using PCR to identify *L. maculans* DNA on tape samples to confirm the presence of ascospores and to check for the occurrence of conidia which cannot be visually identified microscopically. By understanding when spores are released, guidelines for fungicide application can be developed to provide optimal control of blackleg in winter canola.

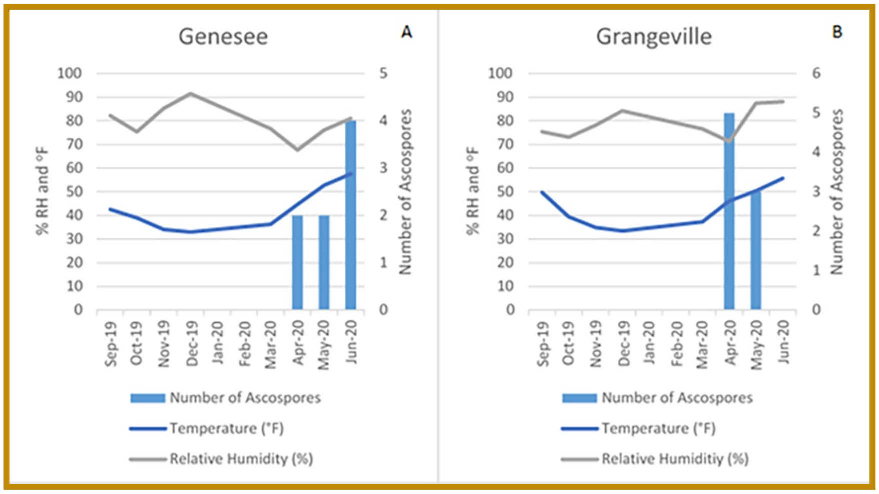


Figure 2. ***Leptosphaeria maculans*** **ascospore counts and weather conditions at Genesee (A) and Grangeville (B) during the 2019-2020 field season.**

To test the effectiveness of fungicide applications to limit blackleg and determine optimal application time, field trials were established in Moscow, Genesee, and Nezperce consisting of cultivars Mercedes (resistant to blackleg) and Amanda (susceptible to blackleg). Foliar fungicide [Priaxor® (fluxapyroxad and pyraclostrobin)] applications were made in the fall, spring, or both. Disease incidence (Fig. 3) in the no-fungicide control plots was low at Genesee (13%) and Moscow (25%), but moderate at Grangeville (61%). The disease incidence was significantly reduced by either a fall (3 to 28%) or spring (1 to 16%) fungicide application, but the lowest disease incidence occurred when fungicides were applied in both the fall and spring (1 to 5%). While no yield response to fungicide application was observed, reducing the incidence and severity of blackleg is critical for the region's seed production industry.

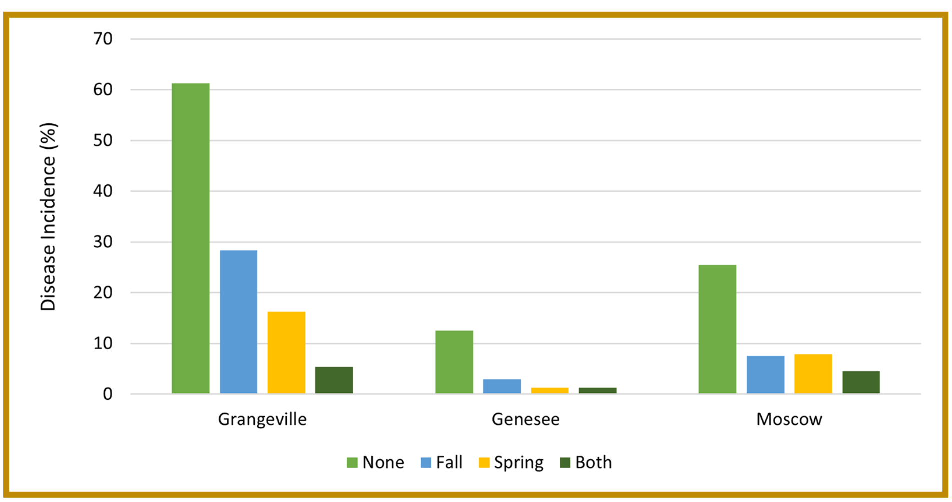
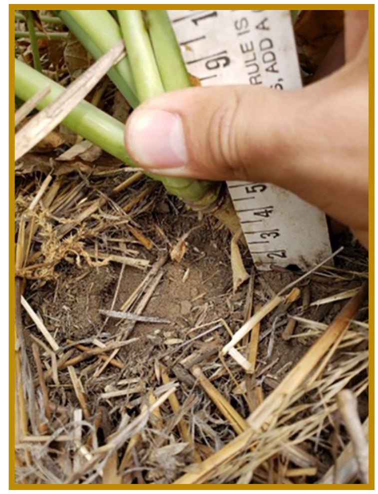


Figure 3. Blackleg disease incidence in winter canola following an application of foliar fungicide in the fall, spring, or both (fall/spring) during the 2019-2020 field season. Bars with the same letter within each group are not significantly different from each other using LSD ($p < 0.05$).

Foliar Applied Plant Growth Regulators as a Method for Improving Winter Canola Winter Survival

JESSE FORD AND ISAAC J. MADSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU

Plant growth regulators are used in agriculture to manage plant size throughout the growing season. In eastern Washington, winter canola production is stymied by planting date decisions. Early planted winter canola can experience crown elongation during the fall which increases its susceptibility to winter kill while late planted water may lack the moisture establish a good stand. By adding a plant growth regulator treatment to early planted winter canola, we hypothesized that the plant growth regulator would reduce the crown height of canola plants and increase winter canola survival rates. Experiments were conducted at Ritzville, Davenport, and La Crosse during the fall of 2020. The planting dates were June 28th, July 10th, July 26th. Split and single rate applications of plant growth regulator were applied, with the first application occurring at the 4 to 6 true leaf stage and the second application being applied in late August. We staked individual plants to track plant specific responses and collected measurements between October 26th and November 4th. These measurements included crown height, crown width, plant canopy width, and leaf count. The following spring, these plants were evaluated for survival between March 8th and April 7th. While crown height has a significant impact on winter survival (Fig. 1), we did not discover significant evidence at most sites that the plant growth regulator application decreased crown height. However, we achieved a significant decrease of the crown height at a trial in Lacrosse (Fig. 2). From the preliminary data it appears that there is a complex relationship between plant density, planting date, and PGRs which affect crown height and winter survival. Further research is being planned to experiment with dosage rates and timing of the plant growth regulator application to discover the potential of plant growth regulators in winter canola production.



Measuring the crown height of a winter canola plant.

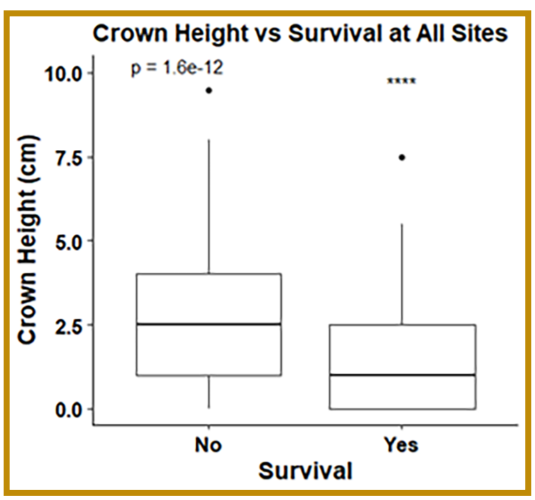


Figure 1. Significant evidence was found that a shorter crown height improves winter survival probability.

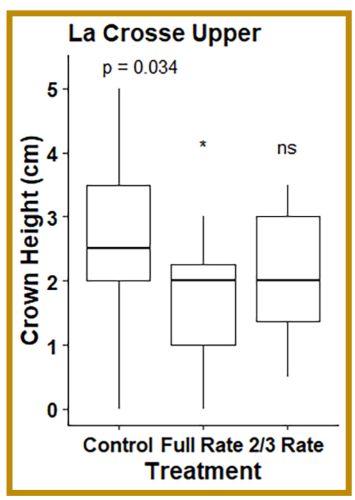


Figure 2. A significant decrease in the crown height of canola receiving a full rate of plant growth regulator at Lacrosse was found.

Phosphorus Fertility Management for Canola

HAIYING TAO[1], AARON ESSER[2], STEPHEN VAN VLEET[2], AND ISAAC MADSEN[1]
[1]DEPT. OF CROP AND SOIL SCIENCES; [2]WSU EXTENSION

Research have found that phosphorus (P) deficiency in canola can result in poor root development, thin stems, narrow leaves, fewer and smaller branches, leaf drop earlier. P application in low P soils can increase yield and promote earlier maturity, but knowledge on how P sufficiency affect seed oil content is unclear. In addition, there is limited literature on P fertilizer recommendations based on soil test or crop removal. The objectives of this research were to (1) study winter and spring canola yield, quality, and economic response to P fertilizer in eastern Washington; (2) calibrate soil test P and establish critical soil test P level for eastern WA; (3) investigate the appropriate soil sampling depth and soil test method for the soil test calibration.

The two-year study was established in fall 2019 and 2020 for winter canola and spring 2020 and 2021 for spring canola on Washington State University Wilke Research and Extension Farm in Davenport, WA. The P management factors studied including rate (0, 20, 40, 60, 80 lbs/acre), timing (fall, split), and interaction with zinc (P fertilizer with/without zinc fertilizer). We will establish two on-farm small plot research with similar design in Pullman, WA in 2021. Soil samples were taken before and after P fertilization at 12 inch deep and each soil core was separated into 0-6 and 6-12 inch segments. Samples were tested for P using Olsen method. Plant samples were taken at major growth stages for measuring total P uptake. We will start analyzing data after harvest in fall 2021. The results will be presented to farmers via presentations at workshops and extension publications in 2022 and 2023.

Phosphorus fertility study trial for winter canola. Photo taken by Keith M. Curran on May 10, 2021

Companion Crops as a Method for Improving Winter Canola Stand Establishment and Winter Survival

JESSE FORD AND ISAAC J. MADSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU

Companion cropping is the practice of cropping two different plant species near each other to benefit each other in some way. In production agriculture, companion cropping typically consists of a cash crop and one or more "companion" crops. The goal is that the companion crops will benefit the cash crop in some way. A cropping system of interest is using spring oats as a nurse crop for winter canola to provide better establishment and winter survival potential for the canola crop. This cropping system is especially of interest to growers with livestock as the oats can improve the feed value of the forage in a grazing situation. We established an experiment comparing monocrop canola to a canola-oat crop near Davenport, WA on July 10th of 2020. This was planted into fallow using a Fabro double disc drill achieved excellent stand counts. Fall stand counts did not show a significant difference in canola establishment between the two treatments (Fig. 1). The canola oat crop did have a higher average stand count of canola at 4.74 plants/ft^2 than monocropped canola at 3.83 plants/ft^2 and showed less variability in stand establishment. There was also no significant difference in winter survival percentage between treatments in both our overall stand counts and individual plants (Figs. 2 & 3). Mono-cropped canola had an average winter survival of 26.5 percent while the companion cropped system had an average just over 24 percent. This disappointing survival rate may be contributed to drought stress caused by excessive overall plant populations that depleted the soil water supply during early fall. The fact there appears to be no significant advantage to mono-cropped canola and that oats may increase stand establishment of winter canola is encouraging for the prospects of companion cropping in eastern Washington. This especially holds true for growers interested in integrating livestock to their cropping systems. We intend to pursue future research into the seeding rates of both canola and oats in a companion crop system as well as the impact of grazing livestock in the system as well.

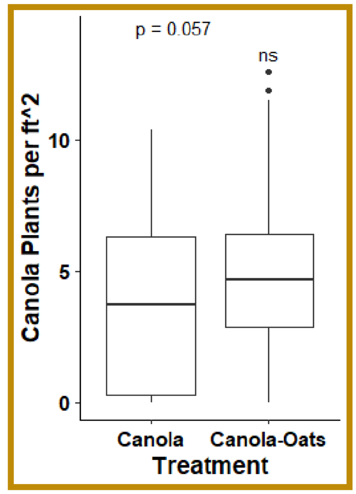


Figure 1.

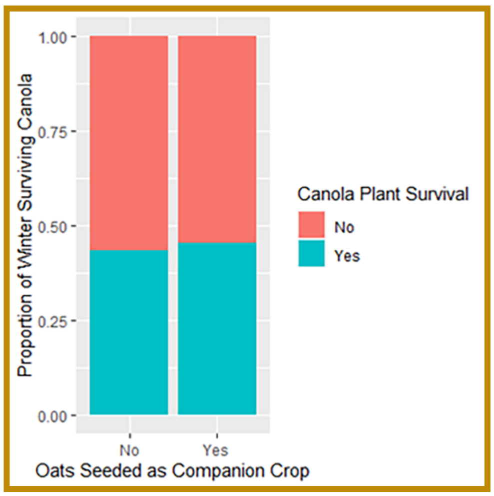


Figure 2.

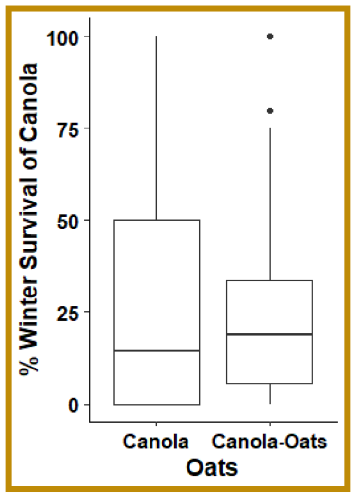


Figure 3.

Peaola Intercropping as a Pest and Beneficial Insect Management Tactic

ROBERT CLARK[1] AND ISAAC MADSEN[2]
[1]DEPT. OF ENTOMOLOGY, WSU; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Monoculture production systems dominate modern industrial agriculture. However, intercropping cash crops may increase productivity while reducing fertilizer input through the inclusion of legumes. One intercrop of interest in the inland Pacific Northwest is peaola (pea-canola). Peas and canola have complimentary above and below ground architectures and have been successfully intercropped at the field scale in Canada. Most intercropping research has focused on seeding rates and fertility. Intercropping strategies have additional benefits as pathways to manage pest insects, pathogens, and beneficial species. By providing pollinator resources and two very different host plant species, peaola intercropping may support more beneficial species while also reducing the risks of pest outbreaks. In 2020 we completed field surveys from a replicated large scale peaola trial near Colfax, WA where we measured the abundance of pests and beneficials among pea, canola, and intercropped peaola. To complete these surveys, in June 2020 we used sweep nets to collect all insects and identified them to functional group (pollinator, parasite, predator, herbivore).

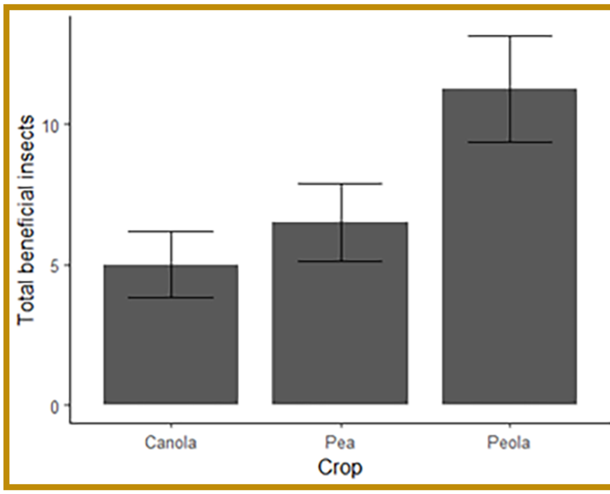


Figure 1. Average counts of beneficial insects (and estimated standard errors) based on 2020 field survey. Bars with error bars that do not overlap are significantly different. Output estimates from negative binomial generalized linear mixed model.

At our field trial site, pest herbivores (mostly pea aphids) were significantly higher in Pea only plots ($P < 0.001$, GLMM, Fig. 1). Beneficial insects, including pollinators, parasitoid wasps, and ladybugs, were significantly higher in Peaola trails compared to either peas or canola ($P = 0.0107$, GLMM, Fig 2). Consequently, even though Peaola contained peas and was located at the same site, the intercropping strategy greatly reduced the threat of pea aphids. This was likely driven by the presence of more beneficial insects in peoala, including two primary biocontrol agents for aphids (wasps and ladybugs). In terms of LER (Land Equivalence Ratio) Peaola trials did not have significantly higher yield than monoculture peas or canola ($P = 0.849$, GLMM, Fig 3) Given that Peaola may require fewer pest management inputs (Fig. 1, Fig. 2), this intercropping strategy may be profitable in years or locations where pest outbreaks occur. Further research may be able to demonstrate if canola yield is proportionally higher due to higher pollinator abundance, and if reduced reliance on pesticides for control of dry pea pests (aphids) may be an economic and ecological benefit of Peaola.

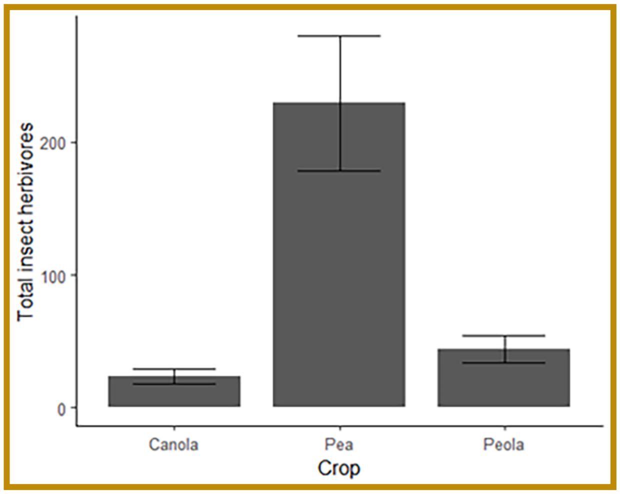


Figure 2. Average counts of insect herbivores (and estimated standard errors) based on 2020 field survey. Bars with error bars that do not overlap are significantly different. Output estimates from negative binomial generalized linear mixed model.

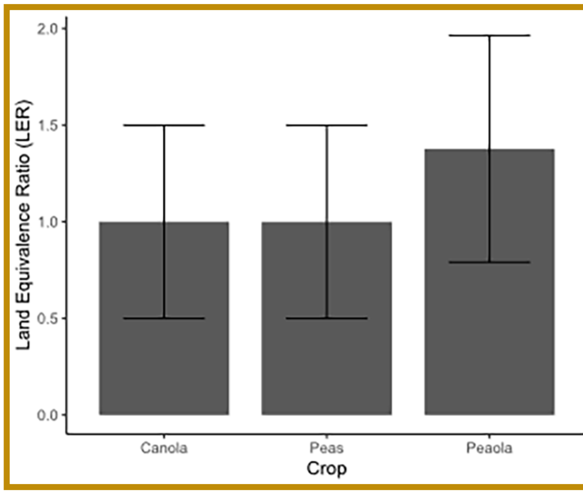


Figure 3. Land Equivalence Ratios (LER) for both canola seed and dry pea seed (and estimated standard errors) based on 2020 field trial. Bars with error bars that do not overlap are significantly different. Output estimates from negative binomial generalized linear mixed model.

Canola Rotation Effects on Soil Microbiology and Subsequent Wheat Yield

BILL SCHILLINGER[1], RON JIRAVA[2], TIM PAULITZ[3], JEREMY HANSEN[3], JOHN JACOBSEN[1], AND STEVE SCHOFSTOLL[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]FARMER COLLABORATOR, RITZVILLE; [3]USDA-ARS, PULLMAN

We are investigating the effects of canola, winter triticale, and winter wheat on soil fungal and bacterial communities and the grain yield of subsequent spring wheat. The study was initiated in 2016 on the Ron Jirava farm west of Ritzville. These are 3-year rotations with a year of fallow after the spring wheat. Spring canola is substituted for winter canola when adequate winter canola stands are not achieved. There are 36 plots with each phase of the three, 3-year rotations present each year. Individual plots are 500 feet long and 30 feet wide.

This experiment is now in its 6th year, thus all three rotations are truly “in rotation”. We closely monitor soil water dynamics from all phases of all rotations and collect accurate grain yield data. Soil microbial activity is currently being assessed using DNA sequencing of rhizosphere soil (i.e., soil adhering to roots) as well as phospholipid fatty acid analysis (PLFA) of bulk soil. Such data can only be obtained through long-term cropping systems experiments.

During the past five years, significantly less overwinter precipitation has been stored in the soil in canola stubble in three years (Fig. 1). Averaged over the five years, canola stubble has stored significantly less over winter precipitation in the soil than winter triticale or winter wheat stubble. These differences were particularly pronounced during a winter of heavy snow accumulation in 2017. There were no significant differences in water storage among treatments during winters with little snow (such as 2019 and 2021). Average spring wheat grain yields for the first four year after canola, winter triticale, and winter wheat have been 33, 41, and 39 bushels/acre, respectively (Fig. 1).

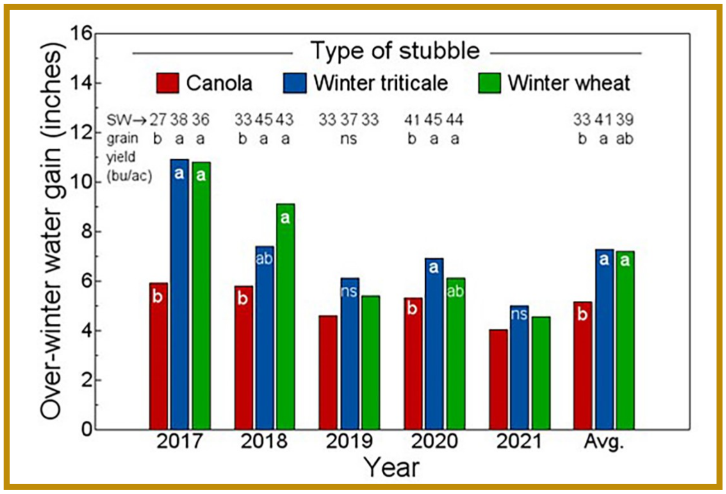


Figure 1. Soil water content in early spring near Ritzville, WA for five years where the previous crop was canola (either winter or spring canola), winter triticale, or winter wheat. Soil water at harvest of these crops was essentially identical every year and stubble remained standing and undisturbed over the winter. Spring wheat grain yield in 2017, 2018, and 2019, and 2020 as well as the 4-year average as affected by the preceding crop is shown above the soil water content bars. Within-year soil water and spring wheat grain yield data followed by a different letter are statistically different at the 5% probability level. ns = no significant differences.

Every year to date, spring wheat grain yields have been significantly related to soil water content measured in early April (Fig. 2). However, as can be seen from the simple linear regression equations in Figure 2, soil water content is not telling the full story on spring wheat yield. We suspect soil microbial activity may play an important role and we look forward to fully analyzing the soil DNA sequencing and PLFA data during this next year.

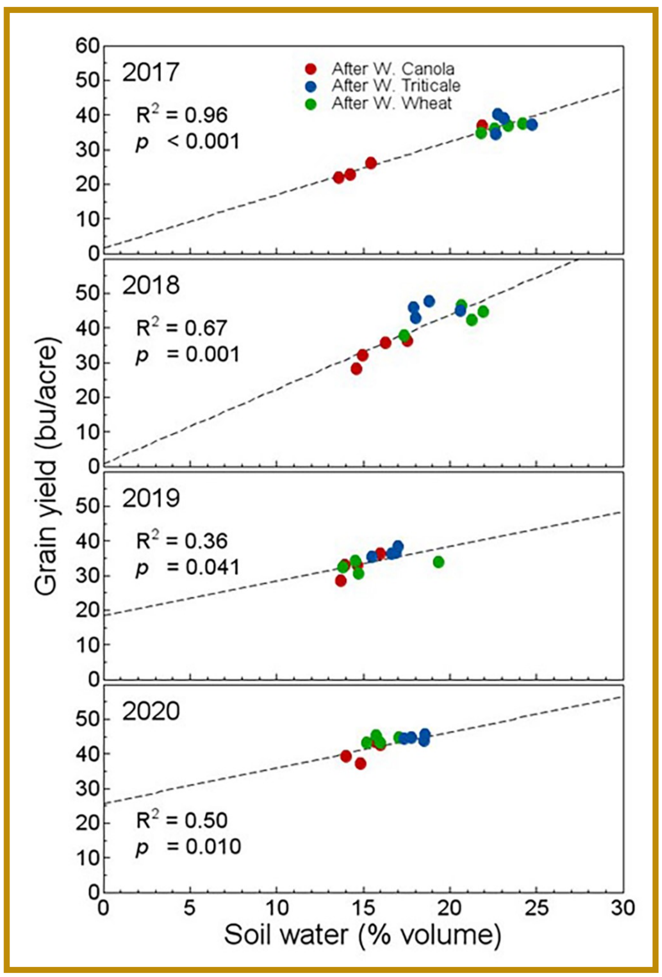


Figure 2. Relationship between soil water content in the 6-foot profile measured at time of planting of spring wheat and the subsequent grain yield of spring wheat where the preceding crop was winter wheat, winter triticale, or canola during four years near Ritzville, WA. Data show that spring wheat grain yield was significantly related to soil water content in early spring, but soil water is only part of the story.

Winter Survival Results from Ralston Winter Canola Variety Trial

JESSE FORD AND ISAAC J. MADSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU

Planting variety trials gives researchers the opportunity to compare varieties for various traits and characteristics beyond final yields. Six varieties of winter canola were planted in a variety trial near Ralston on August 31st into summer fallow using a HZ deep furrow drill. Individual plant measurements and stand counts were collected on October 27th and survival counts were taken on March 17th. The varieties included Phoenix, Mercedes, Claremore, Surefire, Griffin, and Plurax. The plant measurements consisted of crown height, crown width, canopy width, and leaf count. Leaf count was found to be significantly different for Griffin, while all other plant measurements did not differ significantly across varieties (Fig. 1). This was part of a larger research project across eastern Washington to assess winter canola plant sizes entering winter to better predict their winter survival probabilities. Claremore had a significantly higher winter survival rate and Mercedes had a significantly lower winter survival rate when compared across varieties (Fig. 2). However, final spring plant counts were not statistically different across the varieties (Fig. 3).

Staked canola plant near Ralston captured on March 17th after surviving winter.

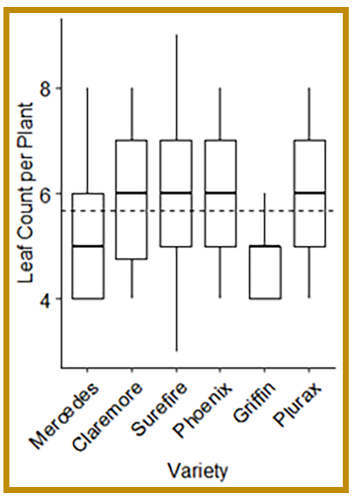


Figure 1. Graph showing that the leaf count for the Griffin variety was significantly lower than the other varieties. The dashed line represents the mean leaf count across varieties.

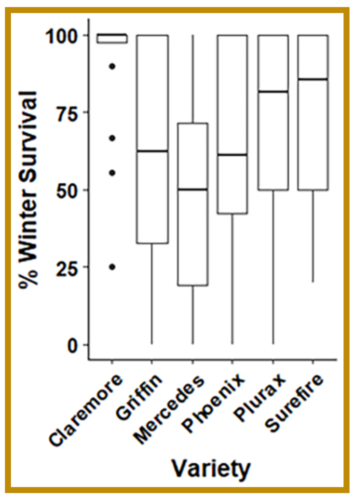


Figure 2. Claremore and Mercedes had significantly different winter survival percentages across varieties with Claremore being significantly higher and Mercedes being significantly lower.

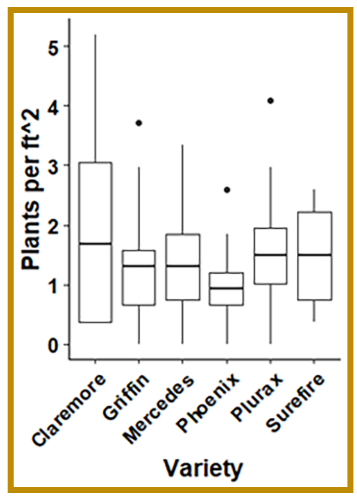


Figure 3. Spring plant counts were not statistically different across the six varieties of winter canola.

Canolage: Dual-Purpose Winter Canola

ISAAC J. MADSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU

Dual-purpose crop production is common in the wheat growing regions of the Southern Great plains and part of Australia. Dual-purpose crop production involves the utilization of the vegetative stage of an over winter grain crop as a forage. The forage crop may be swathed or directly grazed for biomass harvest. The assessment of dual-purpose winter canola (canolage) has largely utilized swathing or mowing to 'simulate grazing'. However, the impacts of swathing are likely different than the impacts of grazing on the seed yield. From 2017 to 2020 we conducted three canolage trial involving live cattle rather than swathing. We believe these results are useful in understanding the impacts of grazing on yield as well as the potential for widespread canolage production in the inland Pacific Northwest. At two different locations and years, Dusty (2017) and Creston (2019), canola seeded in July successfully survived the winter and was harvested the following year. In Dusty during 2017, the severity of grazing was found to decrease canola seed yield (Table). At Dusty in 2018, the canola was seeded in May in the hopes of allowing for two grazing events. The early seeding ended with a killing drought in the fall of 2018 in the ungrazed canola and drought that reduced seed yields to 700 lbs/acre in the grazed canola. The fact that the grazed canola did not completely succumb to drought, while the ungrazed canola did, indicates that grazing had the effect of reducing water usage. Soil moisture probes supported this conclusion as the canola that was grazed had reduced fall moisture usage when compared with the ungrazed canola. The best approach to dual-purpose winter canola in the inland Pacific Northwest appears to be an early July planting and an August or September grazing. Future research will continue to assess the impacts of grazing on winter survival and seed yield in an attempt to optimize canolage production systems in the region.

	Treatments	Yield (lbs/a)	Grazing pressure
Dusty* 2017-2018	Pasture 1	2460	Heavy
	Pasture 2	2140	Severe
	Pasture 3	3320	Light
	Ungrazed	3380	None
Dusty 2019-2020**	Grazed	700	Severe
	Ungrazed	0	None
Creston***	Grazed	1820	Heavy
	Ungrazed	2840	None

*No replication

**May planting resulted in drought

***Replicated strips w/ commercial combine

Peaola Yield and Land Equivalence Ratio Experiments

ISAAC MADSEN AND JESSE FORD
DEPT. OF CROP AND SOIL SCIENCES, WSU

Peaola is the practice of inter cropping peas and canola in the same field at the same time. Intercropping is a common practice in many subsistence systems around the world but is not common in large scale commodity production in industrial agriculture. In recent years there has been a growing interest in the potential for oilseed legume intercropping in industrial agriculture. Research has been conducted in both Australia and Canada and found that legume-brassica systems have the potential to outperform the monoculture comparisons. Beginning in the fall of 2019 the researchers at WSU began establishing pea-canola (peaola) intercropping trials in the grain fallow region of E. Washington. An attempt to establish winter peaola was made at both Ralston and Davenport. However, due to low moisture only the site at Davenport was successfully established. The Davenport site consisted of three N fertilizer rates 0, 30, and 60 lbs/acre. In the spring of 2020 a single spring peaola trial was established near Colfax. At the Colfax site only one fertilizer rate was applied to the peaola. In order to compare intercropping systems to monoculture systems the land equivalence ratio (LER) is calculated. The land equivalence ratio is calculated by summing the relative yields of whatever crops are mixed into the intercrop. The relative yields are calculated using the following equations Relative Pea Yield = Intercropping Pea Yield / Monoculture Pea Yield and Relative Canola Yield = Intercropping Canola Yield / Monoculture Canola Yield. LER can be thought of as an index of over yielding on a per acre basis. When calculating the LER the monocultures of both crops will always have a value = 1. In the Davenport and Colfax locations the LER of the peaola was found to be significantly greater than the control monoculture treatments (Table 1). While the LER is a useful tool for determining the overall over yielding, it does not capture the full picture. Another consideration is the relative yield of the peas and the canola as the price differentials between canola and peas may be great. A comparison of the relative yields shows whether the system is biased to a higher proportion of peas or canola (Fig. 1). The results from Davenport and Colfax show that the system is biased towards canola. With canola being a more marketable crop in the current economic state, we find this encouraging. While yields were quite low at Colfax due to insect damage and shattering loss, the increased LER from peaola was still encouraging. The first year of data from this study has been profitable for increasing our understanding of the potential for peaola in eastern Washington. Future research will focus on stand establishment, fertilizer rates, and insect ecology in peaola systems.

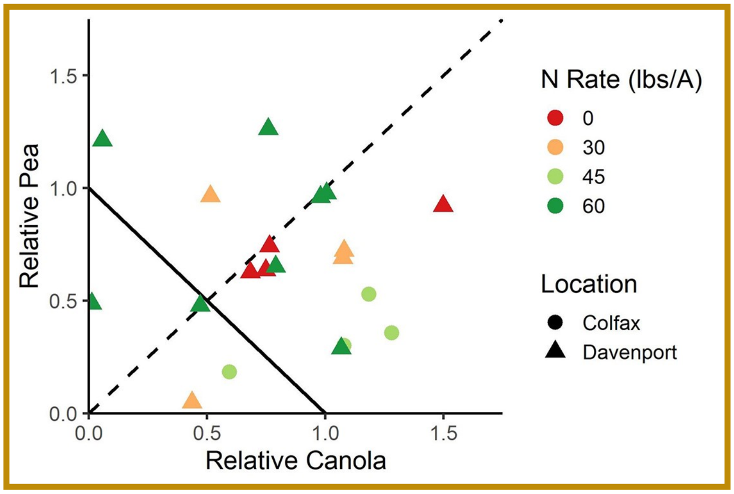


Figure 1. Relative pea vs. relative canola yield from peaola trials conducted harvested in 2020. Trials conducted at the Colfax location were spring seeded, while the trial conducted at Davenport were fall seeded. All points to the right and above the solid line have a cumulative LER of above 1. The points to the left and above the dashed line favor a higher proportion of peas relative to the control, and the point to the right and below the line favor a higher proportion of canola relative to the control. No significant trend in LER, relative pea, or canola yield was found based on N rate.

Summary of LER Table 1

Peaola	1.46	a
Canola	1.00	b
Pea	1.00	b
CV	33.50%	

Location	Crop System	N Rate (lbs/A)	Canola	Peas	LER
Colfax	Canola	90	694	0	1.00
Colfax	Pea	0	0	1273	1.00
Colfax	Peaola	45	718	436	1.38
Davenport	Canola	60	1960	0	1.00
Davenport	Pea	0	0	2455	1.00
Davenport	Peaola	0	1810	1794	1.65
Davenport	Peaola	30	1520	1487	1.38
Davenport	Peaola	60	1259	1938	1.43
Significance					
Location			***	***	ns
Cropping System			***	***	*
N Rate			.	ns	ns
Location X Cropping System			ns	.	ns

Designing Cover and Alternate Crops for Dryland Cropping Systems in the Eastern Oregon: Introduction to Resilient Dryland Farming Appropriation (RDFA)

S. SINGH[1], J. BARROSO[1], F. CALDERON[1], C. HAGERTY[1], K. REARDON[2], AND S. MACHADO[1]
[1]COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU; [2]SOIL AND WATER CONSERVATION UNIT, USDA-ARS, ADAMS, OR

Background

Limited precipitation in eastern Oregon has led to the common practice of fallowing for ~15 months to conserve soil moisture for the wheat crop. Thus, the winter wheat- summer fallow (WW-SF) rotational system has widespread use and is practiced on over 1.8 million hectares in the region. Under the WW-SF system, winter wheat is followed by a 14-month fallow. In the traditional conventional fallow, land is tilled (offset, disk, and subsurface sweep) and rod-weeded to facilitate water storage and weed control. Increasingly, growers are practicing chemical fallow where land is not tilled and herbicides are used for weed control.

Despite reliable grain yields from WW-SF systems, low residue return and lack of crop diversification are having negative impacts on soil health, soil organic matter (SOM), soil pH, and nutrients along with favoring soil-borne diseases. For example, recent studies reported >50% decline in inherent SOM in the top 30 cm of regional Walla Walla silt loam soils under WW-SF system. Researchers at Oregon State University (OSU) are constantly working to develop economically and environmentally sustainable wheat production systems. Integrating cover crops and alternate crops is one way to improve soil health and reduce the negative impacts of WW-SF system. Researchers at USDA-ARS Columbia Plateau Conservation Research Center and OSU's Columbia Basin Agricultural Research Center (CBARC) are evaluating wheat rotations involving cover crops and alternate crops under both low (22 cm) and intermediate (40 cm) rainfall zones in eastern Oregon. The researchers are also testing the potential benefits of these cropping systems on farm economics, soil health, wheat productivity, weed control, and disease suppression.

Wheat-fallow rotation system in the foothills of the Blue Mountains of eastern Oregon.

Objectives

There is currently no locally generated data to inform management decisions to develop alternate cropping systems that will improve soil health without decreasing wheat yields. Our specific goals are:

1. To determine the best adapted cover crops and alternate crops and planting dates (summer, fall, or spring) in low and intermediate precipitation sites of eastern Oregon.
2. To investigate the potential benefits of these crops in a wheat-based system (increased soil nitrogen, soil organic matter, and soil water availability; enhanced soil health; greater, water use efficiency; weed suppression, and reduced disease).

3. To evaluate the profitability of including cover and alternate crops in wheat-based systems.

Methodology

Field trials

Cover crops and alternate crops are grown in rotation with winter wheat at CBARC Pendleton (Umatilla County, OR) and at the Starvation Farms (hosted by Chris Rauch of Morrow County, OR). In these evaluations, cover crops (single- and multi-species) and alternate crops are grown during the fallow phase of the WW-SF system (Table 1). Data will be collected from these trials to test the suitability of these systems in the region.

Table 1. Types of cover crops and alternate crops under evaluation in the RDFA project

Cover crops	Alternate crops
Winter pea	Winter barley
Winter lentil	Winter lentil
Tillage radish	Austrian pea
Spring Barley	Winter pea
Phacelia	Brown mustard
Yellow mustard	Safflower
Common vetch	Flax
Fall cover crop mix	
Winter barley	
Austrian pea	
Brassica	
Spring cover crop mix	
Austrian pea	
Spring mustard	
Spring barley	
Phacelia	
Tillage radish	
Common vetch	

Data collection from the field trials

We have been and will continue to collect data and information on various aspects (Fig. 1) of these intensified cropping systems to identify the best management practices that improve the profitability and sustainability of wheat-based systems in eastern Oregon. Additionally, we will disseminate information derived from these field trials through NRCS and OSU extension bulletins, online platforms (websites, webinars, and social media), and field days.

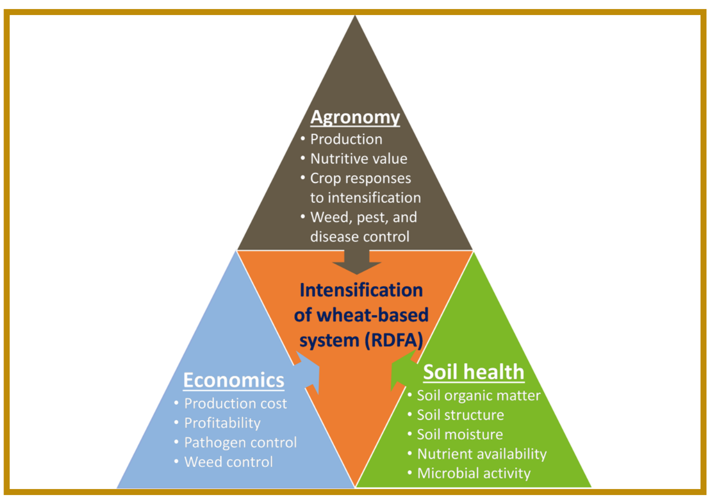


Figure 1. Various aspects of data collection under RDFA project for intensification of wheat systems from multiple study sites.

Winter Pea Response to Seeding Rates and Phosphorus and Sulfur Application in the Rainfed Region of the Pacific Northwest

SAUGAT BASKOTA AND KURTIS SCHROEDER
DEPT. OF PLANT SCIENCES, UI

Winter peas (WP) have been gaining popularity in the dryland cropping region of the Inland Pacific Northwest (IPNW) due to the need for alternative crop to be integrated into the existing cereal-based cropping system to achieve long-term sustainability. WP are an excellent crop that are adapted to the region and can contribute numerous benefits to the overall production of the cropping system. Being a relatively low input and water efficient crop, WP can provide nitrogen to the subsequent crop and reduce the use of inorganic nitrogen fertilizers. WP can be grown for various purposes such as grains, animal grazing, hay or silage, cover crops and green manure. Various studies and variety testing programs in the region have shown the production potential of WP. However, as a relatively new crop in the region for wide-scale commercial production, its response to various agronomic practices has yet to be refined in the region.

Field studies were conducted during the 2018/19 and 2019/20 growing seasons at Genesee, ID and St. John, WA to see the WP response to agronomic factors such as seeding rate (6, 8, 10 and 12 seeds per square foot) and fertilizer (20 lbs./A of phosphorus and sulfur) application. Two commercial cultivars 'Blaze' and 'Windham' were used in this study. Seeding was done in late September in each year into fields that were previously planted with spring cereals.

Crop density was significantly higher in 2019 (8 plants per square foot) compared to 2020 (5 plants per square foot) at both locations. There was a significant effect of seeding rates on crop density. The seeding rate of 12 seeds per square foot had the highest crop emergence with 8 plants per square foot at both locations (Fig. 1). Application of 20 lb./acre of phosphorus and sulfur had no effect on emergence, growth and performance of WP. Overall, WP yield in Genesee (4,125 lb./acre) was almost double compared to St. John (2,216 lb./acre). There was seasonable variation in yield with the highest yield occurring in Genesee in 2020 (4,373 lb./acre), while at St. John 2019 was a more productive year (2,470 lb./acre). When comparing the cultivars, Blaze performed significantly better than Windham in this study (Fig. 2). Additionally, there was a substantial effect of seeding rates on WP yield. In Genesee, seeding rates of 10 and 12 seeds per square foot had significantly higher yield than the rest of seeding rates. In St. John, seeding rates of 8,10 and 12 seeds per square foot produced similar yields, significantly higher than observed with the seeding rate of 6 seeds per square foot (Fig. 3). Protein content of pea seed was not significantly influenced by varying seeding rates or fertilizer application.

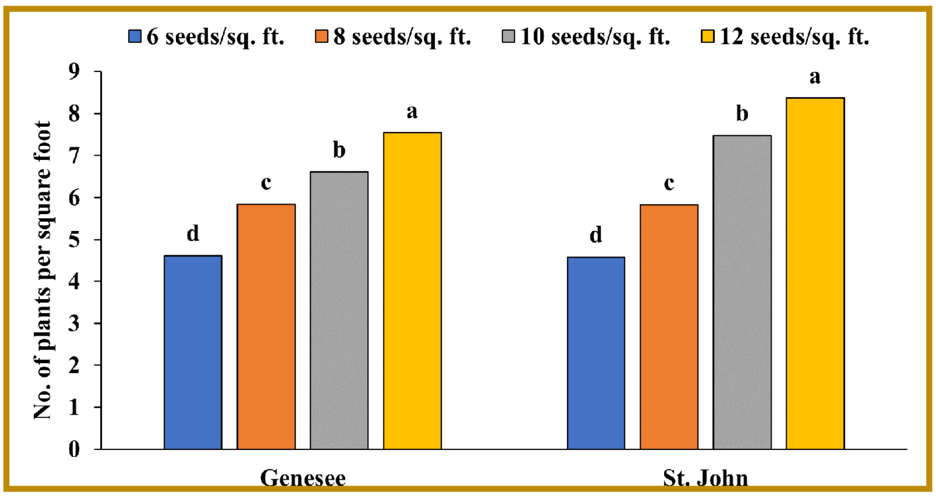


Figure 1. Crop density per square foot of winter pea at Genesee and St. John for two varieties in response to different seeding rates in 2019 and 2020.

This study further validates the production potential of WP in the region. Optimum seeding rate and use of improved cultivars that are adapted to the region will certainly help to increase the overall productivity of WP. WP has the potential to be an alternative fall planted crop that can be incorporated into the cereal-based cropping system of IPNW.

"Landscapes in Transition" is funded through award #2017-68002-26819 from the National Institute of Food and Agriculture.

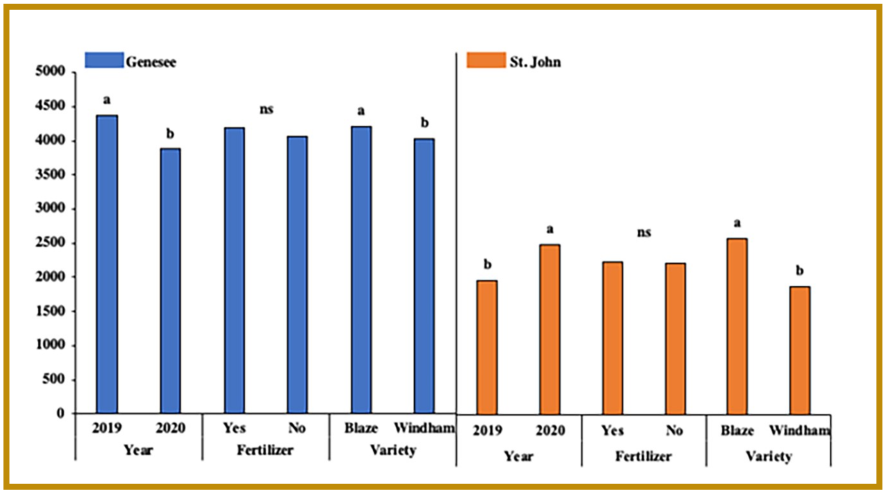


Figure 2. Winter pea yield of Blaze and Windham in 2019 and 2020 with and without 20 lbs./acre of phosphorus and sulfur application.

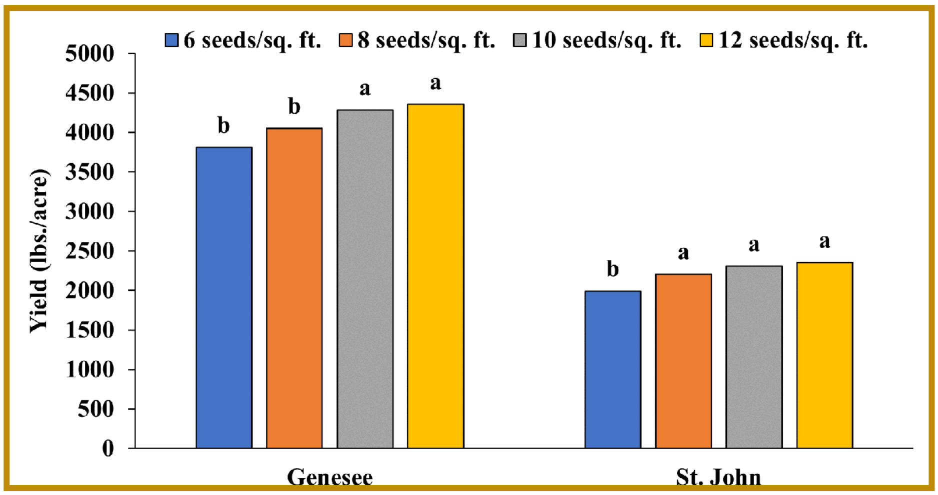


Figure 3. Yield of winter pea at varying seeding rates at Genesee and St. John in 2019 and 2020.

Triticale Grain is No Longer Just for Animals

JOSHUA HEGARTY[1], BILL SCHILLINGER[2], AND ARRON CARTER[2]
[1]DEPT. OF PLANT SCIENCES, UNIV. OF CALIFORNIA AT DAVIS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Triticale is a cereal produced by crossing the female parent of wheat with the male parent rye (*Secale cereal* L.). Both forage and grain types of triticale are grown. The focus here is grain triticale. Over many decades of breeding and agronomic evaluation around the world, triticale has delivered a grain yield advantage of 10-20% over wheat in nearly all environments where it is tested. In 10 years of dryland field experiments at both Lind and Ritzville, WA, winter triticale has produced an average 14% greater grain yield compared with soft white winter wheat. This consistent yield advantage of winter triticale over winter wheat occurs during both wet and drought years. Read full article here: https://www.mdpi.com/2073-4395/10/11/1777

While great progress has been made in yield potential of triticale, the grain quality has remained too poor for human food applications, leaving only animal feed uses for triticale grain. This has caused winter triticale production in eastern Washington to remain economically disadvantageous compared to winter wheat due to the lower market value of triticale grain.

In the last few decades, wheat breeders have gained a detailed understanding of the genetic basis of bread making quality of wheat. Recently, a group of researchers and breeders, lead by Joshua Hegarty at the University of California, Davis, are leveraging this knowledge to systematically improve the bread making quality of triticale. The first generation of triticale with improved grain quality, developed by Adam Lukaszewski at the University of California, Riverside, contain a two gene combination for grain quality, referred to as 'FC2'. In these FC2 lines, two secalin genes, which confer a weak and sticky dough, have been replaced by two of the most important gluten loci from wheat, *GluD1* (5+10) and *GluD3/GliD1*.

Triticale lines containing the FC2 chromosome have been tested over multiple years in California and Colorado and have shown significant improvements in bread making performance. In 2020, a small winter triticale yield trial, including these FC2 lines was harvested at Lind, WA. Many of the lines performed well, with an average yield of 66 Bu/A across the trial, compared to an average of 52 Bu/A for the winter wheat lines (60-pound bushels for both triticale and wheat) (Figure 1). When comparing winter triticale lines with and without the FC2 chromosome, those with FC2 showed a 5.5% increase in grain protein, 15% improvement in bread loaf volume and a 168% improvement in farinograph stability (mixing tolerance) (Fig. 1).

We view "bread quality" as the next frontier for winter triticale. This would add market value to tritcale grain and could be a huge game changer for dryland farming in the Pacific Northwest and around the world.

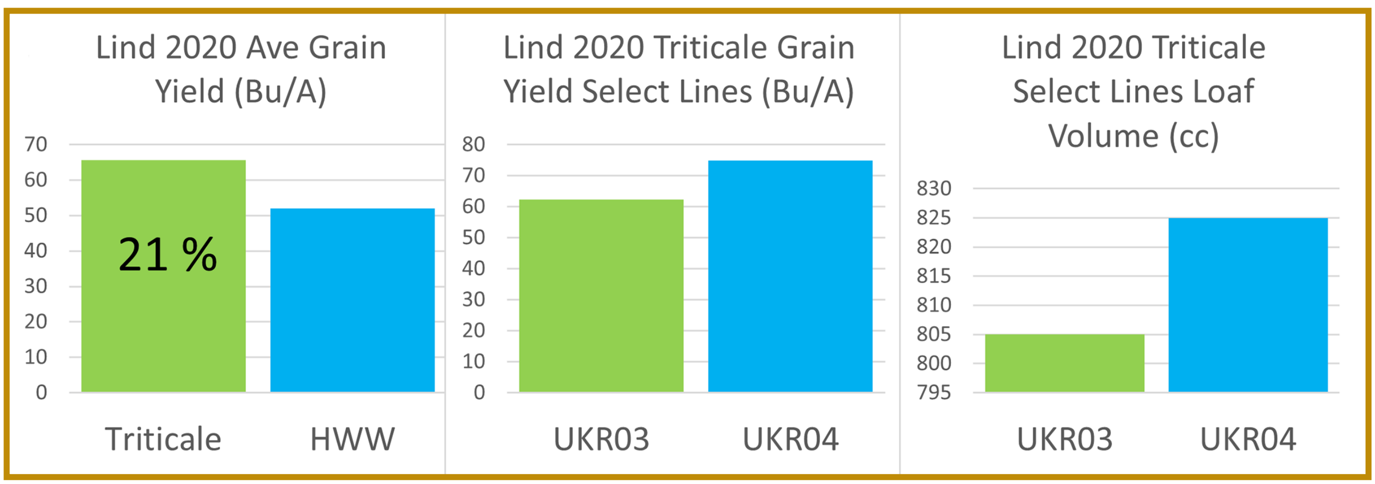
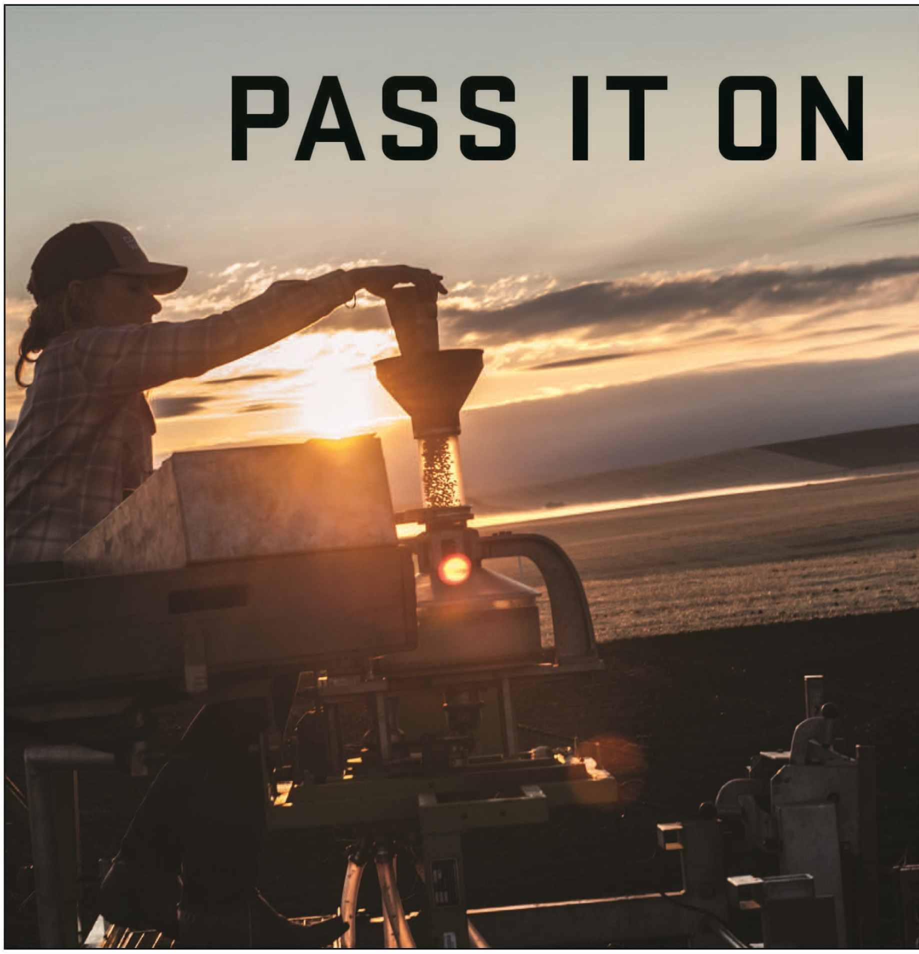


Figure 1. Left- Average grain yield of the 2020 Lind winter triticale and hard red winter wheat (HWW) trials. Middle- Average grain yield of two of the most promising winter triticale lines, UKR03 and UKR04, which yielded 20% and 44% higher than the average of the adjacent HWW trial. Right- Baking performance of two winter triticale lines in 100 g pup-loaf tests, representing 82% and 84% respectively of the loaf volume of a high-quality hard red winter wheat check.

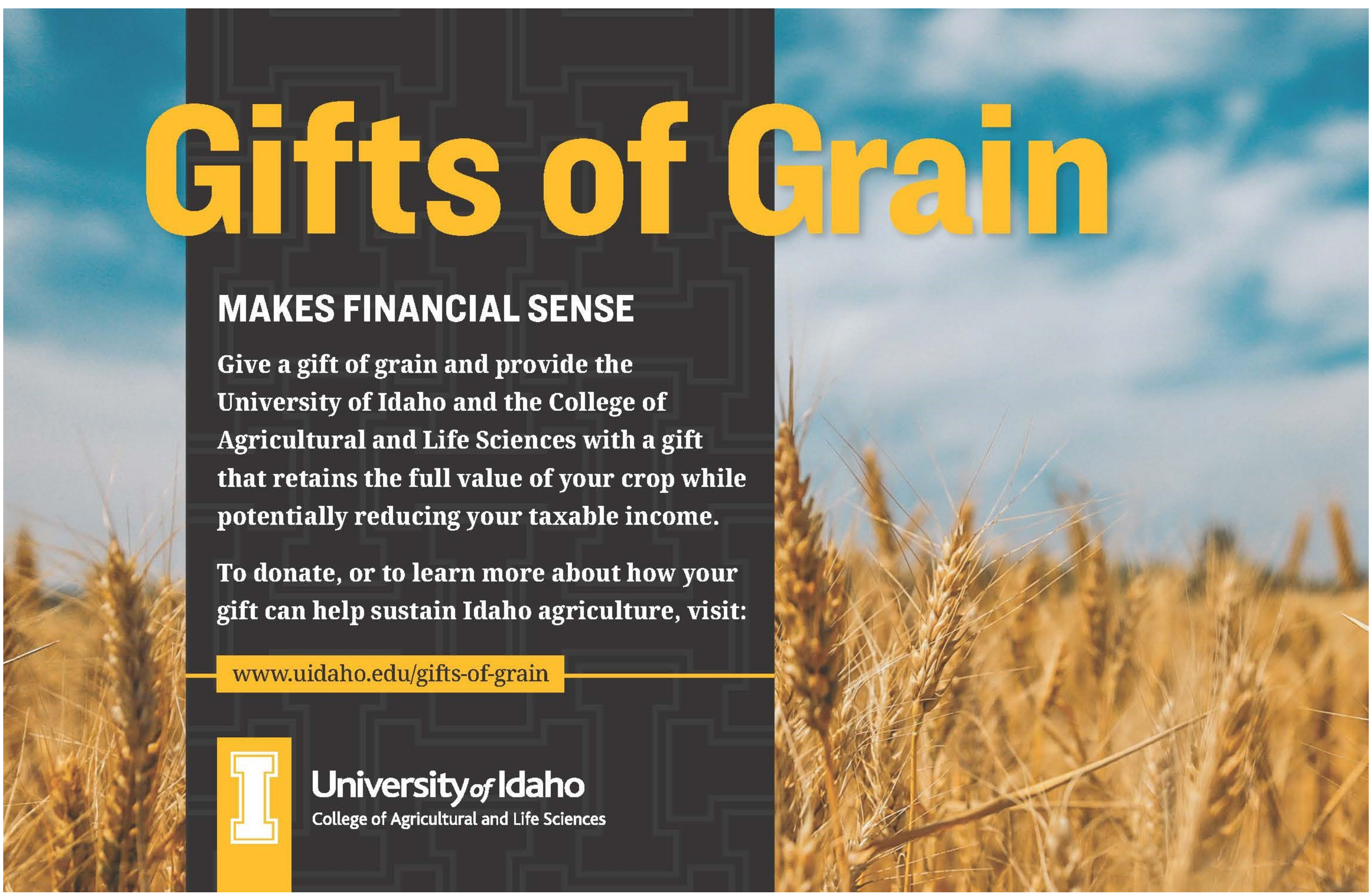


FOR DECADES, Oregon State University's agricultural research stations have helped strengthen the economy in Eastern Oregon and far beyond through practical solutions and increased productivity. By including the OSU Foundation in your will or giving real estate, you can ensure this important work continues, and that your way of life continues on to the next generation.

Contact us to learn more.

Ben McLuen
Pendleton and Sherman Agricultural Research Station Endowments
Benjamin.McLuen@osufoundation.org
541-737-5495

Oregon State University Foundation



1

2

3

Photo Credits

Front Cover
#1—Christina Hagerty
#2—Kayla Yearout-Janowski
#3—Clark Neely

Photo Credits

Back Cover
#1—Christina Hagerty
#2—Clark Neely
#3—Jim B. Davis

Washington State University Extension engages people, organizations and communities to advance knowledge, economic well-being and quality of life by fostering inquiry, and the application of research. Cooperating agencies: Washington State University, U.S. Department of Agriculture, and the Department of Crop and Soil Sciences. Extension programs and employment are available to all without discrimination.