2018
Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS

1


2


3


University of Idaho

Oregon State University

Washington State University

Editors:

WASHINGTON STATE UNIVERSITY
Samantha Crow
Bill Schillinger

OREGON STATE UNIVERSITY
Susan Philips
Mary Corp

UNIVERSITY OF IDAHO
Kurt Schroeder
Doug Finkelnburg
Arash Rashed

Photo by Karen Sowers

Welcome to our 2018 Field Days!

2018 Dryland Field Day Abstracts:
Highlights of Research Progress

Washington State University
Department of Crop and Soil Sciences
Technical Report 18-1

University of Idaho
Idaho Agricultural Experiment Station
Technical Report UI-2018-1

Oregon State University
Department of Crop and Soil Science
Technical Report OSU-FDR-2018

Field Days:
OSU Pendleton Field Day—Pendleton, OR—June 12, 2018
OSU Moro Field Day—Moro, OR—June 13, 2018
WSU Lind Field Day—Lind, WA—June 14, 2018
UI/Limagrain/CHS Primeland Crop Tour—Lewiston, ID—June 19, 2018
WSU Wilke Field Day—Davenport, WA—June 26, 2018

WOCS
WASHINGTON OILSEED CROPPING SYSTEMS
Part of the Washington State Biofuels Initiative

USDA
United States Department of Agriculture
Agricultural Research Service

Table of Contents

Part 1. Breeding, Genetic Improvement, and Variety Evaluation

Part 2. Agronomy and Soils

Part 3. Oilseeds and Other Alternative Crops

Part 4. Pathology, Weeds, and Insects

Photo by Xi Liang

Washington State Oilseed Cropping Systems (WOCS) material in this publication is based upon work that is supported by the Washington State Bioenergy Initiative, NSF IGERT Award 0903714 (NSPIRE), USDA NIFA Award no. 2011-68002-30191 (REACCH), and the Cook Endowment.

Washington State University
Cooperative Personnel and Area of Activity

Kirk H. Schulz	President, Washington State University
André-Denis Girard Wright	Dean of College of Agricultural, Human, and Natural Resource Sciences
Richard T. Koenig	Interim Chair, Department of Crop & Soil Sciences and Horticulture, & Associate Dean of WSU Extension
Scot H. Hulbert	Interim Associate Dean for Research and Director, Agricultural Research Center and Chair, Department of Plant Pathology
Richard S. Zach	Interim Associate Dean, Academic Programs

Agronomy, Conservation Systems, Soil Fertility, and Oilseeds

D. Brown	509-335-1859	dave.brown@wsu.edu
P. Carter	509-382-4741	cart@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
S. Hulbert	509-335-4504	scot_hulbert@wsu.edu
R.T. Koenig	509-335-2726	richk@wsu.edu
D. Llewellyn	509-735-3551	don.llewellyn@wsu.edu
M.M. Neff	509-335-7705	mmneff@wsu.edu
W.L. Pan	509-335-3611	wlpan@wsu.edu
D. Roberts	509-477-2167	robertsd@wsu.edu
R.D. Roe	509-335-3491	rdroe@wsu.edu
W.F. Schillinger	509-235-1933	william.schillinger@wsu.edu
K. Sowers	808-283-7013	ksowers@wsu.edu
B. Sharratt, USDA	509-335-2724	brenton.sharratt@ars.usda.gov
H. Tao	509-335-4389	haiying.tao@wsu.edu
D. Whaley	509-745-8531	dwhaley@wsu.edu

D. Appel, B. Barry, D. Bikfasy, R. Bolton, J. Braden, K. Curran, S. Higgins, C. Hoffman, J. Jacobsen, W. Li, I. Madsen, J. Morse, E. Reardon, R, Rupp, S. Schofstoll, R. Sloot

Breeding, Variety Testing, and Culture of Legumes

Dry Peas, Lentils, Chickpeas

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

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

Dry Beans

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

Cereal Breeding, Genetics, and Physiology

WHEAT BREEDING & GENETICS

K. Garland-Campbell, USDA	509-335-0582	kim.garland-campbell@ars.usda.gov
A.H. Carter	509-335-6198	ahcarter@wsu.edu
K.S. Gill	509-335-4666	ksgill@wsu.edu
S. Hulbert	509-335-4504	scot_hulbert@wsu.edu
S.S. Jones	360-416-5210	joness@wsu.edu
C.F. Morris, USDA	509-335-4062	craig.morris@ars.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@ars.usda.gov

K. Balow, A. Burke, P. DeMacon, V.L. DeMacon, K. Hagemeyer, T. Harris, E. Klarquist, A. Kondratiuk, J. Kuehner, N. Kumar, S. Lyon, W. Nyongesa, S. Rynearson, T. See, G.B. Shelton, R. Sloot, N. Wen

BARLEY BREEDING & GENETICS

K. Murphy	509-335-9692	kmurphy2@wsu.edu

J. Matanguihan, 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

WHEAT HEALTH

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

RUSTS, SMUTS; FOLIAR, VIRUS AND BACTERIAL DISEASES

L. Carris	509-335-3733	carris@wsu.edu
W. Chen, USDA	509-335-9178	w-chen@wsu.edu
X.M. Chen, USDA	509-335-8086	xianming@wsu.edu
C.K. Evans, USDA	509-335-8715	kent_evans@wsu.edu
Y. Liu	509-335-1596	y.liu@wsu.edu
J. Sprott, USDA	509-335-4789	Jason.sprott@ars.usda.gov
M.N. Wang	509-335-1596	meinan_wang@wsu.edu

Soil Microbiology

L. Carpenter-Boggs	509-335-1533	lcboggs@wsu.edu
J.C. Hansen, USDA	509-335-7028	jeremy.hansen@ars.usda.gov
T. Sullivan	509-335-4837	t.sullivan@wsu.edu

K. Muhunthan

Turfgrass Seed Production

R.C. Johnson	509-335-3771	rcjohnson@wsu.edu
W.J. Johnston	509-335-3620	wjohnston@wsu.edu

C.T. Golob

Weed Management

I.C. Burke	509-335-2858	icburke@wsu.edu
E.P. Fuerst	509-339-5213	pfuerst@wsu.edu
D.J. Lyon	509-335-2961	drew.lyon@wsu.edu
T. Miller	360-848-6138	twmiller@wsu.edu

C. Libbey, L. McGrew, L. Molsee, J. Nelson, M. Thorne, H. Wetzel, R. Zuger

Wheat Quality and Variety Evaluation

Wheat Quality

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

M.L. Baldridge, D.A. Engle, E.P. Fuerst, G.L. Peden, D. Jiwan, W.J. Kelley, A.M. Kiszonas, M.J. Lenssen, J. Luna, L. Pierantoni, D. Power, R. Saam, L. Sagen, E. Stout, S. Sykes, S. Vogl, E. Wegner

WSU Extension Cereal Variety Testing

A. Esser	509-659-3210	aarons@wsu.edu

A. Horton, V. Jitkov

WSCIA Foundation Seed Service

D. Hilkin	509-335-4365	darlene@washingtoncrop.com
D. Krause	509-335-4365	darryl@washingtoncrop.com
K. Olstad	509-334-0461	karen@washingtoncrop.com
L. Port	509-334-0461	lauren@washingtoncrop.com
J. Robinson.	509-334-0461	jerry@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

University of Idaho
Cooperative Personnel and Area of Activity

Chuck Staben	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

J. Brown	208-885-7078	jbrown@uidaho.edu
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
C. Rogers	208-397-7000 x113	cwrogers@uidaho.edu
K. Schroeder	208-885-5020	kschroeder@uidaho.edu
G. Shewmaker	208-423-6678	gshew@uidaho.edu
J. Stark	208-397-7000 x107	jstark@uidaho.edu
M. Thornton	208-722-6701 x211	miket@uidaho.edu
O. Walsh	208-722-6701 x218	owalsh@uidaho.edu

C. Centeno, J. Davis, J. Hatch, C. Jackson, L. Jones, C. Lowder, J. McClintick, A. McGinnis, R. Portenier, S. Pristupa, R. Roemer, L. Schroeder, D. White, M. Wingerson

Cereal Breeding, Physiology, and Variety Testing

J. Chen	208-397-4162 x229	jchen@uidaho.edu
D. Fu	208-885-1542	dlfu@uidaho.edu
X. Liang	208-397-7000 x110	xliang@uidaho.edu
J. Marshall	208-529-8376	jmarshall@uidaho.edu
C. Rogers	208-397-7000 x113	cwrogers@uidaho.edu
K. Schroeder	208-885-5020	kschroeder@uidaho.edu
Y. Wang	208-885-9110	ywang@uidaho.edu
F. Xiao	208-885-0120	fxiao@uidaho.edu

C. Jackson, L. Jones, N. Klassen, R. Lawrence, A. McGinnis, S. Pristupa, D. White, J. Wheeler

Crop Diseases

N. Bosque-Perez	208-885-7544	nbosque@uidaho.edu
L-M. Dandurand	208-885-6080	lmd@uidaho.edu
A. Karasev	208-885-2350	akarasev@uidaho.edu
K. Kinzer	208-529-8376	kkinzer@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

M. Ala Poikela, M. Bertram, J. Dahan, K. Fairchild, X. Feng, K. Green, C. Jackson, L. Jones, M. Lent, S. Odubiyi, A. Poplawsky, J. Randall, J. Thinakaran, D. White

Integrated Pest Management

J. Barbour	208-722-6701 x250	jbarbour@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. Schwarzländer	208-885-9319	markschw@uidaho.edu
E. Wenninger	208-423-6677	erik@uidaho.edu

D. Carmona, A. Duarte, N. Fernandez Estillore, B. Harmon, R. Kooliyottil, Z. Mohammadi-Amiri, M. Rashidi, C. Sevy, Y. Wu

Soil Fertility and Management

J. Johnson-Maynard	208-885-9245	jmaynard@uidaho.edu
R. Mahler	208-885-7025	bmahler@uidaho.edu
P. McDaniel	208-885-7012	paulm@uidaho.edu
M. Morra	208-885-6315	mmorra@uidaho.edu
C. Rogers	208-397-7000 x113	cwrogers@uidaho.edu
D. Strawn	208-885-2713	dgstrawn@uidaho.edu
O. Walsh	208-722-6701 x218	owalsh@uidaho.edu

A. Falen, K. Kahl, J. McClintick, I. Popova, S. Pristupa, M. Satterwhite

Weed Management

J. Campbell	208-885-7730	jcampbell@uidaho.edu
P. Hutchinson	208-397-7000 x109	phutch@uidaho.edu
R. Ma	208-885-6009	rma@uidaho.edu
D. Morishita	208-423-6616	don@uidaho.edu
T. Prather	208-885-9246	tprather@uidaho.edu

B. Beutler, K. Frandsen, 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 Wilson Craine

Oregon State University
Cooperative Personnel and Area of Activity

Edward J. Ray	President, Oregon State University
Dan Arp	Dean of the College of Agricultural Sciences
Bill Boggess	Executive Associate Dean
Dan Edge	Associate Dean and Associate Director
Joyce Loper	Associate Dean and Associate Director
Jay Noller	Chair, Department of Crop and Soil Science
Mary Corp	Director, Columbia Basin Agricultural Research Center

Agronomy

S. Machado	541-278-4416	stephen.machado@oregonstate.edu
R. Awale, L. Pritchett		

Barley Breeding

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

Wheat Breeding

K. Garland Campbell	208-310-9876	kgcamp@wsu.edu
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
B. Tuck	541-296-5494	brian.tuck@oregonstate.edu
D. Walenta	541-963-1010	darrin.walenta@oregonstate.edu
D. Wysocki	541-278-4396	dwysocki@oregonstate.edu
A. Wernsing		

Soil Microbiology

D. Myrold	541-737-5737	david.myrold@oregonstate.edu

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
J. Gourlie, C. San Martin Hernandez		

Part 1. Breeding, Genetic Improvement, and Variety Evaluation

Progress of Soft White Winter Wheat Breeding Program at the University of Idaho

---

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

The University of Idaho wheat breeding program in Moscow focuses on soft white winter wheat (SWWW) in collaboration with Limagrain Cereal Seeds (LCS). The primary research objective is to develop new soft white winter wheat cultivars with increased yield, improved agronomic traits, abiotic resistance/tolerance, disease resistance, and end-use quality. The breeding methods include a combination of traditional wheat breeding techniques, double haploid (DH) and molecular marker assisted selection. First generation crosses are made in the greenhouse on the UI campus. Diverse parents are used to make crosses, which included backcrosses and 3-way crosses in order to broaden the genetic base. Select F_1 crosses are identified for DH advancement and the seeds are sent to the Limagrain DH laboratory in France.

Since 2014, four SWWW varieties have been released in the PNW. The first is UI/WSU Huffman, which was released in 2014. The other three are 2-gene Clearfield Plus varieties, including UI Castle CL+, UI Magic CL+ and UI Palouse CL+. In 2017, two SWWW elite lines, "IDN 07-28017B" and "IDN 09-15702A", showed good performance based on the results of WSU, OSU, LCS and UI variety trials. IDN 07-28017B performed well in high rainfall and irrigated environments. Its plant height was similar to WB-528, with a heading date similar to Ovation. It had excellent stripe rust and Fusarium crown rot resistance. IDN 09-15702A performed well in the intermediate rainfall zone. It was among the top 10 yielding varieties in WSU 12 to 20" rainfall locations. Its plant height and heading date were similar to Madsen. It had good stripe rust resistance and good snow mold tolerance.

In 2017, a total of 7 new lines IDN 07-28017B, IDN 09-15702A, IDN 10-08606A, LWW14-75044, LWW15-72223, LWW15-72234, and LWW15-72458 were selected for WSU, OSU, and UI variety trial testing as well as the Western Regional Trials at different locations in Idaho, Washington and Oregon. A total of 37 elite lines selected for Idaho Yield Trials (IYT) which were grown in 6 locations (Bonners Ferry, Fenn, Cavendish, Lewiston, Genesee, and Moscow) in North Idaho, 5 locations (Walla Walla, Reardan, Warden, Fairfield, and St. John) in Washington, and 1 location (Hermiston) in Oregon. A total of 74 advanced breeding lines (F_6 generation) were selected for yield trials at 4 locations (Moscow, Genesee, Tammany, and Ferdinand) in Idaho and 2 locations (Walla Walla and Reardan) in Washington. All generations are planted with LCS' help for ongoing wheat breeding projects.

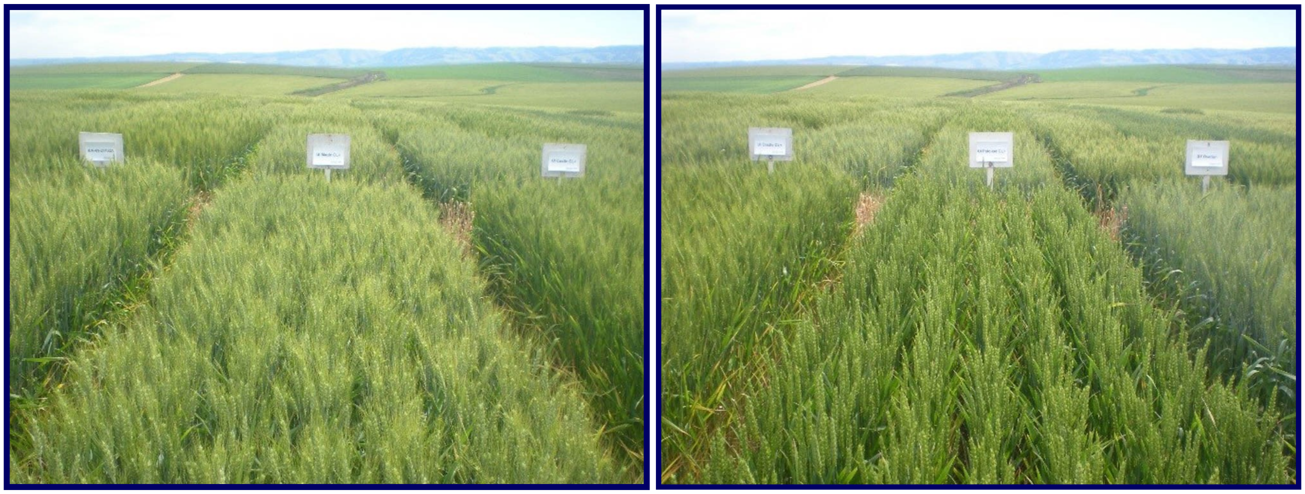


Figure 1. Plots of UI Magic CL+ (left) and awnless UI Palouse CL+ (right) growing in northern Idaho.

Breeding Wheat to be Profitable in the Pacific Northwest

R.S. ZEMETRA[1], M. LARSON[1], A. HEESACKER[1], T. HARRAN[1], H. GUNN[1], C. MUNDT[2], AND A. ROSS[1]
[1]DEPT. OF CROP AND SOIL SCIENCE, OSU, [2]DEPT. OF BOTANY AND PLANT PATHOLOGY, OSU

With current prices for wheat low, it is a challenge for wheat producers to make a profit each year growing wheat. There are three ways a wheat breeder can increase the economic potential for wheat: increased yield, reduced yield loss due to disease, insects and/or weather, and improved end-use quality. The Oregon State (OSU) wheat breeding program is working on all three fronts to produce soft white winter, hard red winter, and hard white winter wheat that are high yielding, disease resistant cultivars with superior end-use quality. Breeding for yield is relatively straight forward and starts by testing promising lines in multiple locations in the sixth generation (F_6) and selecting lines that have high yield potential across locations. This is done for several years to have the advanced lines tested in as many environments as possible. After three years the best lines go into elite and extension testing. An example of the elite line nursery is the Soft White Elite Line Trial (SWELT). Disease testing in collaboration with C. Mundt and quality testing in collaboration with A. Ross starts earlier (F_4 and F_5 generation) to insure the lines that advance to yield testing have the disease resistance and quality needed to reduce input (production) costs for producers and insure markets for wheat produced in Oregon. Sometimes the disease resistance is needed not to reduce input costs but to prevent yield loss. An example of this is breeding for resistance to soil-borne wheat mosaic virus (sbWMV). This disease is found in soil and since it is a virus there are no chemical controls to reduce the impact of the disease. Once it is in the soil it can't be eradicated and will slowly spread with time. The only way to prevent yield loss is through the addition of a gene for resistance to sbWMV. Using a combination of conventional breeding methods to transfer the resistance gene and molecular techniques to identify individual plants that carry the gene the OSU wheat breeding program has been developing winter wheat lines that are resistant to sbWMV. The sbWMV nursery at Pendleton is a non-disease check nursery to confirm yield potential and resistance to other diseases such as stripe rust of the breeding lines carrying the sbWMV resistance gene. Seed from this nursery and the other two sbWMV nurseries is evaluated for end-use quality by A. Ross. Lines with high yield potential and good end-use quality from the sbWMV nurseries then proceed to elite and extension trial testing for further evaluation prior to release.

USDA-ARS Club Wheat Breeding

KIM GARLAND-CAMPBELL[1], PATRICIA DEMACON[2], EMILY KLARQUIST[2], AND NUAN WEN[2]
[1]USDA-ARS; [2]WASHINGTON STATE UNIVERSITY

The focus of the USDA program is to develop high quality club wheat and soft white cultivars, and to incorporate germplasm for disease resistance into soft and hard PNW-adapted lines. The program has yield trials in 11 locations across eastern Washington, Idaho, and Oregon, which allows us to test our cultivars in a variety of different climates and leads to production of better varieties for specific PNW climates.

Castella Club Wheat at Plot Tour in 2017.

ARS Castella (ARS20060123-31C) is the latest variety released by the USDA-ARS. It is a soft white winter club that is taller and has performed well all across eastern Washington. Castella's target area is the intermediate rainfall region. It is resistant to stripe rust and pre-harvest sprouting (PHS) and has shown to be aluminum tolerant as well. Castella has good emergence, good yield potential, and excellent club wheat quality. It can lodge under high levels of nitrogen. Castella is under breeders seed increase at Othello in 2018.

Pritchett was released in 2016 and is a soft white winter club developed by both WSU and the USDA-ARS. Pritchett is targeted to the traditional low-intermediate rainfall club wheat growing region. It has excellent emergence from deep sowing, excellent club wheat quality, and excellent resistance to stripe rust and Cephalosporium stripe disease. Pritchett should replace Bruehl in low rainfall areas due to superior yield, test weight, milling quality, eyespot tolerance, earlier maturity, similar winter survival and moderate snow mold resistance. Grain of Pritchett grades as club wheat more consistently than Bruehl. Pritchett is under Registered seed increase in 2018.

The Garland-Campbell/Steber field crew after Safety Training in June 2017.

The top goals for 2018-2019 are to; 1) screen Washington wheat lines with novel gene for pre-harvest sprouting tolerance in greenhouse for phenotype validation and plant in field this Fall; 2). select advanced breeding lines with snow mold resistance; 3) select early maturing club wheat breeding lines; 4) increase Fusarium screens in greenhouse using improved method ; 5) screen for freezing tolerance on early generation material; 6) implement rapid-breeding protocol on F2 populations in greenhouse to increase gene recombination for line development and early selection of beneficial traits; 7) identify CCN (specifically *H. filipjevi* and *H. avenae*) resistance in wheat varieties adapted to PNW and acquire more knowledge about specific resistance genes.

Winter Wheat Breeding and Genetics at Washington State University

A. CARTER, K. BALOW, A. BURKE, J. GODOY, K. HAGEMEYER, A. KONDRATIUK, T. SEE, AND G. SHELTON
DEPT. OF CROP AND SOILS SCIENCES, WSU

The Winter Wheat Breeding and Genetics Program at Washington State University remains committed to developing high yielding, disease resistant, and high end-use quality cultivars for release to maintain sustainability of production. We are using the newest tools available to accomplish this task and are excited about the breeding lines under evaluation and their release potential. In the fall of 2017, planting conditions were very good and most plots across the state had good emergence and establishment. Good snow cover also has allowed for snow mold tolerance to be screened this year, which will be the second year we have been able to screen two different genetic populations as well as lines in the breeding program. The screening of these populations will allow us to better understand the genetics of snow mold tolerance, as well as incorporate different new sources of tolerance. We have a strong production system of doubled haploid lines which are generating bout 3,500 lines annually. We continue to screen about 200 populations each year with markers to aid in selection for important genes for disease resistance and end-use quality. Our genomic selection efforts are progressing. Models have been developed for many end-use quality traits and are showing good prediction accuracies for these traits. Many genome-wide association studies have been completed to identify markers throughout the wheat genome associated with disease and abiotic stress conditions. These are now being used in the breeding program to make more efficient selections. 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. Collaboratively with the Spring Wheat and USDA Wheat breeding programs, and groups in Biological Systems Engineering, we are utilizing many sensor and image based phenotyping approaches within the breeding program to select for many important traits. 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.

Otto was released in 2011 and is in full commercial production. Otto is a backcross derivative of Eltan crossed with Madsen. Agronomically, it performs very similar to Eltan. It emerges very well from deep planting and survives the winter well despite no snow cover and cold temperatures. It has very high yield potential, excellent snow mold resistance, stripe rust resistance, and has the *Pch1* gene for eyespot foot rot resistance. This line is targeted to the <15" rainfall zones as a replacement for Eltan.

Puma was released in 2013 and is in commercial production. This line is a soft white wheat targeted to various rainfall zones of the state. Puma maintains a very high yield potential averaged over multiple years in both the >16" rainfall zone and the <16" zone. It has high test weight, adult plant resistance to stripe rust, resistance to eyespot foot rot, good tolerance to Cephalosporium stripe, moderate tolerance to low pH soils (aluminum tolerance), and excellent end-use quality.

Jasper was released in 2014 and is also in commercial production. This line is a soft white winter wheat, which appears to be broadly adapted to multiple rainfall regions of the state. This line seems to be very resilient to the drought conditions of 2014 and 2015 and maintained a high yield potential even under these limited moisture conditions. It has very good adult plant resistance to stripe rust, and very good end-use quality. This line has been very competitive with Xerpha for yield potential; and performs well in the intermediate to high rainfall zones of the state.

Sequoia was released in 2015 and is available for commercial production. Sequoia is a hard red winter line targeted to the <12" rainfall zones of the state as a replacement for Farnum and Finley. This line is standard height and has a yield potential similar to Farnum. Sequoia has excellent emergence from deep planting and appears to emerge slightly earlier than other cultivars. Aside from good yield potential this line has average protein content, good test weight, good stripe rust resistance, and very good end-use quality.

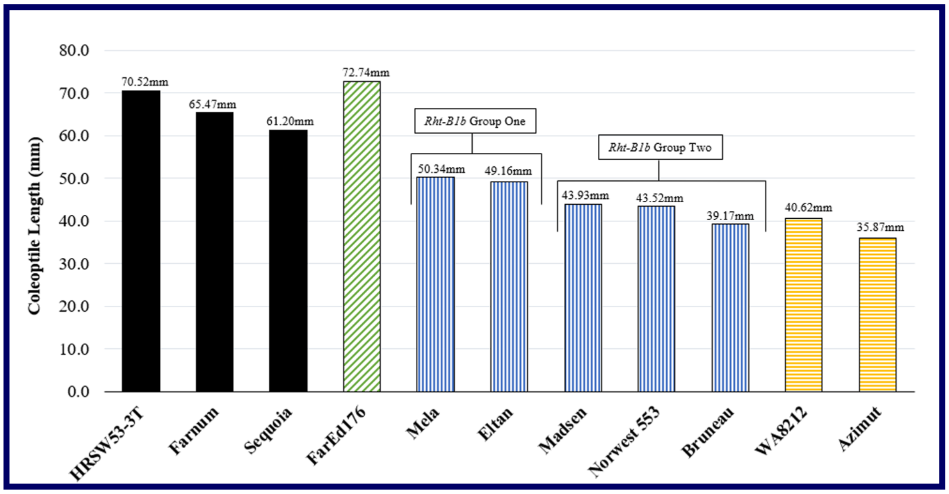
WA8234 is a soft white winter wheat just approved for release from WSU. WA8234 is a soft white winter wheat line targeted the >16" rainfall zones of the state. The line has excellent yield potential across tested environments. WA8234 also has excellent disease resistance, with adult-plant resistance to stripe rust, nematode resistance, eyespot foot rot resistance, and moderate tolerance to low pH soils. Foundation seed will be available for purchase this fall.

Interaction of Gibberellins-A Seed Application, Dwarfing Alleles, and Innate Varietal Emergence Capabilities on Wheat Seedling Emergence

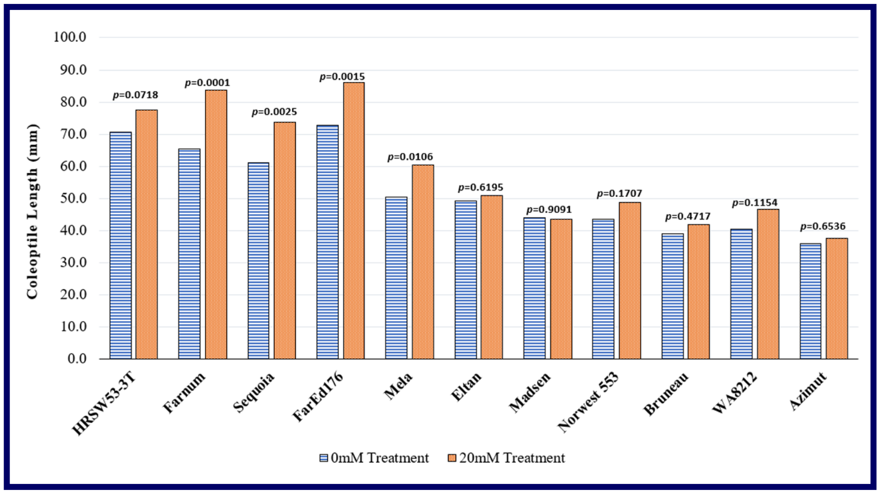
---

ANDREW HORGAN[1], ARRON CARTER[1], KIMBERLY CAMPBELL[1,2], AND CAMILLE STEBER[1,2]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS

Dwarf wheat (*Triticum aestivum* L.) varieties are higher yielding and less prone to lodging due to their short-stature and stiffer straw. Reducing the sensitivity or suppressing the biosynthesis of the phytohormone gibberellins-A (GA) is the most commonly used method in developing dwarfed wheat phenotypes, but this reduction of GA activity within the plant can also inhibit vital processes in seed germination and seedling development. Recent attempts to improve emergence capabilities of deep-planted wheat in Pacific Northwest low rainfall regions have involved applying a fungal derived form of gibberellins (GA_3) as a seed treatment prior to planting. Our research addresses the complex 3-way interaction between GA_3 seed application, the presence of various dwarfing alleles, and varietal differences in emergence capabilities. Varieties were selected based on two factors: presence of *Reduced-Height* (*Rht*) alleles, and their emergence capability in the field. To investigate the response of these varieties to GA_3, we treated seeds with 0mM and 20mM GA_3 and preformed 10-day dark germination assays to measure coleoptile responses, and 14-day in-soil experiments to measure sub-crown internode and first leaf responses. The dark germination assay involved measuring the rate of coleoptile elongation in a soil absent environment, while the in-soil experiment addressed the elongation of the sub-crown



internode region (from the seed to the base of the root crown) and the first leaf length under soil planted conditions. Our results show that the presence of various *Rht* alleles greatly effects not only innate coleoptile length, but also the plant's responsiveness to exogenous GA_3 application. In an initial comparison of innate varietal coleoptile length, we observed an average of around 66.5mm in the wildtype varieties, which was significantly longer than the *Rht-B1b* average of 46.5mm, and longer than the *Rht-D1b* average of 39.7mm. Within the 20mM treated dark germination assays, a significant coleoptile elongation was detected in all four wildtype varieties, except HRSW53-3T. Of the 12 *Rht* varieties, only FarEd176, an *Rht8* variety, and Mela, an *Rht-B1b* variety, showed significant coleoptile elongation to GA_3 treatment. Lastly, the in-soil assay results showed a significant sub-crown internode elongation in all wildtype and *Rht8* varieties, and no response in any of the *Rht-B1b* or *Rht-D1b* varieties when treated with 20mM GA_3. When first leaf elongation was analyzed, no significant differences were detected between 0mM and 20mM treatment groups, suggesting that exogenous GA_3 seed treatment does not have an elongation effect on first leaf development. Our data suggest that while the presence of *Rht* alleles can be a very useful tool in predicting responsiveness to GA_3 application, the variation seen in varieties containing identical *Rht* alleles suggests that there are multiple genetic factors aside from *Rht* genes involved in regulating coleoptile length, and responsiveness to GA_3 application.



Large Mutant Populations of the Common Wheat 'Brundage'

BO LYU, CHAOZHONG ZHANG, QUNQUN HAO, JIWEN QIU, MENGMENG LIN, KATRINA JOHNSON, YUEGUANG WANG, AND DAOLIN FU
DEPT. OF PLANT SCIENCES, UI

'Brundage' is a soft white winter wheat developed by the Idaho Agricultural Experiment Station in 1997. In the past years, it was favored by growers due to its high yield potential and good grain quality. However, this cultivar slowly lost its acreage for two reasons: Its susceptibility to emerging races of wheat stripe rust and a low threshability due to its tenacious glume. It is possible to revive the Brundage acreage by eliminating the two negative traits.

Mutagenesis is a traditional approach for crop improvement. In wheat, many mutant populations have been developed using chemical agents and physical irradiations. Here, we report the development of large mutant populations of Brundage using ethyl methanesulfonate (EMS), fast neutron (FN), and gamma ray (GR). Using 80-mM EMS, we treated

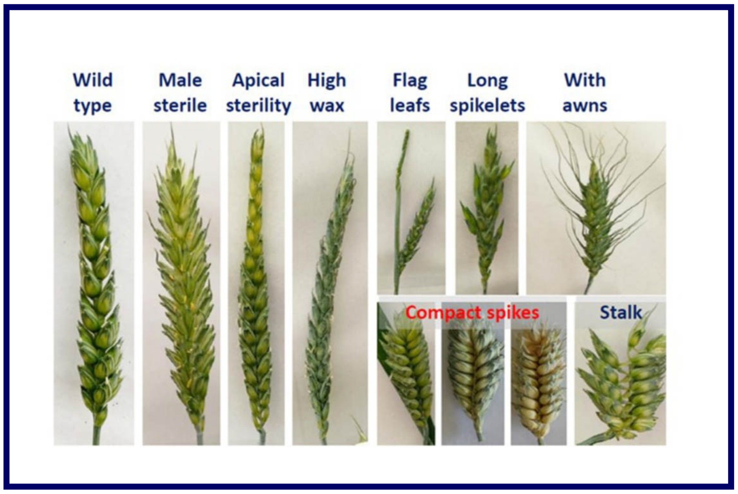


Figure 1. Various head types of the Brundage mutant population.

Brundage and obtained 4,945 M_1 mutant lines. Using 7-Gray FN, we generated 4,841 M_1 mutant lines. We also treated Brundage using 275-Gray GR, and produced 2,043 M_1 mutant lines. In total, we have prepared 11,829 M_1 mutant lines of Brundage, and planted the M_2 seeds as head rows in the UI Parker Farm (Moscow, ID).

The Brundage mutants are associated with a rich phenotype in the M_1 generation. For example, there are various types of head (Fig. 1), which can be used to improve the yield trait. Desirable mutants will be used for specific trait improvement in Brundage and other wheat cultivars in the Pacific Northwest.

The USDA-ARS Western Wheat Quality Laboratory

Craig F. Morris and Douglas A. Engle
USDA-ARS Western Wheat Quality Laboratory

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, arabinoxylans, puroindolines, polyphenol oxidase (PPO), and waxy wheat. Our recent publications include the grain, milling, soft wheat, dough strength, and pan bread quality of CIMMYT‑derived soft-kernel durum wheat germplasm, published in Crop Science. Genotyping‑by-sequencing sequence tags associated with milling performance and end-use quality traits in elite hard red spring wheat were identified and published in the Journal of Cereal Science. A study on the molecular and cytogenetic characterization of the 5DS-5BS chromosome translocation conditioning of soft kernel texture in durum wheat was published in Plant Genome. Two studies on low-molecular-weight glutenins in wheat were published in Cereal Chemistry and the Journal of Cereal Science. Research on the evidence of intralocus recombination at the *Glu-3* loci in bread wheat was published in Theoretical and Applied Genetics. The identification of SNPs, QTLs, and dominant markers associated with wheat grain flavor preference using genotyping---by-sequencing was published in the Journal of Cereal Science. The influence of soft kernel texture on the flour, water absorption, rheology, and baking quality of durum wheat was published in Cereal Chemistry. Pasta production and the complexity in defining processing conditions for reference trials and quality assessment methods was published in Cereal Chemistry. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Jasper, Sequoia, Earl, Pritchett, and Glee.

Genomic Selection for End-Use Quality Traits in Soft White Wheat (*Triticum aestivum* L.)

Jayfred Godoy, Meng Huang, Zhiwu Zhang, and Arron H. Carter
Dept. of Crop and Soil Sciences, WSU

End-use quality traits in soft white wheat are complex traits that are controlled by multiple genetic factors with minor effects. This was consistent with our genome-wide association study (GWAS) results which identified 105 significant SNPs that explained only between 5 – 30% of the phenotypic variation. Genomic selection (GS) is a breeding method to predict breeding values using genome-wide markers. In GS, each marker is weighted based on its influence on the trait and each individual/line is given a genomic estimated breeding value (GEBV) as a function of the total effects of the alleles it carries for all the markers. Plant breeders can use the GEBVs to select which lines to cross in the succeeding breeding cycle. We assessed the application of GS for 21 end-use quality traits using a panel of 469 elite soft white winter wheat from Pacific Northwest breeding programs. Genotype data was generated using the Illumina 90K SNP chip and genotype-by-sequencing (GBS). Genomic prediction was implemented using the R package rrBLUP. Prediction accuracies were calculated as Pearson correlation (*r*) between the GEBVs and observed phenotypes using a 10-fold cross validation with 200 replications. Different marker systems (i.e. SNP chip vs genotype-by-sequencing) and marker densities were also compared to determine their influence on prediction accuracy. In summary, prediction accuracies ranged between 30 – 87% with the highest level of accuracy for flour SDS (sodium dodecyl sulfate) sedimentation. Our results showed that higher accuracies were achieved for highly heritable traits. We did not observe any significant advantage in performance between marker systems (Fig. 1). Marker densities greater than 2480 genome-wide SNPs resulted in similar prediction performance. We are currently improving our models and population size by adding advanced breeding lines to further increase prediction accuracies.

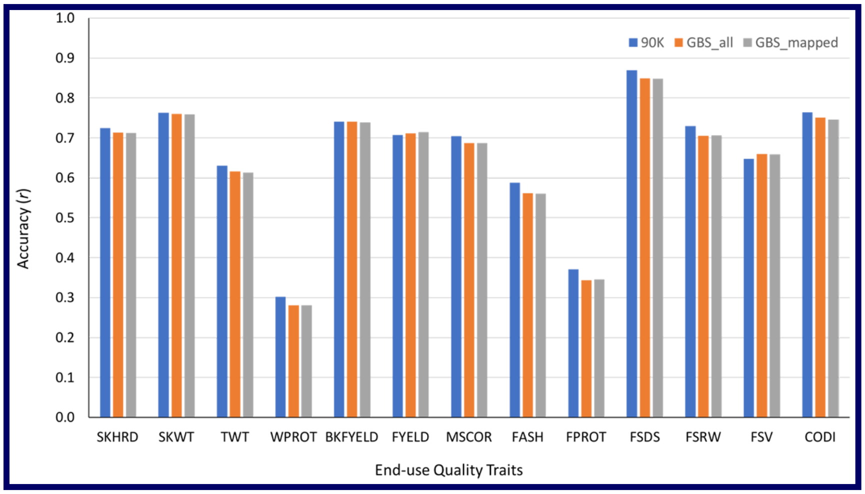


Figure 1. Prediction accuracy (*r*) using SNPs from the Illumina 90K chip, GBS (mapped only) and GBS (mapped and unmapped).

Examining the Relationship Between Seedling Emergence and Coleoptile Length in Pacific Northwest Breeding Lines

---

STEPHANIE SJOBERG[1], CAMILLE STEBER[2], AND ARRON CARTER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS

In low rainfall regions of the Pacific Northwest (PNW), farmers need to plant wheat deeply (as deep as 20 cm) to reach moisture for germination. Only varieties that have vigorous and quick emergence from deep planting yield well under such conditions. Seedling emergence is a function of two underlying factors, germination and coleoptile length. Field observations of seedling emergence do not allow us to parse out the variation due to each of these traits, so this study combines field observations with coleoptile assays on a set of 469 cultivars and advanced soft white breeding lines from Pacific Northwest breeding programs. Percent field emergence from deep sowing was assessed in double row plots planted 12 cm below the soil surface at a semi-arid location (Lind, WA) in two seasons, Fall 2016 and 2017. Percent emerged seedlings were counted for each plot twice after sowing, once at 14-17 days and once again at about 30 days. The deep sowing tests were planted using seed that had been after-ripened for at least one year to ensure loss of dormancy. After-ripened seed was also used in greenhouse coleoptile tests. Coleoptile tests were conducted using 'rag-doll' germination tests in an incomplete block design including check cultivars. Coleoptile total length was measured at a total of 20 days (4 days in 4°C and 16 days in 15°C). This trait was evaluated over three biological replicates from Pullman 2014, 2016, and Central Ferry 2016; biological replicates were made up of 10 technical replicates.

Field emergence taken in Fall 2016 and 2017 ranged from 0-90% and 10-90% for the first observation and 20-90% and 50-100% for the second observation, respectively (Fig. 1). Mean percent field emergence was 49% and 62% for the first

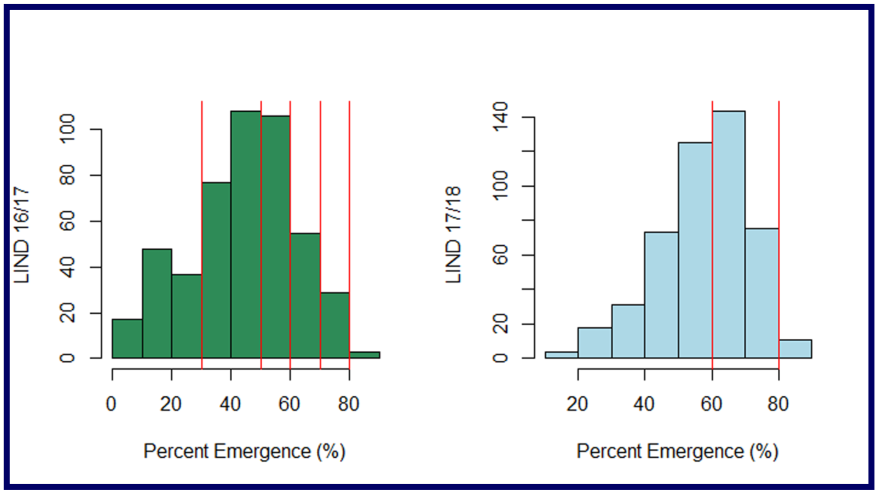
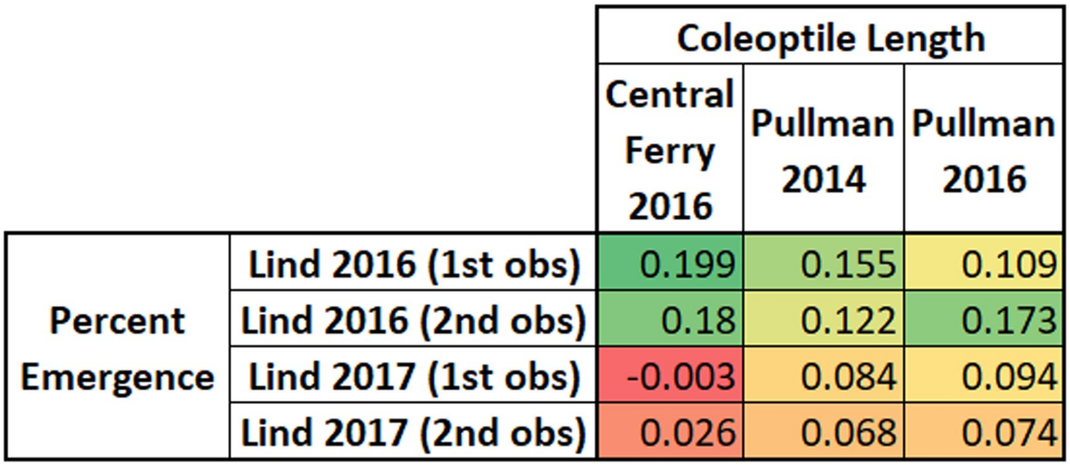


Figure 1. Distribution of Percent Emergence (%) taken at 14-17 days after deep-planting in Lind, WA for two years (A) 2016 and (B) 2017. Red lines indicate relevant varieties. Mean percent emergence was 49% for 16/17 season and 62% for 17/18 season.

observations from Fall 2016 and 2017. The mean coleoptile length ± 95% confidence interval (mm) for the three environments, Central Ferry 2016, Pullman 2014, and Pullman 2016 are 77.13 ± 0.52, 83.71 ± 0.50, and 86.25 ± 0.55, respectively. The difference in mean percent emergence between years is likely due to drier soil conditions in Fall 2016. This can also help explain why there is greater correlation between coleoptile length and percent emergence in Lind 2016 (Table 1). Planting in the dryland area of the PNW is so deep that instead of the coleoptile it is the first leaf that emerges from the soil. If this first leaf encounters even a small amount of surface resistance it will not emerge because it lacks the structure to force itself through the surface. With increased soil moisture in Fall 2017 the soil water potential likely made it easier for the first leaf to push through the surface; lack of soil moisture in Fall 2016 revealed that lines with longer coleoptiles emerged better.

Table 1. Correlations between coleoptile length and percent emergence in two years for 469 PNW soft white winter wheat lines.



		Coleoptile Length		
		Central Ferry 2016	Pullman 2014	Pullman 2016
Percent Emergence	Lind 2016 (1st obs)	0.199	0.155	0.109
	Lind 2016 (2nd obs)	0.18	0.122	0.173
	Lind 2017 (1st obs)	-0.003	0.084	0.094
	Lind 2017 (2nd obs)	0.026	0.068	0.074

What Temperature Shifts Can Induce LMA, a Cause of Low Falling Numbers?

Chloe Chang Liu[1], Camille M. Steber[1,2], and Michael O. Pumphrey[1]
[1]Dept. of Crop and Soil Sciences, WSU; [2]USDA-ARS, Wheat Health, Genetics and Quality Unit

Problem: Late Maturity alpha-amylase (LMA) can cause low falling numbers in wheat grain. The falling number (FN) test measures starch damage due to the presence of alpha-amylase enzyme in grain. Wheat with an FN below 300 seconds can be steeply discounted because low FN is associated with problems with poor end-use quality - cakes that fall and sticky noodles. The FN gets lower as alpha-amylase enzyme levels in the grain increase. Researchers in Australia reported that low FN from LMA is induced by a cold temperature shock between 26 and 30 days after pollen shedding. The question is whether this "window" of LMA susceptibility is the same in Washington wheat, and what sort of temperature differences can cause a low FN problem. **Method:** Wheat plants (soft white spring WA8124) were grown in pots in the greenhouse or in an incubator, and spikes were tagged when they reached pollen shedding. In a time course experiment, wheat was moved into a cold chamber for 7 days at different numbers of days past pollen-shedding (dpp). For every test, there was a control that remained at the starting temperature instead of being moved to the cold chamber. There was a day and night time temperatures cycle in order to mimic the day/night temperature differences in the field. **Results:** We examined: A) a starting temperature of 77 day/64° F night and cold treatment of 64 day/ 46° F night, B) a starting temperature of 73 day/61° F night and cold treatment of 64/46° F night, C) a starting temperature of 73 day/61° F night and cold treatment of 59 day/39° F night, D) a starting temperature of 77 day/64° F night and cold treatment of 77 day/ 39° F night. We learned that if the starting temperature is higher, then the LMA window occurs earlier around 20 to 24 instead of 24 to 27 days past pollen shedding (Fig. 1A vs B). We were surprised to learn the weaker cold shock of 64/46° F actually gave MORE alpha-amylase (would cause lower FN) than a colder shock of 59/39° F (Fig. 1A vs C). We speculate that maybe the seeds aren't as metabolically active at the lower temperature. LMA was induced when the day time temperature stayed the same and only the night time temperature got cooler, but not as much as when both the day and night temperatures dropped (Fig. 1A vs D).

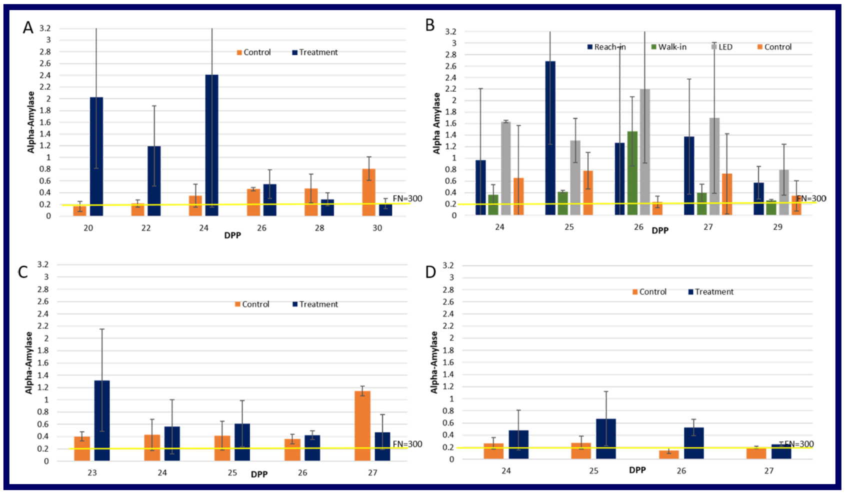


Figure 1. Determining the window of LMA induction at different starting and cold shock temperatures. A) 77/64° F shifted to cold treatment of 64/46° F, B) a starting temperature of 73 day/61° F night and cold treatment of 64/46° F, C) a starting temperature of 73 day/61° F night and cold treatment of 59 day/39° F night, D) a starting temperature of 77 day/64° F night and cold treatment of 77 day/ 39° F night.

Genome-Wide Association Study of Carbon Isotope Discrimination in an Elite Panel of Pacific Northwest Winter Wheat Genotypes

---

LIAM DIXON, JAYFRED GAHAM GODOY, AND ARRON CARTER
DEPT. OF CROP AND SOIL SCIENCES, WSU

The development of drought tolerant wheat varieties is increasingly important. The Pacific Northwest (PNW) is projected to experience greater volatility in precipitation and temperature dynamics over the coming decades, resulting in the onset of more severe and longer-lasting drought events. Maintaining high yield despite these events is critical to the health of agriculture in this region. Central to this objective is the improvement of plant water-use efficiency (WUE). Carbon isotope discrimination (CID) has been identified as an effective trait in selecting for water-use efficient wheat. Carbon from atmospheric CO$_2$ exists in two stable isotopic forms. The most common is ^{12}C, accounting for 99% of atmospheric CO$_2$. The remaining 1% of CO$_2$ is in the form ^{13}C. Wheat preferentially diffuses and fixes ^{12}C during photosynthesis, resulting in a substantially smaller molar abundance ratio of ^{13}C/^{12}C in plant dry matter as compared with the same ratio in the atmosphere. Further, wheat varieties differ in their level of ^{13}C discrimination. Varieties more capable of utilizing ^{13}C—demonstrating lower CID—tend to exhibit higher WUE. In order to help evaluate the utility of this trait to PNW wheat production, a genome-wide association study (GWAS) was conducted. A panel of 458 elite winter wheat genotypes was grown in Pullman, WA for three years (2015, 2016, and 2017), and one year (2017) in Lind, WA and Pendleton, OR. CID data were calculated from carbon isotope analysis of grain samples from the three locations and across all three years for each genotype. Association analysis was performed with 15,229 single nucleotide polymorphism (SNP) markers using FarmCPU implemented in GAPIT software. SNPs were significantly associated with CID if their *P*-values were lower than the Bonferroni correction cut-off at $\alpha = 0.05$. A total of 28 significant SNPs were identified. Additional analysis will be conducted in order to detect associations that are significant across multiple environments.

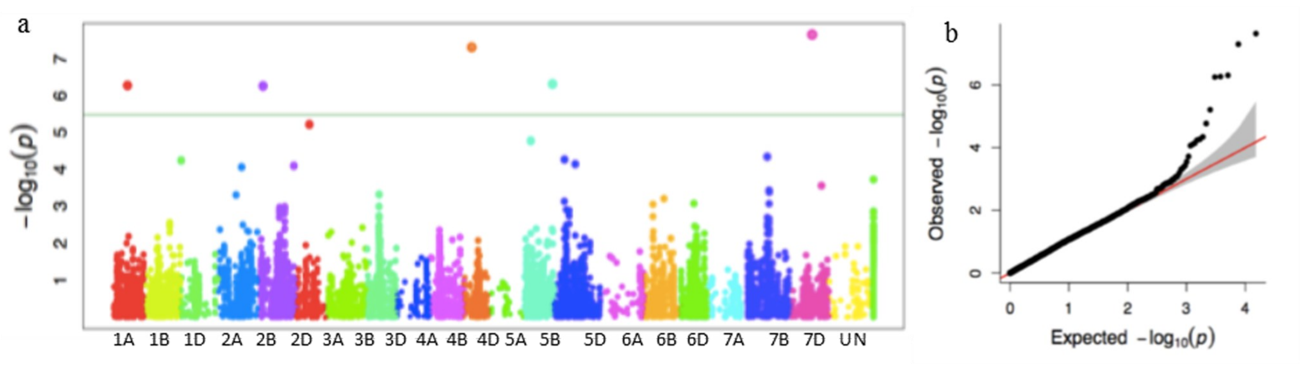


Figure 1. Manhattan plot (a) showing five SNPs significantly associated with CID in the Lind 2017 data. Q-Q plot (b) comparing the distribution of the expected versus the observed *P*-values. The plot also shows a good fit for the model used to conduct GWAS.

Breeding Winter Wheat for an Unpredictable Climate

K.M. Brandt[1], M. Larson[1], A. Heesacker[1], T. Harran[1], C. Mundt[2], and R.S. Zemetra[1]
[1]Dept. of Crop and Soil Science, OSU; [2]Dept. of Botany and Plant Pathology, OSU

The climate in the Pacific Northwest (PNW) is becoming more variable, trending to warmer winters and lower rainfall in May and June. This can have a significant impact on wheat producers in low to intermediate rainfall production zones. One way to address this problem is to breed for traits that minimize the impact of the environmental changes.

Facultative Breeding Project: The rapidly changing climate has already had an effect on the PNW, where we have experienced fewer frost days on average, with this trend only expected to become more pronounced in the years to come. Winter wheat requires gradually decreasing, sustained cold temperatures in order to vernalize and flower in the spring. Warmer winters could delay flowering leading to problems if rain does not occur in late May or June. A solution to this problem is the development of facultative wheat lines that can survive our typical, freezing winters as well as our future unpredictable winters. To do this, molecular markers associated with traits that allow winter wheat to be productive regardless of winter temperatures need to be developed. Using lines developed from a cross between Skiles and Goetze, two winter varieties that differ for vernalization response and photoperiod, field trials have been planted in three Oregon locations in fall, 2016 and fall, 2017. These lines are now being assessed for response to winter field conditions and will also be assessed for the ability to grow with reduced or no vernalization in the future. Information generated from this study will be used in the breeding program to develop new varieties that are adapted to the new environmental realities of the PNW.

Figure 1. Harvesting the 2016-2017 facultative wheat trial at Moro, Oregon.

Capturing Drought-Avoidance Genotypes Using Peroxisome Proliferation Readout

Kathleen Hickey[1], Austin Lenssen[1], Helmut Kirchhoff[1], Asaph Cousins[2], Karen Sanguinet[3], and Andrei Smertenko[1]
[1]Institute of Biological Chemistry, WSU; [2]School of Biological Sciences, WSU; [3]Dept. of Crop and Soil Sciences, WSU

Drought significantly affects agriculture in the US and has resulted in $4 billion in losses in just 2014 alone. Optimization of water management together with improved agricultural practices has caused major yield increases without additional water input. The next significant improvement in sustainable water usage is predicted to be in breeding crops with better performance under limited water availability. We want to facilitate breeding drought-tolerant spring wheat.

One of the key strategies of surviving drought is an avoidance mechanism, which depends on the ability of root systems to reach moisture at deeper soil layers. Breeding crops with deeper and more extensive root systems could potentially improve drought tolerance; however measuring roots in large populations remains an expensive and time-consuming process. The inability of roots to access the soil moisture can diminish the yield by inhibiting carbon fixation and damaging cells through the accumulation of reactive oxygen species (ROS). Plants neutralize ROS using anti-oxidants and ROS-scavenging enzymes. We hypothesize that more efficient neutralization of ROS would improve yield under drought. However, measuring accumulation of ROS in plant tissues is challenging. Developing approaches for identification of plants with deep roots and efficient ROS scavenging would improve the efficiency of breeding efforts.

Our work focuses on solving the above technological handicaps. Reduction of soil moisture content and ROS accumulation causes higher abundance of microscopic structures called peroxisomes inside plants as shown in Figure 1. It means peroxisomes can be used as proxy for root system architecture and ROS homeostasis under drought conditions. We developed a technique for measuring peroxisome abundance in total protein extracts. Now we are measuring the correlation between size and overall architecture of root systems, efficiency of ROS-neutralization, photosynthesis, peroxisome abundance, transcription of genes, and yield. Our work is funded by the USDA -NIFA, BioAg, The OA Vogel Wheat Research Fund, and CAHNRS.

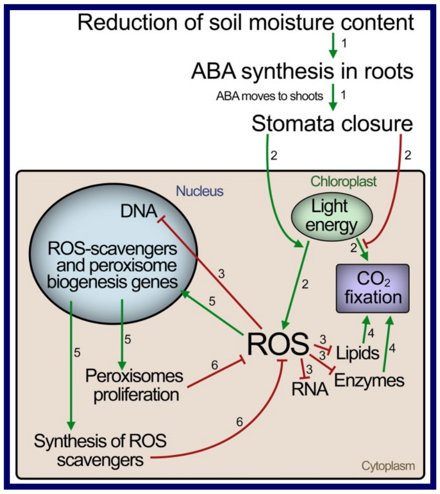


Figure 1. Peroxisomes as a proxy for drought stress.

1. Roots perceive reduced soil moisture content and produce ABA, which is transported to shoots. After reaching the shoots, ABA induces stomatal closure.

2. Stomatal closure reduces CO_2 fixation and, as a consequence, more light energy collected by the chloroplast is converted to ROS.

3. ROS damage lipids, structural proteins and enzymes, RNA, and DNA in all cellular compartments.

4. Damage to lipids and proteins further compromise CO_2 fixation as well as other chemical reactions in the cell. The ROS production increases.

5. ROS activate expression of ROS scavengers and peroxisome biogenesis factors.

6. Neutralization of ROS ameliorates the oxidative damage to the cellular components. Consequently, the chances of cell survival during stress recovery would increase.

Analysis of *SALP1* Genes in Wheat to Improve Drought Tolerance

Rhoda A.T. Brew-Appiah, Zara B. York, and Karen A. Sanguinet
Dept. of Crop and Soil Sciences, WSU

It is estimated that by 2050 there will be a 20% drop in precipitation rates in the dryland wheat-growing areas of Washington state as well as an increase of up to 7 °F in the mean annual temperature. Previous studies have shown that drought can cause a decline in both yield and baking quality of the flour. Recently, a novel little membrane protein was identified in rice named SALP1. We found hexaploid wheat contained seven *SALP* gene coding sequences in Chinese

Spring (Fig. 1), the variety used for genomic studies. *SALP1* was significantly upregulated in the roots of the drought tolerant varieties Drysdale and Louise when compared to the drought susceptible variety Chinese Spring at the 8-hour and 24-hour time points (Fig. 2). Here we used Chinese Spring, Drysdale and Louise to obtain full-length sequences of the *SALP1* gene family in wheat, which are being used in the investigation of the developmental and tissue-specific expression patterns of wheat *SALP* genes. This will provide data that can be used in the development of genetic markers for breeding new drought tolerant wheat varieties for the dryland areas of Washington state.

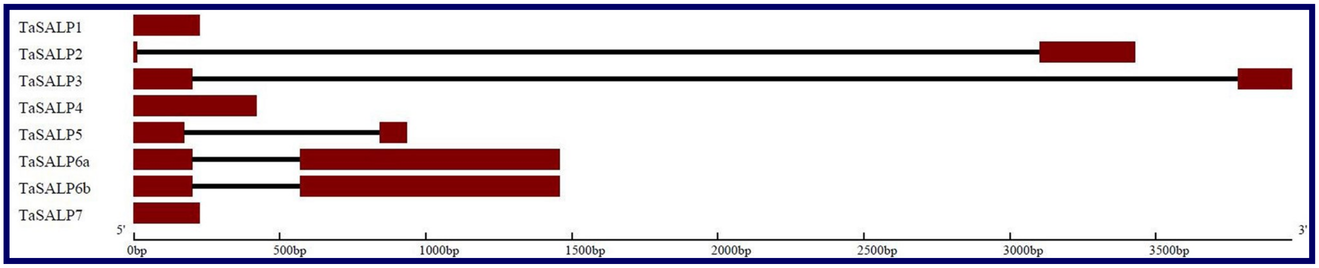


Figure 1. Gene structures of the seven *SALP* genes in hexaploid wheat.

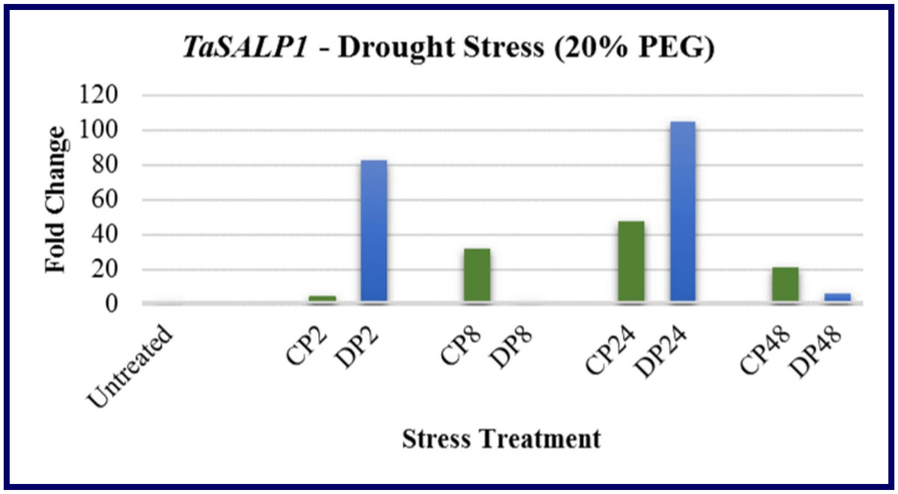


Figure 2. Fold change expression levels of *TaSALP1* in Chinese Spring (green bars: CP2, CP8, CP24, CP48) and Drysdale (blue bars: DP2, DP8, DP24, DP48) under drought stress for 2 hours, 8 hours, 24 hours, and 48 hours.

Winter Wheat that Weathers the Winter

ERIKA KRUSE[1], TIM MURRAY[2], DAN SKINNER[3], AND ARRON CARTER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]DEPT. OF PLANT PATHOLOGY, WSU; [3]USDA, ARS: WHEAT GENETICS, QUALITY PHYSIOLOGY AND DISEASE RESEARCH

More than one hundred million bushels of wheat are produced in Washington state each year. Approximately 80% is winter wheat and is prone to damage from snow mold and freezing temperatures during the winter. Selection for mold and cold tolerant wheat is complicated by the fact that many genes are involved in these traits and highly specific environmental conditions are necessary for disease development. Therefore, marker-assisted selection has the potential to greatly facilitate breeding for tolerant wheat varieties by enabling the selection of lines with the most, or most impactful, quantitative trait loci (QTL). In fact, we have reported four QTL associated with freezing and/or snow mold tolerance in a population derived from elite breeding lines, Finch and Eltan. Our current study aims to determine the effectiveness of marker-assisted selection for multi-gene traits like snow mold tolerance using selected and unselected populations. Further research will involve RNA sequencing to investigate differences in gene expression over time in select Finch-Eltan lines with different combinations of mold and cold tolerance.

Besides genes, sugar accumulation in the crown region can also contribute to snow mold and cold tolerance. Understanding the link between tolerance and dynamics of carbohydrate stores will help breeders improve the winter hardiness of winter wheat. Different sugars in the crown have been demonstrated to serve as cryoprotectants or to limit snow mold growth, so we will investigate the accumulation and maintenance of carbohydrate stores in the crown region over time in those lines with different combinations of mold and cold tolerance. Better understanding of the physiological and genetic differences between susceptible and tolerant plants will facilitate breeding for more winter-hardy winter wheat.

Part 2. Agronomy and Soils

Biosolids and Conservation Tillage: Impacts on Soil Fungal Communities in Dryland Wheat-Fallow Cropping Systems

---

DAN SCHLATTER[1], BILL SCHILLINGER[2], ANDY BARY[3], BRENTON SHARRATT[1], AND TIM PAULITZ[1]
[1]USDA-ARS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU; [3]WSU, PUYALLUP

Organic amendments and conservation tillage are important management tools for reducing soil erosion and improving soil health in agricultural systems, yet the impacts of these practices on soil microbial communities is poorly understood. We evaluated the effects of biosolid amendments and conservation tillage on soil fungal communities in a dryland wheat –summer fallow cropping system in the inland Pacific Northwest. Biosolids or synthetic fertilizer was used in combination with conventional (disk) or conservation (undercutter) tillage in a long-term field experiment at Lind, WA. Fungal communities were characterized from soil and biosolid aggregates after the second application of biosolids in 2015 and before and after the second application of biosolids in 2016 using high-throughput amplicon sequencing.

Biosolid amendments substantially altered fungal community composition, but not diversity, relative to synthetic fertilizer. In contrast, although many more fungal taxa were influenced by conservation tillage when synthetic fertilizer was applied, conservation tillage had relatively little effect on soil fungal communities receiving biosolids, suggesting that the form of N supplied (mineral or organic) may mediate the effects of increasing surface crop residue on fungal communities. Biosolid-mediated shifts in fungal communities were correlated with differences in soil characteristics, especially C, N, and P, and were persistent for at least three years after the initial biosolid application (Fig. 1). A small number of taxa, including *Fusarium, Ulocladium, Gymnoascus, Mortierella,* and *Neurospora*, were highly enriched by biosolids in soil and dominated fungal communities of biosolid aggregates. Results show biosolids can have strong and lasting impacts on soil fungal communities, likely due to their effects on soil nutrients, and select for a small number of fungi capable of utilizing biosolids as a food source.

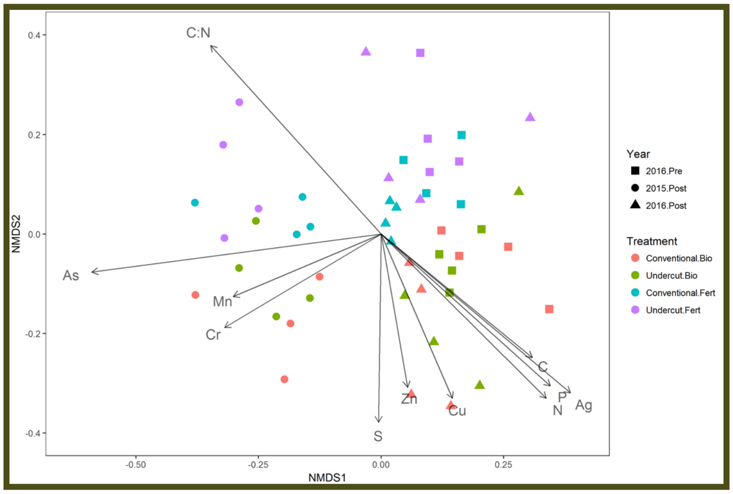


Figure 1. NMDS ordinations of soil fungal communities in June in 2015 and 2016 and in 2016 prior to (Pre) and following the second treatment (Post). Vectors represent significant correlations ($p<0.05$) with soil chemical characteristics in post-treatment samples, where the vector length is scaled by the correlation coefficient.

Wheat Variety-Specific Bacterial Community Recruitment in Soils from High and Low Rainfall Zones

CHRISTINE JADE DILLA-ERMITA[1], RICKY LEWIS[2], TARAH SULLIVAN[2], AND SCOT HULBERT[1,2]
[1]DEPT. OF PLANT PATHOLOGY, WSU; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Soil microbial communities (microbiomes) are involved in diverse ecological services in agriculture such as improved soil quality and nutrient uptake, abiotic stress tolerance and soil-borne disease suppression. With this in consideration, attention have been drawn to the recruitment and manipulation of these microbiomes as advancements in DNA sequencing technologies have enabled the efficient examination of soil microbiomes. The identification of disease-suppressive soil microbiomes has become the "holy grail" of soil-borne disease management, especially in direct-seeded wheat. Understanding plant factors that influence the recruitment of potentially disease "suppressive" microbiomes is imperative in the sustainable manipulation of useful microbiomes. We previously found significant microbiome differences in field plots planted with different wheat varieties and are now comparing varieties grown in pots to develop more rapid assays for characterizing microbiomes of more varieties along with the effect of different soil types. To identify soil microbiomes that are wheat variety-specific, six winter wheat varieties (Madsen, Lewjain, Eltan, Hill81, PI561725, and PI561727) were planted for three 35-day cycles in the growth chamber to mimic three seasons of wheat cropping. Pullman (high rainfall) and Lind (low rainfall) soils were used, and watering was regulated to mimic the amount of water available to plants in these two rainfall zones. Rhizosphere soil, which is heavily influenced by roots and is the most microbially active compartment in the soil, was collected after the third cycle and the DNA was sequenced to generate thousands of 'barcodes' for the microbes present in each sample. The 35-day cycles in both Pullman and Lind generated significantly different microbiomes among wheat genotypes, revealing the importance of soil type in plant selection of microbes. Based on statistical tests, wheat variety influenced the abundance of 85 and 53 bacterial taxa in Pullman and Lind soils, respectively. Further experiments are needed to determine whether three 35-day cycles are enough to recruit putative disease "suppressive" microbiomes. Additionally, ongoing experiments are setup to determine the roles of these bacterial taxa in soil-borne disease suppression and/or improved plant fitness during pathogen infection.

Feasibility of Growing Cover Crops in a Wheat-Fallow System in Northeast Oregon

RAKESH AWALE[1], STEPHEN MACHADO[1], PRAKRITI BISTA[1], AND RAJAN GHIMIRE[2]
[1]COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU; [2]AGRICULTURAL SCIENCE CENTER, NEW MEXICO STATE UNIVERSITY

Growing cover crops in place of fallow may improve soil properties, but deplete soil water availability to subsequent cash crops and reduce crop yields in drylands. A 2-year winter wheat-cover crop rotation experiment was established in 2014/15 crop-year at the Columbia Basin Agricultural Research Center (CBARC) near Pendleton, Oregon to evaluate the effects of cover crops on plant available water, wheat yield, and soil properties. Cropping systems were winter wheat grown in rotation with (i) traditional 13-months fallow (control), or with short-season spring cover crops including (ii) Austrian pea, (iii) Lenetah barley, (iv) Ida gold yellow-mustard, and (v) mixture of all cover crop species under no-till, with each phase of the rotation present every year. Wheat was planted in early October and harvested at physiological maturity in July of the following year. Cover crops were sown in late March to early April, and were mowed and sprayed with glyphosate prior to seed setting in early to mid-June.

Wheat grain and straw yields were low in 2015 due to less growing season precipitation received in the establishment year (Fig. 1). Over the next two crop-years (2016 and 2017), wheat grain yields improved across all treatments due to high growing season precipitations but yield did not differ when grown in rotation with fallow or cover crops. In 2016, among cropping systems, the cover crop-mix treatment produced the highest wheat yield of 80 bu/ac, which was 10 bu/ac and 8 bu/ac more compared to wheat yields following yellow-mustard and pea cover crops, respectively (Fig. 1a). In the same year, cover-cropping generally increased wheat straw yields than fallow, and significantly so with barley cover crop over fallow by 1.1 ton/ac (Fig. 1b).

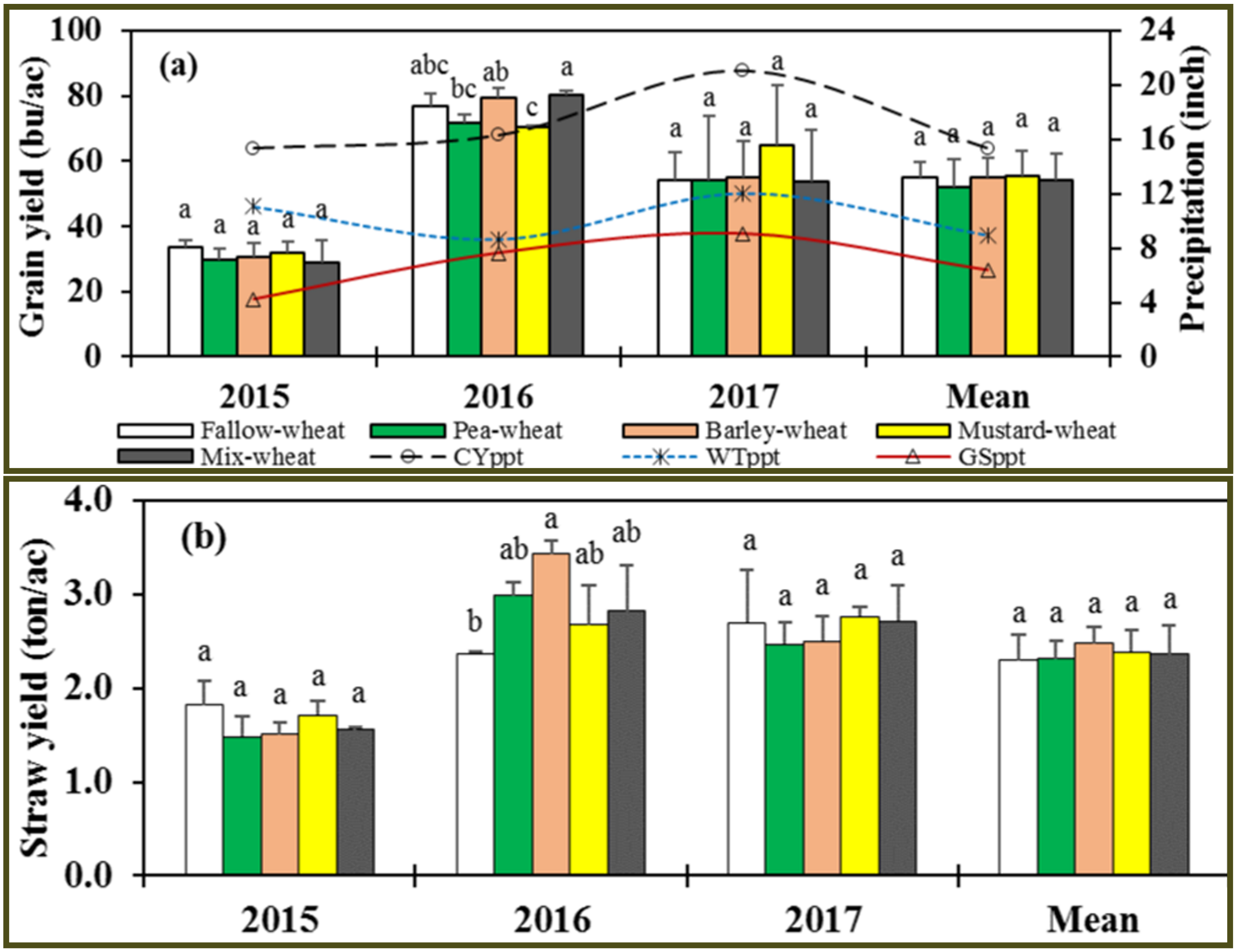


Figure 1. Wheat (a) grain yields and (b) straw yields following fallow and cover crops in 2015-2017 at CBARC. Means with same letters within a crop-year are not significantly different at the 0.05 probability level. CYppt, Crop-year precipitation (Oct-July); WTppt, winter precipitation (Oct-Feb); GSppt, growing season precipitation (Mar-July).

During the 2016 and 2017 growing seasons, plant available water within the top 3.3-feet soil profile and wheat water-use efficiencies did not differ among cropping systems (Table 1). There were no differences in soil organic carbon, total nitrogen, pH, and bulk density at the 8-inch soil surface among cropping systems in 2017, and averaged 13 mg C kg^{-1}, 1.1 mg total N kg^{-1}, 5.2 pH, and 1.3 g/cm^{3}, respectively. Overall, the study indicated that short-season spring cover crops can be grown during fallow in a 2-year winter-wheat-fallow rotation without depleting soil water availability to subsequent wheat crops and compromising grain yields in eastern Oregon. However, the influences of cover crops on soil properties were limited by the short duration of the study.

Table 1. Cover crops effect on wheat water-use efficiencies in 2016 and 2017 growing seasons

Cropping systems	†Water use efficiency (bu/ac/inch)		
	2016	2017	Mean
Fallow-wheat	7.2 a	4.4 a	5.8 a
Pea-wheat	7.0 a	4.3 a	5.6 a
Barley-wheat	7.3 a	4.5 a	5.9 a
Mustard-wheat	6.8 a	5.3 a	6.1 a
Mix-wheat	7.7 a	4.4 a	6.0 a

†Water use efficiency was calculated by dividing wheat grain yield by the sum of growing season precipitation and soil water depleted in the top 3.3-feet profile from the onset of active wheat growth until harvest. Means with same letters within a crop-year are not significantly different at the 0.05 probability level.

Multi-Species Cover Crops in Dryland Cereal & Grain-Legume Rotation

DOUG FINKELNBURG, KEN HART, AND JIM CHURCH
UI EXTENSION

Integrating multi-species cover crop mixes into dryland farming rotations to improve soil health is of interest to PNW farmers but little information currently exists on the effects of different mixes on a long-term crop rotation. This ongoing study seeks to demonstrate the effects on crop production of using cover crop mixes in a winter wheat, spring barley and spring pea direct-seeded rotation. There were four cover crop-mix treatments and either full or minimal residue removal. Cover crops were spring seeded in year-1 of the study followed by fall wheat, spring barley and then spring pea. Cover crops were planted in the fall following the fall wheat crop and after the following spring barley crop. Spring pea yields were greater following the 2-, 8- and 12-species mixes and chem-fallow compared the yields following the 5-species mix. Pea yields were greater under minimal residue removal than full (burning) in all cases except following the 5-species mix. It is likely unremoved residue increased moisture retention during the dry, 2017 summer and resulted in increased yields regardless of presence or absence of fall cover crops. Results were analyzed using a generalized linear mixed model.

Table 1. Fall planted cover crop mixes.

Species	2-species	5-species	8-species	12-species
	lbs/acre			
Austrian Winter Pea	32	14	8	6
Everleaf Oat	25	10	5.5	4
Daikon Radish		2.5	1.5	1
Sorghum Sudan Grass		7	4	3
Hairy Vetch		7	4	3
Rapeseed			1.5	1
Appin Turnip			1	1
Brown Flax			3	2
Manta Millit				1
Crimson Clover				1
Sunflower				1
Winter Lentil				1

Table 2. Spring pea yields following cover crop mixes and full or minimal residue removal.

Cover Crop Mix	Sp. Pea Yield
2-species	1332^{a}
12-species	1320^{a}
8-species	1300^{a}
Chem-fallow	1297^{ab}
5-species	1208^{b}

Cover Crop Mixes	Residue Management	Sp. Pea Yield
2-Species	Min	1423^{a}
2-Species	Full	1241^{bc}
5-Species	Min	1253^{bc}
5-Species	Full	1164^{c}
8-Species	Min	1395^{a}
8-Species	Full	1205^{bc}
12-Species	Min	1422^{a}
12-Species	Full	1218^{bc}
chem-fallow	Min	1359^{ab}
chem-fallow	Full	1235^{bc}

Soil Carbon: Quantifying Loss Associated with Wind Erosion

BRENTON SHARRATT[1] AND BILL SCHILLINGER[2]
[1]USDA-ARS, NORTHWEST SUSTAINABLE AGROECOSYSTEMS RESEARCH UNIT; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Soil carbon (C) can affect water holding capacity, aggregation, nutrient cycling, and microbial activity and thus soil quality. Wind erosion, however, negatively affect these processes because removal of fine soil particles by wind results in the loss of C. The objective of this study was therefore to quantify the loss of C from windblown agricultural soils in the Inland Pacific Northwest (PNW). Creep and Big Spring Number Eight samplers (Fig. 1) were used to trap soil eroding from dryland agricultural fields located throughout the low precipitation zone of the PNW during major wind events over an 8-year period. The samplers were positioned at heights of 0 to 5 ft above the soil. We found the eroded sediment was generally enriched in C as compared with the parent soil. Averaged across all sites and wind events, the eroded sediment contained 3.2% more C than the parent soil. Loss of C measured during single wind events was as high as 16 lbs/ac, but historical accounts suggest that loss approached 1225 lbs/ac in the region. The gradual decline in soil C since the advent of farming in the region 135 years ago is commonly thought to be due degradation by microbes and oxidation. However, our data suggests that loss of soil C may also be due to wind erosion. Farmers in the winter wheat-summer fallow region are encouraged to adopt conservation tillage practices to retain residue and soil aggregates on the surface and thereby reduce wind erosion and preserve soil C.

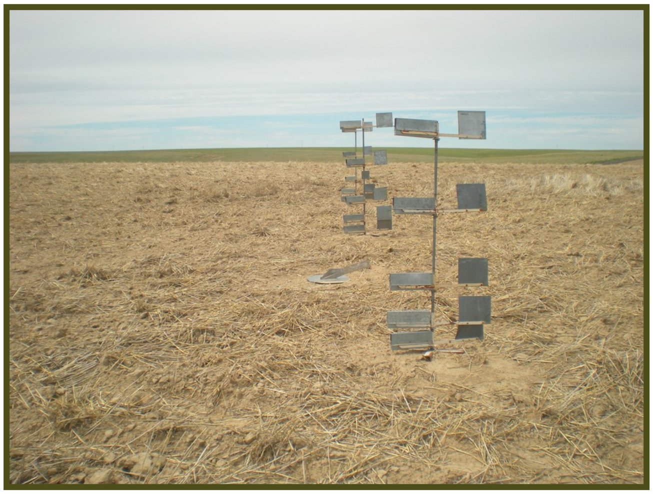


Figure 1. Big Spring Number Eight samplers are mounted at various heights on poles while creep samplers are located at ground-level between the poles. The photo was taken after spring tillage in 2012.

Optimizing Liming Rates for Low pH Soils in Northern Idaho

ANDREW LEGGETT AND KURTIS SCHROEDER
DEPT. OF PLANT SCIENCES, UI

Soil pH has been declining steadily in northern Idaho for decades, primarily due to the consistent use of ammonium-based fertilizers. Low soil pH can result in aluminum toxicity, less nitrogen fixation in legume crops and reduced efficiency of fertilizer, all of which can lead to reduced vigor and yield. A recent soil survey indicates that a significant portion of fields in northern Idaho have a pH below 5 with increased quantities of soluble aluminum and could benefit from lime application. While acute symptoms of severe aluminum toxicity associated with low pH are uncommon, growers have observed declining yields in some fields. Previous examination of calcium carbonate ($CaCO_3$) applied at rates up to 1 ton/A resulted in insufficient shifts in soil pH and inconsistent yield responses in wheat and pea.

In a new study, field plots at five locations were established to test higher rates of lime application. Rates of 0, 1, 2 and 3 tons of $CaCO_3$ were applied to the soil in the fall of 2016 and incorporated to a depth of approximately 3 to 6 inches. Winter wheat was seeded at three locations near Potlatch and Tensed, ID in the fall of 2016.

A positive yield response was observed at all three locations with increases of up to 9 to 11 bu/A at Potlatch-2 and Tensed-1 (Fig. 1). The lack of significant yield response at Tensed-2 may be attributed to a combination of several factors, including late planting and wet soil conditions at planting which resulted in soil compaction, likely contributing to moderate Fusarium crown rot disease at the site. Composite soil samples collected in June of 2017 indicated a significant increase in soil pH, calcium saturation and total base saturation with increasing $CaCO_3$ rate at all sites (Fig. 2).

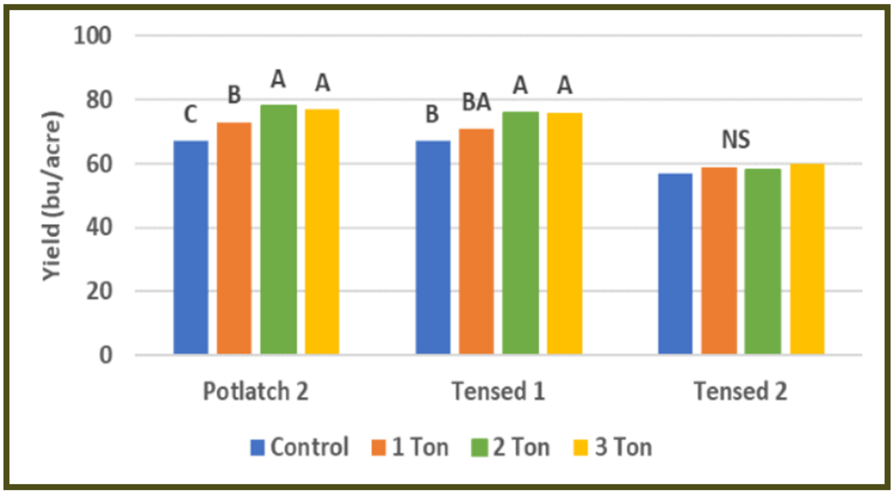


Figure 1. 2017 winter wheat yields. Yields within sites with a different letter are significantly (p<0.1) different from each other.

There also was a substantial decrease in the quantity of potassium chloride (KCl) extractible aluminum, particularly in the top 3 inches. With 2 and 3 ton/A rates of $CaCO_3$ the quantity of aluminum was reduced to nearly 0 ppm in the top 3 inches and substantially reduced at the 3-6-inch depth. This study will continue for a minimum of 6 years to determine the long term economic return following application of higher rates of lime. As opposed to lower rates of lime applied more frequently, application of 2 to 3 ton/A of $CaCO_3$ has the benefit of potentially producing a more immediate and greater crop response to the application, particularly when higher rates are recommended following soil testing, and providing a more long-term solution to soil acidity.

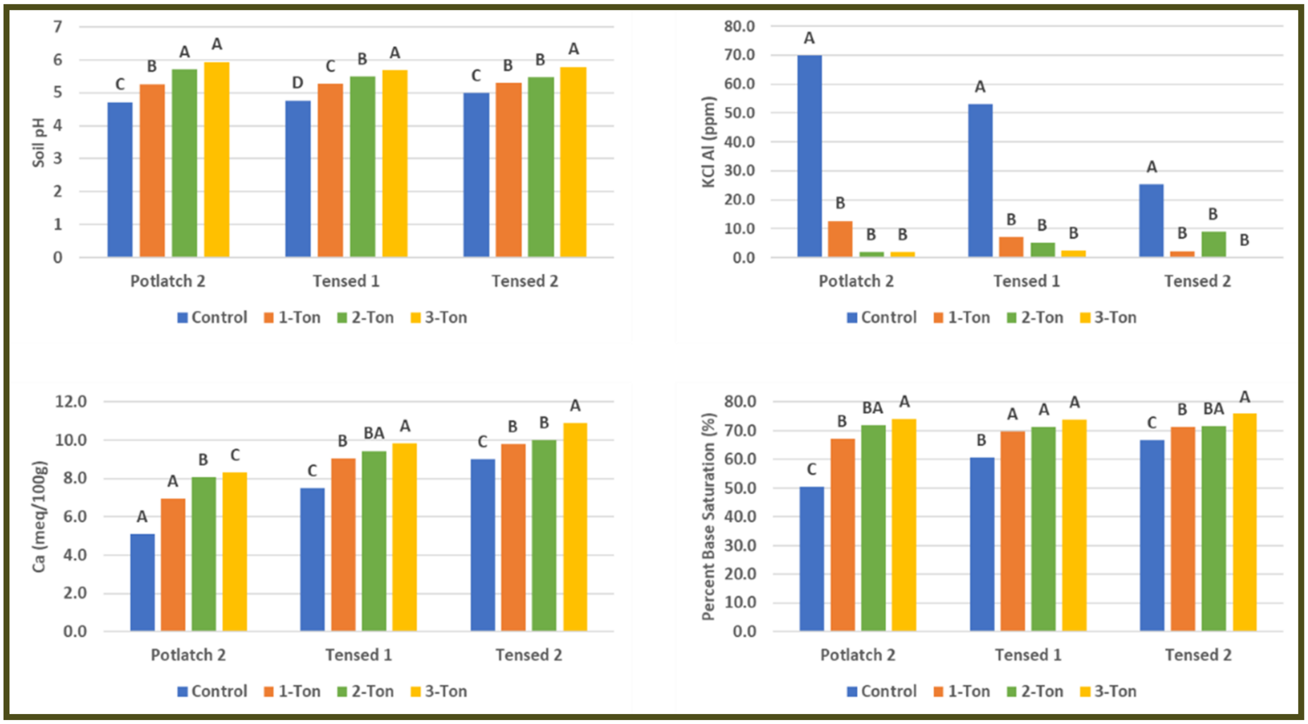


Figure 2. Effect of lime on soil ph, KCl Al, Ca, and percent base saturation in the top 3 inches of soil. Values within sites with different letters are significantly (p<0.1) different.

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

AARON ESSER AND DEREK APPEL
WSU EXTENSION

The WSU Wilke Research and Extension Farm is located on the eastern edge of Davenport, WA. Washington State University maintains and operates this facility. The farm is in a direct seed cropping system utilizing no-till fallow, winter

The new shed at WSU Wilke Research and Extension farm.

wheat, spring cereals and broadleaf crops. Broadleaf crops are incorporated when weed pressures and market prices create opportunities for profitable production. The predominant cropping system practiced by farmers in this region is a 3-year rotation, which includes summer fallow, winter wheat, and spring cereals. Farmers are interested in intensifying rotations to reduce fallow years and increase crop diversity to improve long-term agronomic and economic stability.

The south side of the farm is divided into seven plots; three plots are in a more traditional 3-year crop rotation, and four plots are in an intensified 4-year crop rotation. The north side of the farm remains in an intensified rotation that forgoes summer fallow and is in a continuous cereal grain production. Economic return over input costs (seed, fertilizer, pesticides) is analyzed in three-year averages to help remove some of the year-to year variability (Fig. 1). Fixed cost associated with the farm are not included because of the variability from farm to farm across the region. Overall no significant difference in economic return over input costs has been detected between the 4-year and 3-year rotation at \$112 and \$115/ac. The continuous crop rotation has been significantly less at only \$70/ac. More information and reports can be found at http://wilkefarm.wsu.edu/.

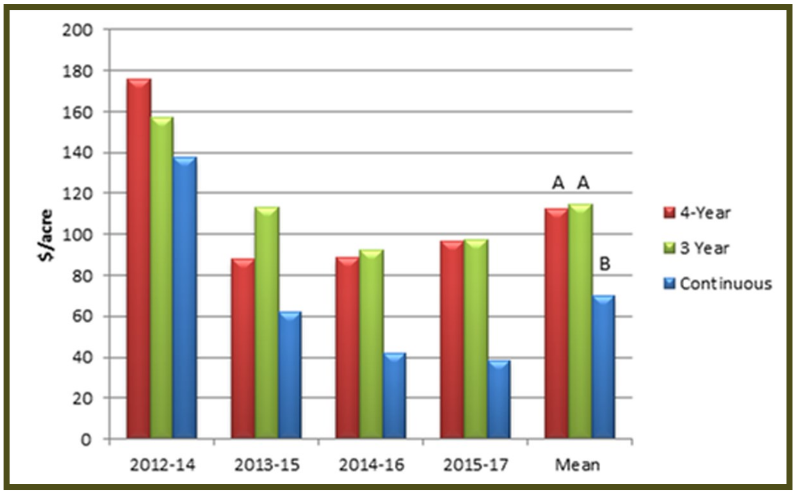


Figure 1. Three-year average economic return over input costs of 3-year, 4-year, and continuous cropping systems at the WSU Wilke Farm. Costs do not include fixed costs associated with the farm. Means within columns assigned different case letter are significantly different (*P*<0.10).

Diversifying Wheat-Based Cropping Systems with Integration of Legumes and Cover Crops

---

SAUGAT BASKOTA[1], JODI JOHNSON-MAYNARD[1], SANFORD EIGENBRODE[1], ERIN BROOKS[1], CLARK SEAVERT[2], SHELLEY PRESSLEY[3], BRIAN LAMB[3], CLAUDIO STOCKLE[3], IAN BURKE[3], DAVID HUGGINS[4], REBECCA MCGEE[4], AND KURTIS SCHROEDER[1]
[1]UNIVERSITY OF IDAHO; [2]OREGON STATE UNIVERSITY; [3]WASHINGTON STATE UNIVERSITY; [4]USDA-ARS

The dryland inland Pacific Northwest is mostly dominated by a wheat-based cropping system. The region is diverse with regard to precipitation with approximately 10-inch annual rainfall in central Washington, increasing to more than 20-inch annual rainfall in northern Idaho. Each agroecological zone within this region struggles with unique challenges. Availability of moisture is a major concern in the low rainfall cropping systems, which has required farmers to rely on a winter wheat-fallow rotation with very limited options to diversify. In transitional zones with approximately 14 to 18 inches of annual precipitation, fallow may be practiced in one out of three years, increasing the risk of soil erosion. Alternatively, in the high rainfall, annually cropped regions there can be problems with high soil moisture as was observed with the above normal rainfall received in the spring of 2017. Excessive spring precipitation can lead to delayed spring seeding and increased soil compaction. Diversification and intensification of rainfed wheat-based cropping system is necessary to develop a resilient system to climate fluctuations.

Some practical options being examined to address these issues are incorporation of additional fall seeded crops such as winter pea, cover crops and further integration of livestock in the cropping system by taking advantage of potential grazing of cover crops. A four-year study was initiated in 2017 with the goal of developing a resilient crop rotation system with a focus on increasing crop diversity and examining its impact on weeds, insect and soil health. Field plots were established in Genesee, ID which is an annual cropping zone and at St. John, WA which is a transition cropping zone. Winter pea and fall seeded cover crops are being incorporated in place of traditional spring crops or fallow, and compared to the standard cropping system for each region. Related studies are already underway in Ritzville, WA to examine integration of winter pea. Table 1 shows the different treatments of crop rotations that will be in the field for the next 4 years. At each site, all the components of crop rotation will be present in each year and each component will follow the rotation in the following year.

A team of scientists from the University of Idaho and Washington State University will examine winter survival, yield parameters, moisture trends, residue levels, weed densities, insect dynamics, economics, and soil health indicators. We expect to provide guidelines on developing resilient and diverse cropping systems that could lead to reduced fallow, improved soil health and increased profitability. There is a need to development a robust cropping system which has long-term agronomic and economic stability.

Table 1. Diversified and intensified crop rotation at Genesee, ID and St. John, WA.

Annual Cropping Zone (Genesee, ID)	Transitional Zone (St. John, WA)
Winter pea—winter wheat—spring wheat	Winter pea—winter wheat—spring wheat
Chickpea—winter wheat—winter cover crop	Spring cover crop—winter wheat—spring wheat
Chickpea—winter wheat—spring wheat	Fallow—winter wheat—spring wheat

Economics of Liming Acidic Soils on the Palouse

KATHLEEN PAINTER[1] AND KURTIS SCHROEDER[2]
[1]UI EXTENSION; [2]DEPT. OF PLANT SCIENCES, UI

In many areas of the inland Pacific Northwest dryland cropping region, soils are becoming increasingly acidic, primarily due to decades of ammonium-based fertilizer applications. In this region, yield response to declining pH levels were estimated for spring pea, lentil, barley and winter wheat by Mahler and McDole in the 1980s. In other areas of the country, periodic applications of lime are used to counteract this problem, as low pH soils are less able to utilize nutrients in the soil and support healthy crops, and soluble aluminum can accumulate in acidic soils and cause toxicity to sensitive plants. Measuring the costs and benefits of lime application to soils in Idaho is one component of a research project funded by the Idaho Wheat Commission.

As opposed to typical fertilizer applications that are made each year, lime applications should be treated as a capital investment, as the effects last for many years. Field research in western Canada has shown positive impacts on soil pH and crop yields for alfalfa, barley and wheat from a single application of lime lasting from 16 to 27 years. In order to measure the economic impacts of lime applications, annualized costs of lime applications need to be compared to annual benefits in terms of the value of yield gains. Unfortunately, there are many uncertainties in this process, such as the value of future yield gains and yield increases over time, by crop.

Three rates of ground limestone (1, 2, or 3 tons per acre) were compared to a control with no lime application. The cost of ground limestone is $74 per ton for the product which included delivery from Lewiston, ID, to plots in Potlatch and Tensed, ID plus $13 per acre for application. Liming treatments were estimated to be effective for 10 years for the 1-ton rate, 15 years for the 2-ton rate, and 20 years for the 3-ton rate, resulting in an annualized value of liming of $12 per acre for the 1-ton rate, $17 per acre for the 2-ton rate, and $20 per acre for the 3-ton rate, assuming an annual discount rate of 6%.

Yield gains at the Potlatch site averaged 6 bu per acre for the 1-ton rate, 11 bu per acre for the 2- ton per acre rate, and 10 bu per acre for the 3-ton rate. Based on an estimated farmgate value of wheat of $4.45 per bu, the per acre gains from liming were estimated at $27 per acre for the 1-ton rate, $49 per acre for the 2-ton rate, and $45 per acre for the 3-ton rate. These values exceeded the annualized costs of liming by $15 per acre for the 1-ton rate, $32 per acre for the 2-ton rate, and $25 per acre for the 3-ton rate, despite the low wheat price of $4.45 per bu (Fig. 1).

At the first Tensed site, the value of yield gains from liming exceeded costs by $6 per acre for the 1-ton rate, $23 per acre for the 2-ton rate, and $20 per acre for the 3-ton rate (Fig. 1). At the second Tensed site, the value of these yield gains were less than the liming expenses, resulting in losses of $3 per acre for the 1-ton rate, $13 per acre for the 2-ton rate, and $7 per acre for the 3-ton rate (Fig. 1). Lime applications have the potential to have long lasting positive impacts for crop yields in areas of this region with low pH soils. Further research is being conducted to answer additional questions on yield impacts over time for various locations and with different liming rates.

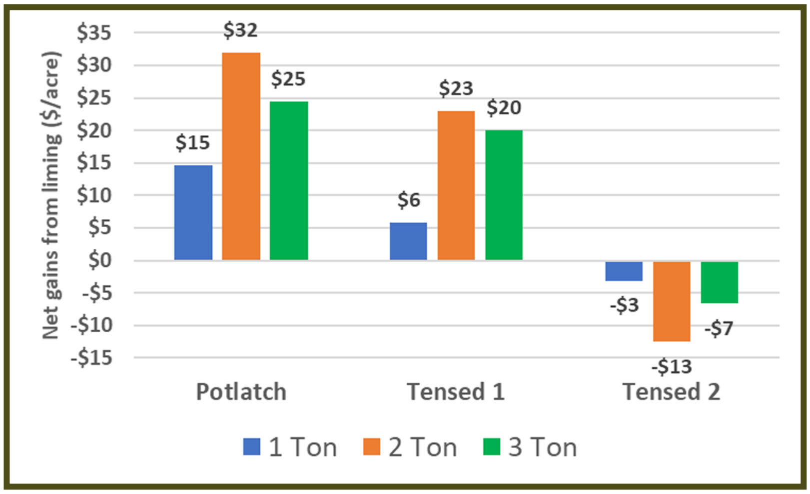


Figure 1. Net average annual gain from three rates of lime applications at three Idaho sites, based on a $4.45 per bu farmgate average wheat price for 2016 ($/bu).

Predicting Winter Wheat Straw Decomposition

ALEJANDRA N. ROA[1], NATHAN S. NIELSEN[1], JAYFRED GODOY[1], ERIKA B. KRUSE[1], TAMI L. STUBBS[2], AND ARRON H. CARTER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]PALOUSE CONSERVATION DISTRICT

The Palouse region of Washington state faces deteriorating soil quality from erosion. Farmers list the difficulty of managing residue on the hills of the Palouse as an obstacle to adopting conservation farming practices that conserve topsoil quality. Towards the eastern border of Washington, the higher rainfall results in more crop residue, which requires a faster rate of decomposition in cultivars for this region. Towards Central Washington, decomposition rates need to be slower in order for the residue to provide sufficient ground cover during fallow years. Decomposition rates have been correlated with the composition characteristics of cell wall constituents. These can be determined by current chemical methods but there is a need for an efficient high-throughput method of obtaining this information for breeding programs and seed producers. Near Infrared Reflectance Spectroscopy (NIRS) has been shown to be a high throughput tool for predicting cell wall constituent composition. In similar studies, NIRS has been successful at predicting the performance of complex traits like decomposition. A Finch by Eltan (FxE) population of 152 individuals was planted across multiple years in various locations and is being analyzed with fiber analysis and NIRS. This data will be part of a calibration set used to derive prediction equations for the cell wall constituents: NDF, ADF, ADL, nitrogen, carbon, nitrogen-to-carbon ratio, cellulose and hemicellulose. A Quantitative Trait Locus (QTL) analysis will be run with the FxE data to correlate genetic regions to cell wall constituents and composition patterns associated with decomposition rates. Additionally, a panel of 480 winter wheat cultivars from 2016 and 2017 in multiple locations will also undergo fiber analysis and NIRS analysis. These will serve as an expansion of the calibration set for the prediction equations in order to create more robust equations that can accommodate more variability. A Genome Wide Association Study (GWAS) will be run on the 480 cultivars to identify molecular markers that are associated with variation in cell wall composition. Preliminary data indicates lines with higher nitrogen and lower lignin content in the straw leads to more rapid straw decomposition. The distinct populations and NIRS calibrations will allow us to create an efficient method of predicting cell wall composition, decomposition potential, decomposition rate and provides a tool for breeding programs to evaluate the quality of straw residue. This information can then be provided to farmers to help them select cultivars that will fit their residue requirements and facilitate their transition to conservation farming so they can conserve their soil while remaining economically productive.

Does Windblown Dust Emitted from Fields Treated with Biosolids Contain Harmful Chemicals?

BRENTON SHARRATT[1], BILL SCHILLINGER[2], AND ANDREW BARY[2]
[1]USDA-ARS, NORTHWEST SUSTAINABLE AGROECOSYSTEMS RESEARCH UNIT; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Wind erosion of agricultural lands in the low precipitation zone of the Inland Pacific Northwest affects both soil productivity and air quality. Biosolids have been applied to drylands in this region, but wind erosion of these lands might transport biosolid particulates and associated chemicals offsite and impact environmental quality. Therefore, we assessed the chemical composition of soil and windblown sediment from a biosolids field experiment at Lind, Washington. Synthetic fertilizer and biosolids were applied to a silt loam prior to primary tillage in the spring (April) during the fallow phase of a winter wheat – summer fallow rotation. Wind erosion was assessed after the first rodweeding (mid-June) and sowing winter wheat (early September) in 2015 and 2016 using a portable wind tunnel. The wind tunnel (Fig. 1) generated 40 mph winds and airborne sediment inside the tunnel was collected using an isokinetic sampler. The soil and airborne sediment collected on the two sample dates both years were analyzed for heavy metals, macronutrients and micronutrients. Application of biosolids resulted in higher concentrations of heavy metals in the soil. For example, zinc (Zn) concentration in soil was 21% higher for biosolids than synthetic fertilizer after rodweeding in 2015. Differences in metal concentrations between fertilizer treatments, however, were not apparent in windblown sediment. Similar results were found for nutrient concentrations in soil, but concentrations in windblown sediment were at least 10% lower for biosolids than synthetic fertilizer on at least one measurement date. Our results suggest little difference in the chemical composition of windblown sediment between biosolids and synthetic fertilizer treatments. Biosolids, however, are beneficial for increasing C and N content in soil. A full report of this study is available at: Pi, H., B. Sharratt, W.F. Schillinger, A. Bary, and C. Cogger. 2018. Chemical composition of windblown dust emitted from agricultural soils amended with biosolids. *Aeolian Research* 32:102-115.

Figure 1. Portable wind tunnel used to collect windblown sediment from soils amended with biosolids at Lind, Washington. The photo was taken after sowing wheat in September 2015.

Dust-Associated Microbiomes from Dryland Wheat Fields Differ with Tillage Practice and Biosolids Application

Dan Schlatter[1], Bill Schillinger[2], Andy Bary[3], Brenton Sharratt[1], and Tim Paulitz[1]
[1]USDA-ARS; [2]Dept. of Crop and Soil Sciences, WSU; [3]WSU, Puyallup

Wind erosion is a significant threat to the productivity and sustainability of agricultural soils. In the dryland winter wheat-fallow region of Inland Pacific Northwest, farmers increasingly use conservation-tillage and no-tillage practices to control wind erosion. In addition, some farmers in this dry region apply municipal biosolids to soils as fertilizer and a source of stable organic matter. The impacts of soil management practices on emissions of dust microbiota to the atmosphere are understudied. We used high-throughput DNA sequencing to examine the impacts of conservation tillage and biosolids amendments on the transport of dust-associated fungal and bacterial communities during simulated high-wind events over two years in a long-term biosolids experiment at Lind, WA.

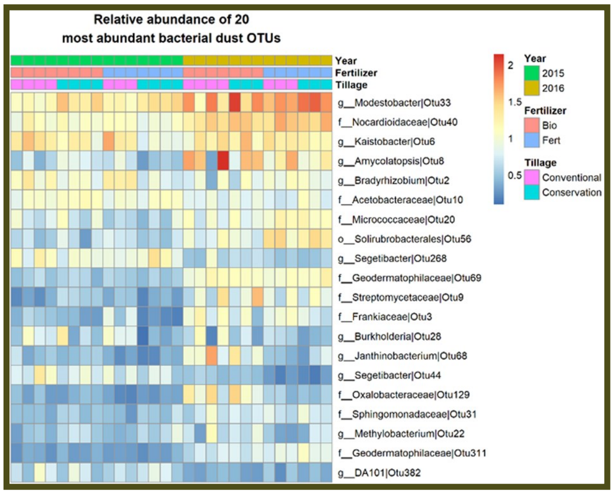


Figure 1. Heatmap of the relative abundances (Log2(1+X)-transformed sequence counts) of the 20 most abundant bacterial OTUs.

The fungal and bacterial communities contained in windblown dust differed significantly with tillage (undercut conservation tillage versus tandem disk conventional tillage) and fertilizer (synthetic vs. biosolids) treatments (Fig. 1). However, the richness and diversity of fungal and bacterial communities of dust did not vary significantly with tillage or fertilizer treatments. Taxa enriched in dust from fields undercutter tillage represented many plant-associated taxa that likely grow on residue left on the soil surface, whereas taxa that were more abundant with tandem-disk tillage were those that likely grow on buried plant residue. Dust from biosolids-amended fields harbored greater abundances of taxa that likely feed on introduced carbon. Most human-associated taxa that may pose a health risk were not present in dust after biosolids amendment, although members of Clostridiaceae were enriched with this treatment. Results show that tillage and fertilizer management practices impact the composition of bioaerosols emitted during high-wind events and have potential implications for plant and human health.

Evaluating a Cover Crop Mix in the Dryland Area in Southern Idaho

Xi Liang[1], Arash Rashed[2], Christopher Rogers[1], and Juliet Marshall[2]
[1]Dept. of Plant Sciences, UI Aberdeen; [2]Dept. of Entomology, Plant Pathology, and Nematology, UI Aberdeen

Dryland areas in southern Idaho are characterized by short growing seasons and dry conditions. Crop rotations in the region are severely limited, and production primarily consists of winter and spring cereal “rotations” with summer fallow practices. Growers have shown an increased interest in integrating cover crops into dryland cropping systems, but there is little information on the feasibility in dryland areas. To investigate the feasibility of integrating cover crops in dryland cereal cropping systems, three-year field studies were established on two dryland cereal farms in Arbon Valley and Rockland in southern Idaho. Three rotational treatments were arranged at both locations, including winter wheat-fallow-winter wheat, winter wheat-fall planted cover crop mix-winter wheat, and winter wheat-spring planted cover crop mix-winter wheat, from 2015 to 2018. Cover crops were either planted in late September 2016 or early April 2017, and terminated in early July 2017 at both locations. The cover crop mix consisted of turnip, radish, vetch, spring pea, and field pea with a ratio of 1:1:5:10:10 and was planted at a seeding rate of 30 lb/acre, as recommended by USDA NRCS. The experimental plot is 50 by 100 feet with six replicates of each rotational treatment following a randomized complete block design. For the rotation with fall-planted cover crops, field pea and hairy vetch survived after the winter and spring pea failed to withstand the winter hardness in both Arbon Valley and Rockland. Turnip and radish survived the winter in Arbon Valley, but failed in Rockland. The air temperature in Rockland was as low as -20°F with snow cover mostly during the winter of 2016-2017. In both Arbon Valley and Rockland, total biomass of all cover crop species from the fall planting (Arbon Valley: 530 lbs/ac; Rockland: 1043 lbs/ac) was higher than spring planting (Arbon Valley: 298 lbs/ac; Rockland: 479 lbs/ac), but in Arbon Valley, biomass of turnip and radish from the spring planting was higher than the fall planting. Selection of cover crop species should thus consider environmental conditions and management practices. Species that are able to withstand winter, such as field pea and hairy vetch, could be planted in the fall and produce greater biomass during the long growing season. Species with poor winter survival, such as spring pea, turnip, and radish, could be planted in the spring and terminated by winterkill.

Figure 1. Cover crop mix planted in the fall 2016 (left) and spring 2017 (right).

Part 3. Oilseeds and Other Alternative Crops

Large-Scale Canola Variety Trials – An Outreach Success Story

KAREN SOWERS[1], DENNIS ROE[1], SCOT HULBERT[2], LABAN MOLSEE[1], DANIEL STENBAKKEN[3], AARON ESSER[1], AND KEITH CURRAN[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]DEPT. OF PLANT PATHOLOGY, WSU; [3]VITERRA/PACIFIC COAST CANOLA

Canola acreage hit a record high in Washington state and the Pacific Northwest in 2017. Contributing factors include local crushing facilities offering competitive pricing, below normal wheat prices, and more growers recognizing the many agronomic benefits canola has to offer in both dryland and irrigated production regions. With the increased awareness of canola as a viable rotation crop, the need for education on all production fronts is essential to improve the chance of success of first-time and veteran canola growers.

Variety selection is a key item on the 'Canola 101' list. With funding assistance from Viterra, Inc. we have conducted large-scale spring and winter canola variety trials on farms in eastern Washington and north central Oregon since 2016. What has evolved with the trials was far more than we anticipated in terms of research and Extension. Several researchers on the WSU-WOCS team have added projects within and alongside the trials, including fertilizer management, plant population, nitrogen cycling, and pollinators (see related abstracts). Industry has supplied seed, provided weigh wagons for harvest, and helped with data collection. Oregon State University has assisted with data collection at The Dalles site.

Most importantly, we are building relationships with the canola growers hosting the plots who then reach out to more growers and others near them who may or may not be familiar with canola. The end result has been increased participation by all stakeholders, and a comprehensive review during field tours of the variety trials, WOCS research, and industry, OSU, and UI canola information. We reached 190 people through tours at our 2017 variety trials that featured a wide range of presentations (Fig. 1).

Figure 1. Tours at all of the canola variety trials were well attended. Photo from the St. John winter canola site.

Yield results from the 2016-17 winter canola and 2017 spring canola variety trials are in the tables below. Winter canola yields were at or above historical records at St. John and Ralston. St. John had the highest mean yield of 3,046 lbs/acre, followed by Ralston and Odessa at 2,971 and 2,352 lbs/acre, respectively. Spring rains and saturated soils prevented us from applying weed control which affected the Odessa site the most as it had heavy catchweed bedstraw and other weed pressure. Despite clear visual differences in early season vigor of the spring varieties, there were no significant yield differences at any of the trials locations. Planting was delayed several weeks due to wet soils which likely reduced overall yield potential as several high temperature events occurred during flowering. Full reports are available on the WOCS website (www.css.wsu.edu/oilseeds).

Yield results of 2016-17 Winter Canola Variety Trials

Variety	Odessa		Ralston		St. John	
	——————lbs/acre——————					
Amanda	2,424	a	3,193	a	3,370	ab
Claremore	2,249	a	2,654	b	3,125	ab
Edimax	2,337	a	3,468	a	3,519	a
Griffin	2,390	a	3,188	a	2,887	b
HyClass 225	2,333	a	3,202	a	3,121	ab
Largo	2,380	a	1,840	c	2,258	c
Mean	2,352		2,971		3,046	
Tukey HSD (0.05)	ns		425		486	
CV(%)	9.7		6.0		6.9	

Means which share a letter do not differ significantly.
ns= not significant

Yield results of 2017 On-farm Spring Canola Variety Trials

Variety	Almira		Pullman		Walla Walla	
	——————lbs/acre——————					
BY 5545 CL	1,162	a	2,055	a	1,563	a
BY 6080 RR	1,277	a	1,984	a	1,519	a
HyClass 930	1,002	a	2,117	a	1,588	a
InVigor L233P	970	a	2,385	a	1,500	a
Nexera 2024 CL	1,037	a	1,971	a	1,235	a
DL 1506 CL	1,182	a	1,959	a	1,363	a
Mean	1,105		2,078		1,461	
Tukey HSD (0.05)	510		617		429	
CV(%)	19.3		12.9		12.8	

Means which share a letter do not differ significantly.

We are continuing the trials for another season with winter plots at Mansfield, Ritzville, and The Dalles, OR, and spring trials at Walla Walla, Ralston, and Davenport.

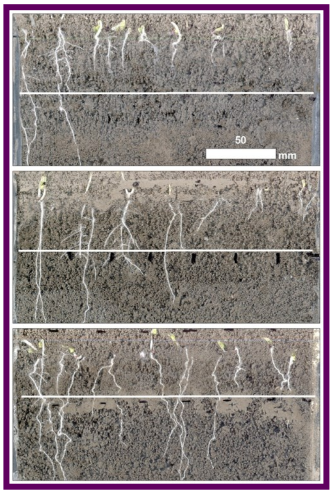
Many thanks to our cooperators: David Brewer, Jesse Brunner, Rob Dewald, Jesse Brunner, Curtis Hennings, Ross Jordan, Douglas Poole, Mark & Brendan Sherry, and Traig Weishaar.

Seed provided by Bayer CropScience, BrettYoung, Caldbeck Consulting, CPS, Croplan by Winfield, Dow AgroSciences, Kansas State University, Rubisco Seeds, Spectrum Crop Development, and University of Idaho.

Selecting Nitrogen Source to Minimize Damage Caused by Free Ammonia

ISAAC MADSEN AND WILLIAM PAN
DEPT. OF CROP AND SOIL SCIENCES, WSU

When planning N fertilizer application, the source of the fertilizer should be considered in order to optimize nutrient availability as well as to avoid damaging seedling root systems. Canola root systems have been shown to be sensitive to urea banded below the seeds. The two primary considerations when choosing a safe source of N fertilizer are the salt toxicity and ammonia/ammonium toxicity. The conversion of ammonium to free ammonia is primarily controlled by the initial pH of the fertilizer reaction. A high pH will lead to more free ammonia than ammonium. Free ammonia has been shown to be extremely toxic to plant cells. Therefore, fertilizers with a high pH would be expected to release more free ammonia and consequently have a higher level of toxicity. Urea, Anhydrous Ammonia, and Aqua Ammonia all have pH greater than 8 in solution. Fertilizers with a pH lower than 8 are Ammonium Sulfate, Mono-Ammonium Phosphate, and Di-Ammonium Phosphate. In this study we compared the application of ammonium sulfate (AS) (pH = 5-6, partial salt index = 3.52), urea (pH = 8.5-9.5, partial salt index = 1.61), and urea ammonium nitrate (UAN) (pH = 7, partial salt index = 2.22). The fertilizer was banded below the seed at incrementally increasing rates from left to right. Urea (top) showed the most damage, followed by AS (middle) and UAN (bottom). The images from this study are currently being evaluated to develop 'safe' planting guidelines for banding N fertilizers below canola seeds.



Take away points: It was determined that canola roots are more sensitive to urea than ammonium sulfate or UAN. This is likely because urea would produce higher levels of free ammonia following dissolution.

Soil Microbial Community Response with Canola Introduced into a Long-Term Monoculture Wheat Rotation

JEREMY HANSEN[1], BILL SCHILLINGER[2], TARAH SULLIVAN[2], AND TIM PAULITZ[1]
[1]USDA-ARS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

With increasing acreage of canola (*Brassica napus* L.) in the Inland Pacific Northwest (PNW) of the USA, we investigated the effect of this relatively new rotational crop on soil microbial communities and the performance of the subsequent wheat (*Triticum aestivum* L.) crop. A relevant objective for the use of rotation crops is to increase the performance of subsequent crops. The degree of influence on soil biological properties and crop productivity is, however, crop specific. Canola plants contain glucosinolates, which upon cell rupture and during the decay of residue, hydrolyze to produce isothiocyanates. The production of isothiocyanates is the mechanism responsible for the biofumigation effect, which can reduce the inoculum of soilborne pathogens. However, the non-selectivity of isothiocyanates has potential to also impact beneficial soil organisms.

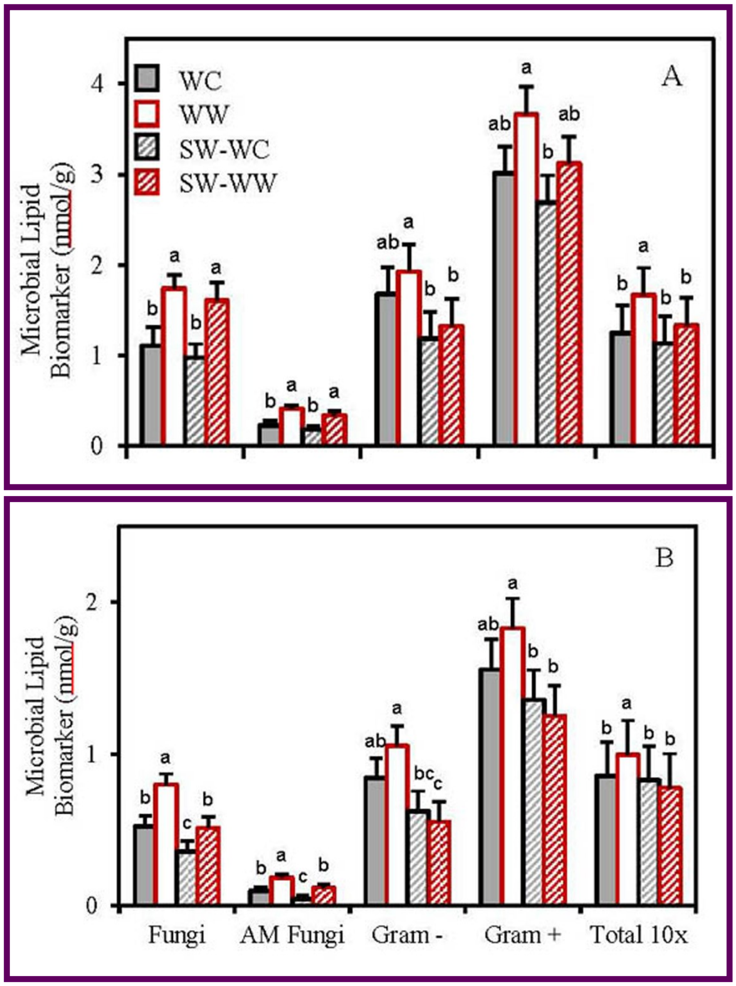


Figure 1. Soil microbial lipid abundance. Biomarker groups and total PLFA concentrations (nmol/g) of soil at 0-5 (A), and 5-10 (B) cm depths from crop years 2009 to 2014 (6 replicates each year). Values are least square means (n=120). Error bars indicate standard error. Values within each biomarker group with different letters are significantly different ($p \le 0.05$)

In a 6-year on-farm canola-wheat rotation study conducted on the Hal Johnson farm east of Davenport, WA, grain yields of spring wheat (SW) following winter canola (WC) were reduced an average of 17% compared to yields following winter wheat (WW) (see related article on page 40). With soil samples collected and archived from that study, the objective of this research was to determine the differences and similarities in the soil microbial communities associated with WC and WW, and if those differences were correlated to SW yield response. Microbial biomass and community composition were determined using phospholipid fatty acid analysis (PLFA).

Results showed that WC generally led to decreased microbial biomass compared to WW. Notably, fungi, and AM fungi were more prone than bacteria to the apparent canola rotation effect. The reduction in fungi and AM fungi were also observed in SW following WC, indicating a residual affect (Fig. 1). However, the longer-term effects (i.e., after one year) were negligible. These results demonstrate the relationship between soil microbial community composition and crop productivity. Our data suggest that WC can have significant effects on microbially-mediated soil processes such as nutrient cycling that could potentially produce short-term yield declines in subsequent crops. Data from this study will help enable regional farmers to adjust their sequence of planting canola in wheat-based rotations to allow for continued crop diversification and to maintain optimum crop yield potential.

SOB3/AHL29 Regulates Seed Size and Hypocotyl Elongation in Plants

Pushpa Sharma Koirala[1], Jianfei Zhao[2], and Michael M. Neff[1]
[1]Dept. of Crop and Soil Sciences, WSU; [2]Dept. of Biology, University of Pennsylvania

Seed shape and size are important agronomic traits because they can affect yield, ease of harvesting, and seedling establishment especially under adverse conditions (e.g. drought, weed and pest pressure). The development of crop varieties that have large seeds and long hypocotyls as seedlings yet maintain normal growth characteristics as adults is challenging for traditional breeding because the regulation of seed/seedling size is a complex and can also be linked to other agronomic traits such as heading date or flowering time.

Based on our previous findings, some of the *AHL (AT-Hook Containing, Nuclear Localized)* genes play crucial roles in determining seed size and hypocotyl length in *Arabidopsis thaliana*, a model brassica plant. When we express particular mutant forms in two of the *AHL* genes *AHL29/SOB3* (*Suppressor of Phytochrome B-4 #3*) and *AHL27/ESC* (*ESCAROLA*) the resulting transgenic *Arabidopsis thaliana* plants have normal adult growth that give rise to larger seeds and seedlings with longer hypocotyls than the wild type. *Arabidopsis thaliana* and *Camelina sativa* are from same family (Brassicas) and both have similar genomes. *Camelina sativa* is an emerging oilseed crop in dryland cropping systems. We have also seen similar results when generating transgenic *Camelina sativa* overexpressing the same mutant forms of *AHL29/SOB3* and *AHL27/ESC*.

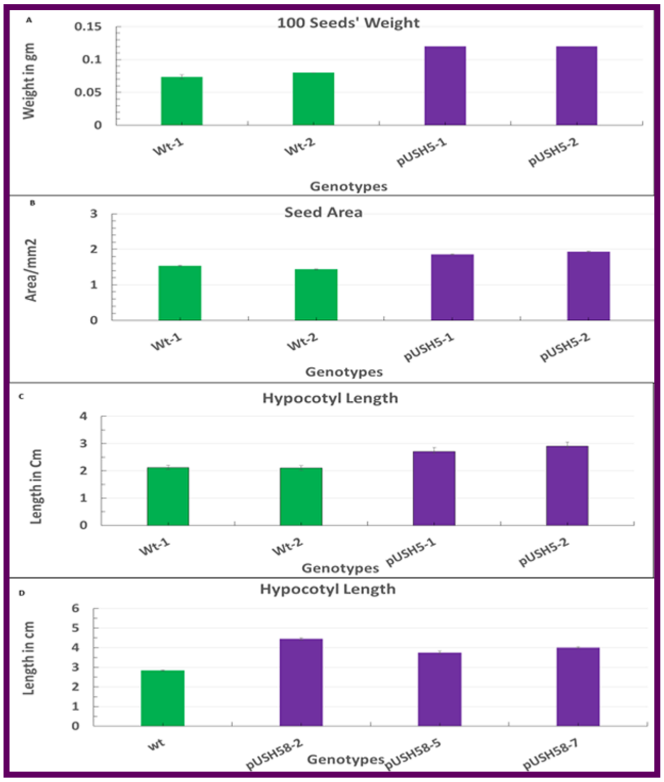


Figure 1. Graphic representation of transgenic *Camelina sativa* expressing the *Arabidopsis thaliana SOB3-6* mutation (pUSH5) based on (A) seed weight, (B) seed area and, (C) hypocotyl length.

Based on our preliminary results, we proposed: (1) to compare seed size of different mutations of *Arabidopsis thaliana AHL29/SOB3* and *AHL27/ESC* to identify the specific mutations that confer bigger seeds and longer hypocotyls than the wild type and; (2) translate the finding from *Arabidopsis thaliana* to the oil seed crop *Camelina sativa*.

In this study we have generated transgenic lines of *Arabidopsis thaliana* overexpressing different *AHL* mutations. We have then generated transgenic *Camelina sativa* plants overexpressing similar mutated *Arabidopsis thaliana* genes as well as similar genes from *Camelina sativa* (*SOB3-6-like*). Seedlings hypocotyl length, seed size and seed weight were then measured and analyzed using the appropriate software.

Our results show that transgenic plants expressing a particular mutation in *SOB3* (*SOB3-6*), as well as a similar mutation in *ESC* (*ESC-11*), confer bigger seeds and taller seedlings than non-transgenic lines in *Arabidopsis thaliana*. The *SOB3-6* mutation can make seeds that are 50% bigger and seedlings that are twice as tall as non-transgenic plants. In addition, the *ESC-11* mutation can make seeds that are ~25% bigger and seedling that are 50% taller than non-transgenic plants. Other mutations we have created in *SOB3* can make seedlings slightly taller but cannot make seeds any bigger than wild type. When we overexpressed the *Arabidopsis thaliana SOB3-6* mutation in *Camelina sativa*, seeds can be 50% bigger and seedlings can be 50% taller than non-transgenic plants. When we overexpressed the *Camelina sativa SOB3-6-like* mutation in *Camelina sativa,* seeds can be 50% bigger and seedlings can be ~65% taller than non-transgenic plants. Taken together, *SOB3* modulates seed size and hypocotyl length in *Arabidopsis thaliana* and *Camelina sativa* which, may lead to better seedling establishment and increased yield in dryland cropping system.

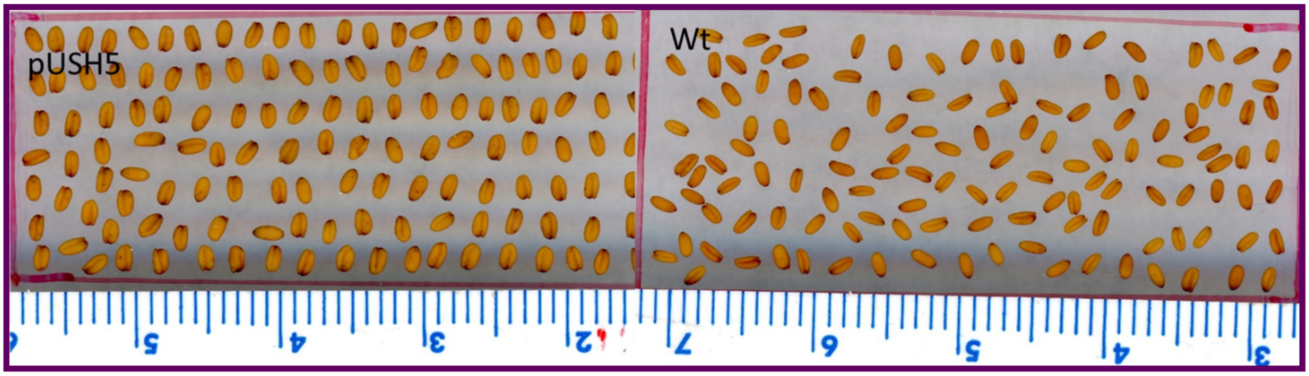


Figure 2. Picture is of transgenic *Camelina sativa* seeds expressing the *Arabidopsis thaliana SOB3-6* mutation compared to non-transgenic wildtype plants (Wt).

Exploring Relationships Between Pollinators and Canola

RACHEL OLSSON AND DAVID CROWDER
DEPT. OF ENTOMOLOGY, WSU

Background: The eastern Washington and northern Idaho region has an ideal climate for growing canola. Canola sees a 30% increase in yield when insect pollinated compared with wind pollination alone. The long flowering period for canola coincides with bee nest initiation in the early spring and can provide floral resources for bees throughout a majority of the bee foraging season. We aim to explore the relationship between the physical properties of canola flowers and pollinators native to our region. We hope to offer management strategies to increase canola yield and improve food resources for wild bees in the inland northwest.

Research goals: We are interested in exploring the environmental impact on the nutritional resource availability of canola as a food for bee colonies through two approaches. First, we are examining how environmental conditions such as canola variety, presence of insect herbivores, plant pathogens, and water stress affect the plant traits that are attractive to bees. We will measure nectar sugar concentration, protein makeup of pollen, flower abundance, and flower petal size. These measurements will take place both in the field and in the greenhouse. Second, we will survey the bee species present in the inland northwest and experimentally monitor how variation in diet affects bees' ability to provide pollination services to canola, and how those services affect canola yield.

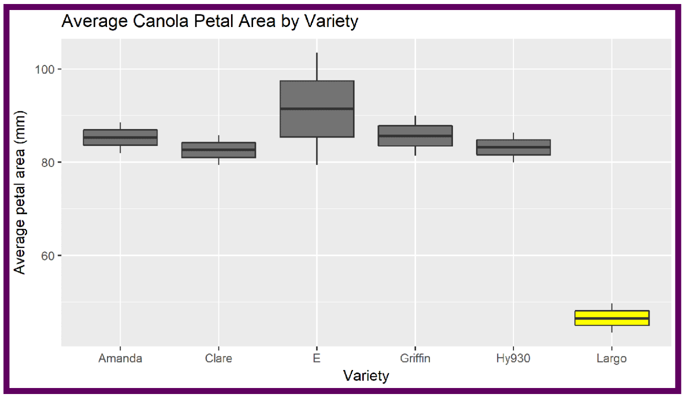


Figure 1. Canola petal size by variety.

Results to date: In 2017, we collected canola flowers at six different farms and research plots in eastern Washington and northern Idaho. We found that the variety Largo had significantly smaller petals than the other varieties sampled (Fig. 1).

We also found the wheat fungal pathogen *rhizoctonia solanum* present in the fields. This fungus can colonize canola, so we ran an experiment in our greenhouses to test whether the presence of the pathogen in the soil would have similar effects on canola. We found that the presence of the pathogen did not affect the development time of the plants. However, we found that plants grown in soil with rhizoctonia had larger flowers (Fig. 2), and more flowers (Fig. 3) than plants that were not exposed to rhizoctonia.

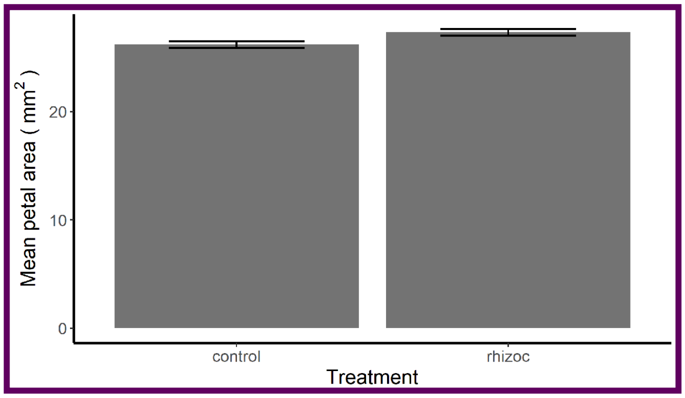


Figure 2. Canola exposed to rhizoctonia had larger flowers.

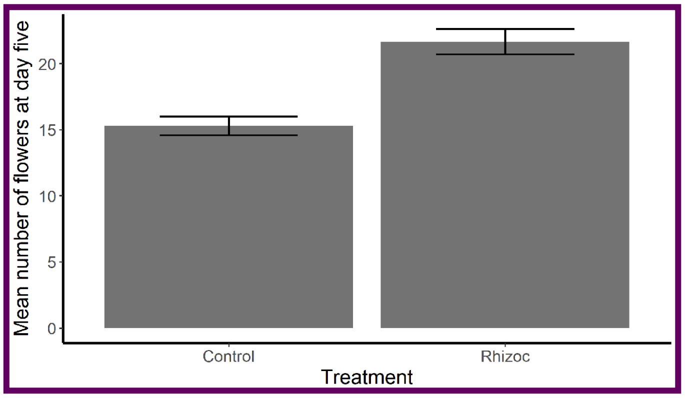


Figure 3. Canola exposed to rhizoctonia had more flowers per plant.

Canola versus Wheat Rotation Effects on Subsequent Wheat Yield

BILL SCHILLINGER[1], TIM PAULITZ[2], HAL JOHNSON[3], JOHN JACOBSEN[1], AND STEVE SCHOFSTOLL[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS; [3]COLLABORATING FARMER

Canola is considered the most promising, domestically-produced oilseed crop for diversifying wheat-based cropping systems in the Inland Pacific Northwest. Canola serves as a break or non-host crop for many important soilborne pathogens of wheat and helps farmers control weeds. The vast majority of studies in the literature report that canola has a positive effective on subsequent wheat yield.

We conducted a 6-year field experiment near Davenport, WA to measure the effects of winter canola (WC) versus winter wheat (WW) on the subsequent production of spring wheat (SW). Averaged over the years, there were no differences between WC and WW in soil water use or overwinter water recharge into the soil following these crops (Fig. 1). Subsequent SW had excellent plant stands, was weed free, was adequately fertilized, and had no foliar or root diseases. Root lesion nematode populations were miniscule and insignificant. Average SW seed yield following WC was 49 bu/ac versus 58 bu/ac following WW (Table 1); a 17% reduction (p<0.0001). Visual differences in SW plant height and head density between treatments were also apparent (Fig. 2). Spring wheat grain yield differences could not be attributed to the variables measured.

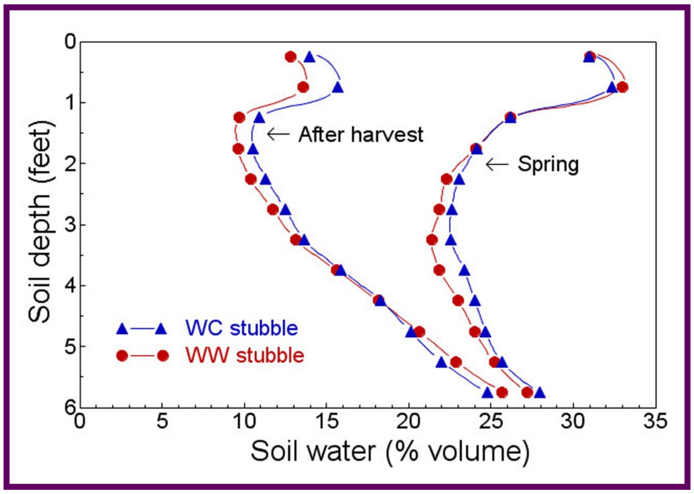


Figure 1. Spatial distribution of volumetric soil water in the 0-to 180-cm soil profile after harvest of WC and WW in August and overwinter soil water recharge following these two crops measured in late April. Data are averaged over five years.

Table 1. Seed yield of winter canola (WC) and winter wheat (WW) and the subsequent seed yield of spring wheat (SW) following either WC or WW.

Seed yield (kg ha^{-1})						
Crop Year	WC	WW	Crop Year	SW after WC	SW after WW	p-value for SW
2008	674	4593	2009	2875 b[a]	3858 a	0.0002
2009	721	5561	2010	4314	4381	0.3656
2011[b]	3235	7424	2012	2762 b	3806 a	0.0013
2012	4256	7226	2013	5167	5666	0.0593
2013	4129	7072	2014	1219 b	1948 a	0.0004
5-yr avg	2603	6375[c]	5-yr avg.	3267 b	3932 a	< 0.0001

[a] Within-year spring wheat grain yield means followed by a different letter are significantly different at p<0.05.
[b] Winter canola was killed by cold during the 2010 crop year; therefore, no WC or WW harvest in 2010 nor SW crop in 2011.
[c] Analysis of variance was not conducted for seed yield differences between WW and WC.

We believe whatever factor(s) responsible for reduction in SW yield following WC is/are short lived as evidenced by no differences in yield of second-year SW when back-to-back SW (i.e., WC-SW-SW and WW-SW-SW) was grown in two years. Similarly, in the dry (<12-inch annual precipitation) region of the PNW where a 2-year WW-SF rotation is commonly practiced, there have been no reports of WW yield decline in a 4-year WC-SF-WW-SF rotation compared to 2-year WW-SF.

Figure 2. Spring wheat after WW versus after WC at time of harvest in August 2014 near Davenport, WA. Note the pronounced visual differences in plant height and head density between treatments.

In May of every year of our study, replicated soil cores in the WC, WW, and SW phases of the experiment were collected and archived in 2-inch increments to a depth of 6 inches. As part of his doctoral soils research at WSU, Jeremy Hansen conducted comprehensive laboratory analysis of these cores each year to determine any soil microbial differences. Specifically, Dr. Hansen used phospholipid fatty acid analysis of the soil to determine treatment differences in biomarker groups of fungi, mycorrhizae, Gram-negative, and Gram-positive bacteria which may help explain our field-study results (see Hansen et al. article on page 36).

Making Connections and Making a Difference: WSU-WOCS Extension & Outreach

KAREN SOWERS[1], DENNIS ROE[1], AARON ESSER[1], RACHEL BOMBERGER[2], SCOT HULBERT[2], DALE WHALEY[1], BILL SCHILLINGER[1], AND TIM PAULITZ[3]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]DEPT. OF PLANT PATHOLOGY, WSU; [3]USDA-ARS

The primary function of the Extension and outreach side of the Washington State Oilseed Cropping Systems (WOCS) project is to be the conduit between the researchers on the team and all stakeholders in the canola industry. At the same time, input from growers, crop consultants, seed suppliers, processors, agencies, and other university personnel is a key component in shaping what questions the WOCS field and greenhouse studies are designed to answer. Communication is our top priority as we share results from research and demonstration trials. This includes phone calls, emails, radio and newspaper interviews, news releases, presentations, field tours, workshops, website (www.css.wsu.edu/oilseeds), Facebook page (WSU Oilseeds), serving as a WSU liaison to the WA Oilseed Commission, WSU Dryland Crops Team member, and the formation of a Pacific Northwest Canola Association (see abstract on pg. 46). Our field tours and winter workshops once again set attendance records in 2017-18. We strive to involve a broad spectrum of stakeholders and presentation methods in all our events, and that has proven to be a valuable method to increase attendance. A record 317 individuals attended our 2018 Oilseed Workshops at Hartline, Richland, and Colfax, with 170 attending for the first time (Fig. 1). We also met our goal of more than half of attendees being producers at each location. Our invited speakers from the Canola Council of Canada and Kansas State University added their perspectives and knowledge about canola production and were very well received. More details

Group listening to a presentation at one of the three workshops given in January 2018.

about the field tours based at our large-scale canola variety trials can be viewed on pg. 34. Record canola acreage in Washington (60,000) and the 4-state PNW region (221,000) in 2017 underscores the importance of continued education and outreach, and the WOCS team is up to the task!

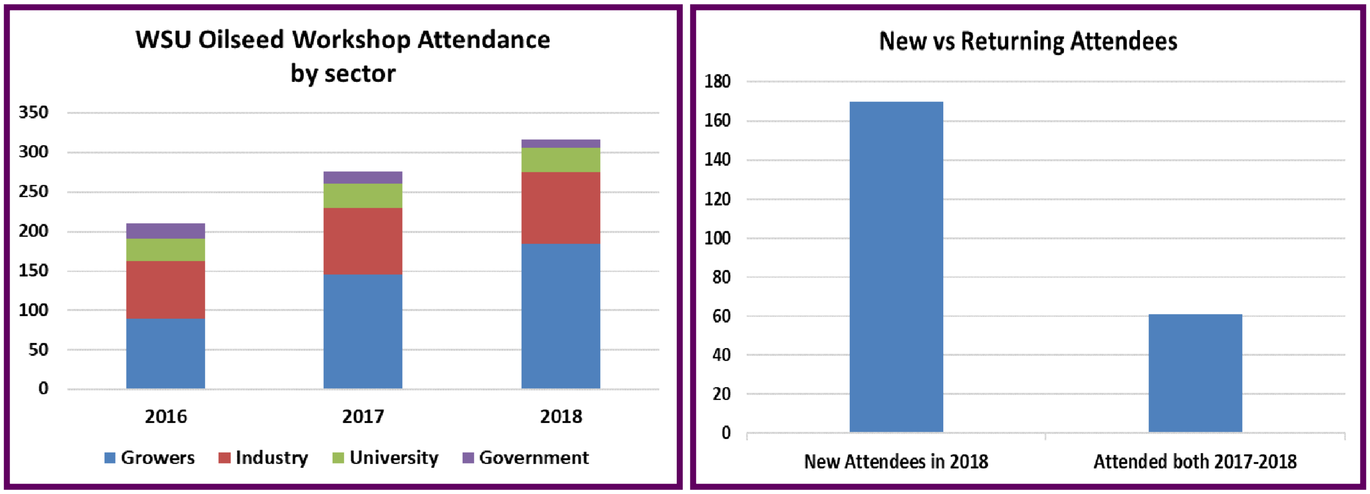


Figure 1. Attendance trends at the last three WSU-WOCS Oilseed Workshops (left), and first-time attendees in 2018 (right).

2017 Pacific Northwest Variety Trial Results

Jim B. Davis[1], Megan Wingerson[1], Ashley Job[1], Alan Wernsing[2], Don Wysocki[2], Aaron Esser[3], and Jack Brown[1]
[1]University of Idaho; [2]Oregon State University; [3]Washington State University

The acreage of canola (*Brassica napus, B. juncea,* and *B. rapa*) in the Pacific Northwest continues to slowly increase as more growers show an interest in the crop. This is due in part to canola offering growers an alternative crop for rotations in an agricultural system that is predominated by small cereal grains. Currently depressed prices for wheat, caused by a worldwide surplus, have also contributed to the increased interest in canola.

To support the grower community, comprehensive yield trials are needed to evaluate new cultivars throughout the varied environments found in the Inland Pacific Northwest. With this objective in mind, researchers at the University of Idaho established the PNW Spring Canola Variety Trial in 1994 and the PNW Winter Canola Variety Trial in the fall of 1995. These trials have successfully attracted cultivar entries from numerous seed companies, with 176 winter varieties from 22 companies and 326 spring varieties from 33 companies submitted for testing over the lifespan of the trials. The trials are currently funded by USDA-NIFA Supplemental and Alternative Crops Competitive Grants Program and by the commercial companies that submitted their cultivars or advanced breeding lines to be tested in the PNW trials.

In 2017, 13 different commercial companies and public breeding programs submitted 52 distinct cultivars or breeding lines for testing, 21 winter types and 31 spring types. Three control varieties were included in each trial, for a total of 24 winter and 34 spring entries. Winter trials were grown at eight sites; Moscow, Genesee, Craigmont, and Grangeville, Idaho; Odessa and LaCrosse, Washington; and Pendleton and Hermiston, Oregon. Spring trials were grown at nine sites; Bonners Ferry, Moscow, Genesee, and Craigmont, Idaho; Davenport, Fairfield, and Dayton, Washington; and Pendleton and Hermiston, Oregon. The sites at Odessa and Hermiston were irrigated; the remaining sites were rainfed.

Winter cultivar yields ranged from 3,562 to 4,427 lbs. per acre when averaged across all sites. Mean seed yield varied widely between sites, with mean yields at individual sites ranging from 2,093 to 5,486 lbs. per acre, with an overall trial mean of 3,910 lbs. per acre. The five commercial canola cultivars with highest yields were 'Mercedes', 'Plurax CL', 'Edimax CL', 'Arsenal', and 'Atenzo.' The next best performing cultivars were 'Durola' rapeseed, 'Amanda' and 'Torrington.' Some winter damage was seen at the LaCrosse site, and Arsenal and Atenzo showed more mortality than the other entries.

Spring cultivar yields ranged from 1,125 to 1,838 lbs. per acre when averaged across the seven dryland sites. (Hermiston was excluded from the means because of not all varieties were grown at that site.) Mean seed yield by site ranged from 800 lbs. per acre to 2,479 lbs. per acre, with an overall mean of 1,512 lbs. per acre. The five cultivars with highest yields were 'HyCLASS 930 RR', 'NCC 101S', 'HyCLASS 955 RR', 'DKL 71-14BL RR', and 'DynaGro 200 CL'. The trials at several sites, including Bonners Ferry, Moscow, and Fairfield, yielded less than expected due to delayed seeding caused by wet weather during the optimum seeding window.

Detailed reports with data tables are available at: *http://www.cals.uidaho.edu/brassica/.*

Ongoing Experiments to Protect Canola Seedlings from Horned Lark Depredation

BILL SCHILLINGER[1], KEN BALLINGER[2], AND JOHN JACOBSEN[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]ARKION LIFE SCIENCES

Horned lark (*Eremophilia alperestis* L.) depredation of pre-emerged and newly-emerged canola seedlings is an increasing concern for both dryland and irrigated farmers in the Inland PNW. Horned lark (Fig. 1) is a native bird species throughout Canada, the United States, and most of Mexico. They are permanent year-round residents of the PNW.

The first report of horned lark damage to canola was at Lind in 2006 where they destroyed a 0.25-acre winter canola experiment. The geographic range of their canola seedling depredation has since extended into Adams, Grant, Douglas, Lincoln, and Spokane Counties. Some canola farmers have recurrent problems with this bird whereas neighboring canola farmers have never been affected. There are two documented cases at separate locations in Adams County where entire 125-acre irrigated circles of both winter and spring canola were destroyed by horned larks.

Many attempts have been made to control horned lark feeding on canola seedlings. These have included loud propane-powered noise cannons, placement of glittery flags and reflecting 'disco balls' in the field, mixing garlic powder with the canola seed before planting, and laser lights. These control strategies have not been effective. The most effective control method tried to date was by an Adams County farmer who hired a falconer from the Tri-Cities to have several of these predator birds fly over his fields for several days when canola seedlings were emerging. This, obviously, is a very expensive control method.


© Terry Sohl

Figure 1. The Horned Lark is a ground-dwelling bird commonly found in open areas and in fallow fields throughout North America. Photo by Terry Sohl (with permission).

We have a new experiment underway at Lind and Ritzville in 2018 for both spring and winter canola. A nontoxic seed treatment called Avipel^{TM}, registered and marketed by Arkion Life Sciences in Delaware, is widely used to effectively control black bird and crow damage to corn and rice seed. The active ingredient in Avipel is anthraquinone, and organic chemical that occurs naturally in dozens of plant species. Avipel imparts a bitter taste to the corn seed. However, horned larks do not eat the canola seed but rather the cotyledon leaves of the emerging seedling. We need the seed treatment to act 'systemically' or, in other words, get inside the canola plant tissue to impart a bitter taste in the coleoptile leaves. Dr. Ballinger feels he may have developed a means to do this and has treated some spring canola seed that we sent him. Replicated field experiments with and without seed treatment will be established both this spring (April) and in late August for winter canola.

Horned larks are a native species and are protected by law. Our purpose is not to harm horn larks but rather to deter them. Avipel is a non-toxic bird repellent, not a bird poison. We are following EPA and FDA rules. We will send replicated samples of harvested canola seed for laboratory analysis to ensure there are no traces of the seed treatment in the harvested seed.

Improving Nitrogen Use Efficiency for Winter Canola Using 4R Stewardship

MARISSA PORTER, HAIYING TAO, WILLIAM L. PAN, ISAAC MADSEN, AND KAREN SOWERS
DEPT. OF CROP AND SOIL SCIENCES, WSU

Winter canola has potential as an alternative cash crop to wheat. Canola also has tremendous rotational benefits for soil health, weed and disease control, and the subsequent wheat crop. Careful fertility management is important to ensure maximum yield and quality; however, fertility management research specifically for winter canola production is limited. In fall 2016, three nitrogen (N) fertility trials were started to investigate the optimum rate and timing of N-fertilizer application for winter canola. Trials were established in three areas that represent different yield potentials, soil types, crop rotations, and climatic conditions. Two dryland trials were located near the towns of St. John and Hartline in Washington and one irrigated trial located near Odessa, WA. The primary objectives are to learn N uptake during the growing season, to estimate optimum rate and the best timing for N application for canola grown in different environment with different yield potentials, and to evaluate how N affects canola yield and oil content. In the 2016-2017 trial, there were no statistically significant differences in yield or total above ground biomass among N treatments. Lack of yield response to N may be due to high variability in plant counts within plots and high soil residual N at planting. Above ground tissue N increased at all growth stages with increased N rate. Split and spring-only N application resulted in greater above ground tissue N when compared with fall-only application. Seed oil and protein content were found to be inversely related, with higher N rate contributing to higher protein content and lower oil content. The second year of trials is underway, with dryland sites in Colfax, WA; Latah, WA; Troy, ID; and one irrigated site in Echo, OR.

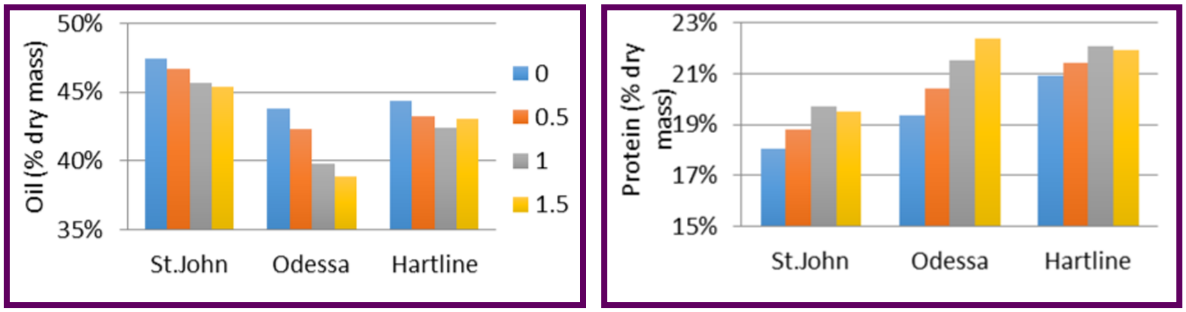


Figure 1. Seed oil and protein content as affected by N application. 0 indicates no N applied, 1 indicates full recommended rate based on Koenig et al., 2011. 0.5 and 1.5 represent 50% and 150%, respectively, of recommended N rate. Grouping is by field location.

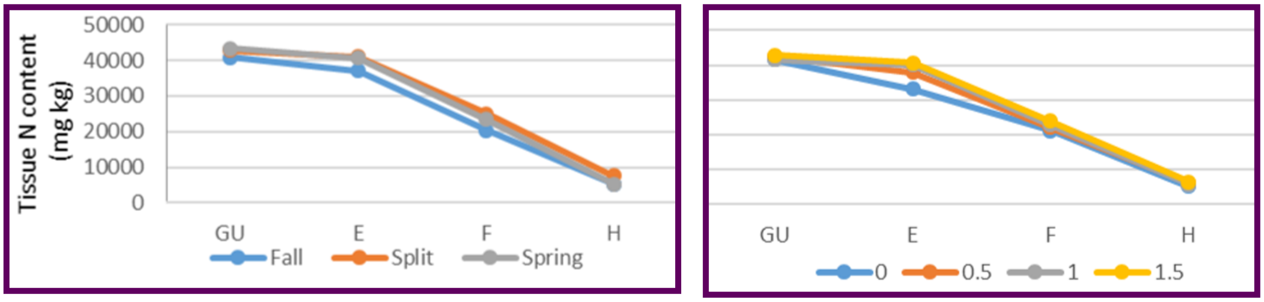


Figure 2. Above-ground tissue N content (mg kg-1) at Greenup (GU), Elongation (E), Flowering, and Harvest (H) as affected by N application timing (A) and rate (B) in St. John, WA in 2016-17.

Water and Temperature Stresses Impact Canola (*Brassica napus* L.) Fatty Acid, Protein, and Yield over Nitrogen and Sulfur

W. Ashley Hammac[1], Tai M. Maaz[2], Richard T. Koenig[3], Ian C. Burke[3], and William L. Pan[3]
[1]Purdue Agronomy Dept.; [2]International Plant Nutrition Institute; [3]Dept. of Crop and Soil Sciences, WSU

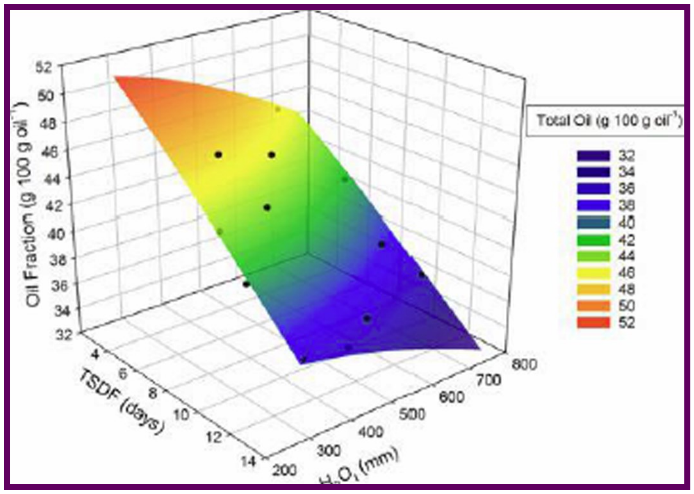


Figure 1. Total oil response to total available water (H2Ot) and atmospheric temperature (TSDF) at (adjusted R2 = 0.57).

Interactive effects of weather and soil nutrient status often control crop productivity and quality. An experiment was conducted to determine effects of nitrogen (N) and sulfur (S) fertilizer rate, soil water, and atmospheric temperature on canola (*Brassica napus* L.) fatty acid (FA), total oil, protein, and grain yield. Nitrogen and sulfur were assessed in a 4-yr study with two locations, five N rates (0, 45, 90, 135, and 180 kg ha−1), and two S rates (0 and 17 kg ha−1). Water and temperature were assessed using variability across 12 site-years of dryland canola production. Effects of N and S were inconsistent. Unsaturated FA, oleic acid, grain oil, protein, and theoretical maximum grain yield were highly related to water and temperature variability across the site-years. A nonlinear model identified water and temperature conditions that enabled production of maximum unsaturated FA content, oleic acid content, total oil (Fig. 1), protein, and theoretical maximum grain yield (Fig. 2).

Water and temperature variability played a larger role than soil nutrient status on canola grain constituents and yield.

For further reading, see on line reprint: Hammac, A.H., T.M. Maaz, R.T. Koenig, I.C. Burke, W.L. Pan. Water, temperature, and nitrogen effects on canola (Brassica napus L.) yield, protein, and oil. Journal of Agriculture and Food Chemistry 65: 10429–10438. https://pubs.acs.org/doi/abs/10.1021/acs.jafc.7b02778

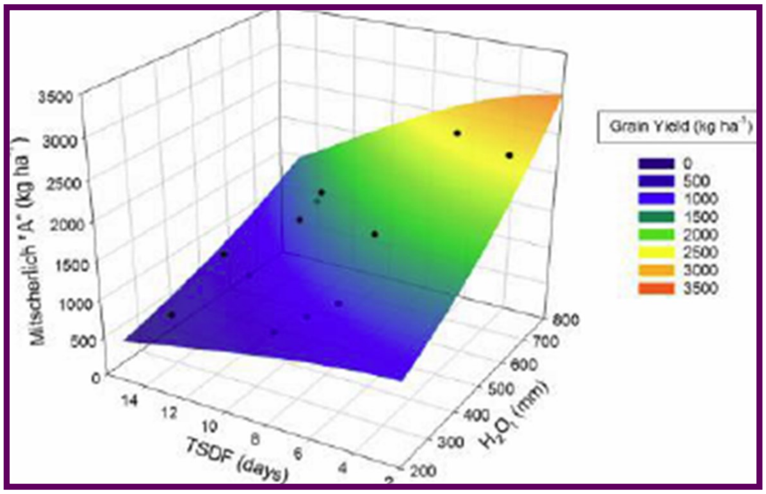


Figure 2. Mitscherlich theoretical maximum grain yield response to total available water (H2Ot) and atmospheric temperature (TSDF) at (adjusted R2 = 0.64)

Rhizosphere Microbial Communities of Canola and Wheat at Six Paired Field Sites

Jeremy Hansen[1], Bill Schillinger[2], Tarah Sullivan[2], and Tim Paulitz[1]
[1]USDA-ARS; [2]Dept. of Crop and Soil Sciences, WSU

Plant physical and chemical characteristics are known to alter rhizosphere microbial communities, but the effect of introducing canola into monoculture wheat rotations is not clear. Results from a field study in eastern Washington showed that winter canola (WC) influenced the bulk soil microbial community and differentiated it from the community associated with winter wheat (WW) (see articles on page 40 and page 50). Abundance of soil fungi, including mycorrhizae, was reduced with the introduction of WC.

The objective of this research was to determine the differences and similarities in the rhizosphere microbial communities of WC and WW. Canola and wheat rhizosphere soil was collected from six dryland farms in Adams and Douglas Counties, WA. Each farm was a paired site with WC and WW grown in adjacent fields of the same soil type, landscape orientation, and crop history. Canola, or any non-cereal crop, had never been grown previously at the experimental sites. Microbial biomass and community composition, determined using phospholipid fatty acid analysis (PLFA), revealed differences that were primarily associated with landscape position at the initial fall sampling (Fig. 1A). Data from spring samples, however, showed significant differences in microbial communities between WC and WW rhizosphere soils (Fig. 1B). Data suggest that initial (fall) microbial community composition were an artifact of previous histories of monocrop wheat production and varied with expected differences in landscape position. As the crops developed, microbial communities became more dissimilar and were discriminated by crop species. Our results show that WC can have significant effects on rhizosphere microbial biomass and community structure in wheat-based cropping systems (see related article on page 36). Changes in microbial abundance and community structure can affect microbially-mediated soil processes, and potentially the performance of subsequent crops.

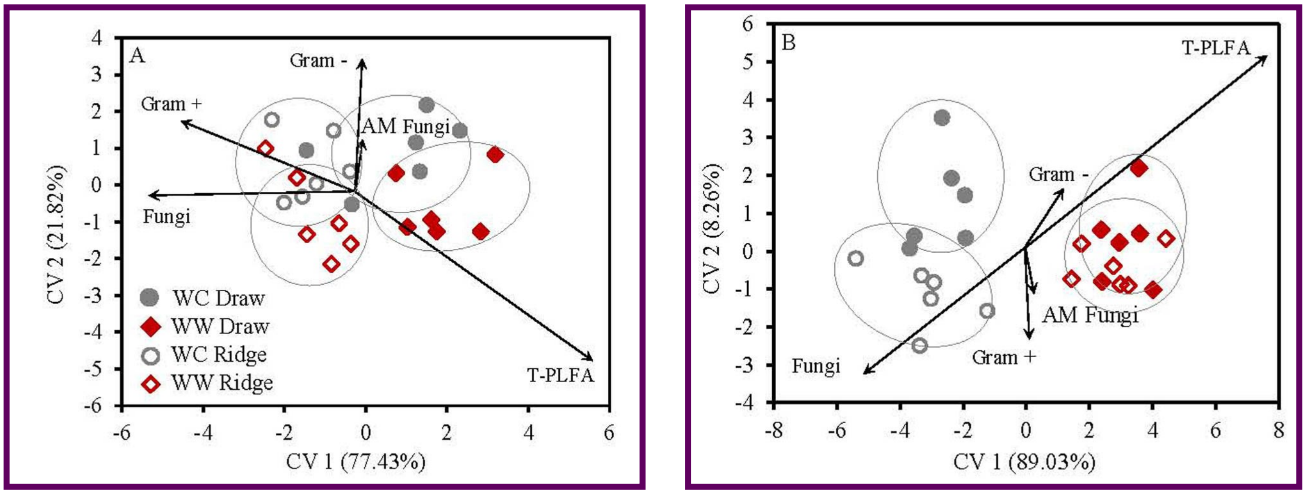


Figure 1. Canonical variates for lipid biomarker groups in winter canola (WC) and winter wheat (WW) at two landscape positions. Vectors represent standardized canonical coefficients for each biomarker group and total PLFA (T-PLFA), from fall 2015 (A), and spring 2016 (B). Vector magnitude and direction indicate the contribution of each biomarker group to each canonical variate. Each sample point is represented and cluster by treatment. Each cluster is accompanied by a mean ellipse at the 95% confidence interval (Treatments groups that differ significantly have confidence ellipses that do not intersect).

Pacific Northwest Canola Association Becomes Reality

Karen Sowers
Dept. of Crop and Soil Sciences, WSU

At this time last year there was talk of having a Pacific Northwest Canola Association (PNWCA) up and going in short order. So what has happened during the past year? A steering committee for the association comprised of PNW canola producers, industry members, and university faculty met in June 2017, and a Certificate of Incorporation was received in July, making the PNWCA official. Ten Producer Members from Idaho, Montana, Oregon, and Washington were elected to the board of directors in November. The Producer Members met in January of this year to elect officers and discuss next steps, including hiring an executive director. Another meeting was held in March, and the board approved hiring Karen Sowers as interim executive director. A membership campaign kicked off in April to gain grower, industry, and agency membership.

The PNWCA believes it can be a key player in the effort to increase canola acreage, improve production per acre, and collaborate with and educate stakeholders involved with the canola industry in the 4-state region. The PNWCA will create a united effort from PNW canola growers, universities, ag industry, and agencies to address legislative needs, generate additional canola research funding, and forward the canola industry in the PNW.

The board of directors are all looking forward to supporting the mission of the PNWCA of ***"Growing the canola industry in the Pacific Northwest through education, advocacy, and marketing."***

PNWCA Board of Directors (Producers)

Tim Dillin – Bonners Ferry, ID

Dale Flikkema – Belgrade, MT

Ray Mosman – Nezperce, ID – President

Don Nagy – Sunburst, MT

Randy Perkins – Athena, OR

Douglas Poole – Mansfield, WA

Anna Scharf – Amity, OR

Dennis Swinger – Lind, WA – First Vice President

Jon Walters – Walla Walla, WA – Second Vice President

Kyle Wasson – Whitewater, MT

Pictured here at the March 5 meeting of the Pacific Northwest Canola Association are: Anna Scharf, Randy Perkins, J.R. Swinger, Dale Flikkema, Tim Dillin, Douglas Poole, Karen Sowers, and Ray Mosman.

Spring Canola Seeding Rates

R.J. ZUGER AND I.C. BURKE
DEPT. OF CROP AND SOIL SCIENCES, WSU

Increased spring canola seed rates could increase crop stand establishment canopy development and ultimately, weed competitiveness and productivity by maximizing yield potential. In 2016 and 2017 studies were established in different rainfall zones to evaluate seeding rate effects on canola yields using a singulating planter. All studies were planted with spring canola variety Hyclass 930 using an eight row Monosem planter on 10" row spacing calibrated to deliver seeding rate treatments. Seeding rates in 2016 were 3 (hilldrop), 4, 5, 6, 7, 8, 10, or 12 lb A^{-1}, and seeding rates in 2017 were 4, 5, 6, 7, 8, 10, 11, and 12 lb A^{-1}. Plots were 10' by 75' long. All studies were conducted in a randomized complete block design with 3 replications. The 2016 study was harvested using a Kincaid plot combine with a 5-foot header and the 2017 studies were all harvested using a 5-foot header Wintersteiger plot combine. In 2016, the initial Pullman study was planted on April 20th, 2016 at the Cook Agronomy Farm near Pullman, WA, in a high rainfall zone with annual precipitation of greater than 17 inches. The site was in a no-till system. In 2017, the repeated Pullman study was planted a no-till system on May 9, 2017

Planting the Davenport, WA canola study on May 18, 2017.

at the Palouse Conservation Field Station near Pullman, WA, also in a high rainfall zone. Canola crop emerged on May 22, 2017. The field site had an accumulative precipitation of 20.86" total for 1 year prior to harvest date of the trial. The Walla Walla study was planted on April 21, 2017 in a grower's field north of Walla Walla, WA, also in a high rainfall zone. Site was in a conventional tillage system and had been fertilized prior to planting by grower. Canola emerged on May 5, 2017. The study was harvested on August 14, 2017. The field site had an accumulative precipitation of 20.87" total for 1 year prior to harvest date of the trial. The Davenport study was planted on May 18, 2017 into a conventional system at the Wilke Research and Extension Farm near Davenport, WA. Davenport, WA, is in a medium rainfall zone with annual precipitation of 12 to 17 inches. Canola emerged on May 29, 2017. The study was harvested on August 22, 2017. The field site had an accumulative precipitation of 17.19" total for 1 year prior to harvest date of the trial. All data were subjected to an analysis of variance using the statistical package built into the Agricultural Research Manager software system (ARM 8.5.0, Gylling Data Management).

In 2016, spring canola stand counts increased as the seeding rate increased, with 10 plants m^{-1} for the 4 lb A^{-1} treatment and 31 plants m^{-1} for the 12 lb A^{-1} seeding rate (Table 1). As seeding rates increased, yields also increased. Yield for the seeding rate of 12 lb A^{-1} was higher than the lowest seeding rate of 4 lb A^{-1}, with 1362 lb A^{-1} compared to 824 lb A^{-1}. In Pullman in 2017, there was no difference in canola stand counts, however, as seeding rate increased so did the number of plants m^{-1}, with 13 plants m^{-1} for the 4 lb A^{-1} treatment and 28 plants m^{-1} for the 12 lb A^{-1} seeding rate (Table 2). As seeding rates increased, yields also increased. Yield for the seeding rate of 12 lb A^{-1} was greater than the lowest seeding rate of 4 lb A^{-1}, with 1825 lb A^{-1} compared to 1487 lb A^{-1} (Table 2). In Walla Walla, stand counts increased as the seeding rate increased, with 7 plants m^{-1} at the 4 lb A^{-1} treatment and 25 plants m^{-1} for the 12 lb A^{-1} seeding rate. As seeding rate and stand counts increased, branching per plant decreased from 3.3 branches per plant to 1.4 branches per plant. There were no differences in yield for any seeding rate in Walla Walla (Table 2). The lowest seeding rate of 4 lb A^{-1} produced 1928 lb A^{-1} yield and the highest seeding rate produced 1764 lb A^{-1} yield. Stand counts, or plants per meter, increased at the planting rate increased with 12 plants m^{-1} for 4 lb A^{-1} and 38 plants m^{-1} for the 12 lb A^{-1} rate. No differences in yield were observed for any seeding rate (Table 2). The lowest seeding rate of 4 lb A^{-1} produced 819 lb A^{-1} yield and the highest seeding rate, 12 lb A^{-1}, produced 841 lb A^{-1} yield. A singulating drill is a useful tool for reducing seed costs while increasing stand uniformity, as it allows for compensation to the wide range of seed counts and germination rate found in canola seed lots. Although a singulating planter will not likely facilitate reduced seeding rates, it will reduce overall seed use without compromising stand, when used correctly.

Table 1. Stand counts and yield for 2016 Pullman, WA, spring canola seeding rate study (Hyclass 930). Pullman, WA, 2016. DAP = days after planting. Means followed by the same letter are not statistically significantly different ($\alpha=0.05$).

				June 21, 2016 62 DAP	*August 18, 2016*
Trt	**Seeding Rate**			**Stand Counts**	**Yield**
	seed/m	**seed/ft**	**lb/A**	**plants/meter**	**lb/A**
1	26	8	4	10 a	824 a
2	32	10	5	15 ab	985 ab
3	39	12	6	16 ab	1012 ab
4	46	14	7	18 abc	970 ab
5	52	16	8	23 bc	1006 ab
6	66	20	10	25 cd	1222 ab
7	79	24	12	31 d	1362 b
Hill drop	20	6	3	12 a	1139 ab
			LSD	*6*	*304*

Table 2. Stand counts and yield for Pullman, Walla Walla, and Davenport WA, spring canola seeding rate study (Hyclass 930) in 2017. DAP = days after planting. Means followed by the same letter are not statistically significantly different ($\alpha=0.05$).

Pullman, WA

				July 20, 2017 72 DAP	*September 6, 2017*
Trt	**Seeding Rate**			**Stand Counts**	**Yield**
	seed/m	**seed/ft**	**lb/A**	***plants/meter***	***lb/A***
1	26	8	4	13	1487 ab
2	32	10	5	17	1534 ab
3	39	12	6	16	1297 a
4	46	14	7	17	1623 ab
5	52	16	8	18	1471 ab
6	66	20	10	25	1742 b
7	73	22	11	23	1696 b
8	79	24	12	28	1825 b
			LSD	*NS*	*241*

Walla Walla, WA

				June 29, 2017 69 DAP	*August 14, 2017*
Trt	**Seeding Rate**			**Stand Counts**	**Yield**
	seed/m	**seed/ft**	**lb/A**	***plants/meter***	***lb/A***
1	26	8	4	7 a	1928
2	32	10	5	11 ab	1855
3	39	12	6	10 ab	1804
4	46	14	7	12 ab	1791
5	52	16	8	14 bc	1828
6	66	20	10	18 cd	1812
7	73	22	11	21 de	1854
8	79	24	12	25 e	1764
			LSD	*4*	*NS*

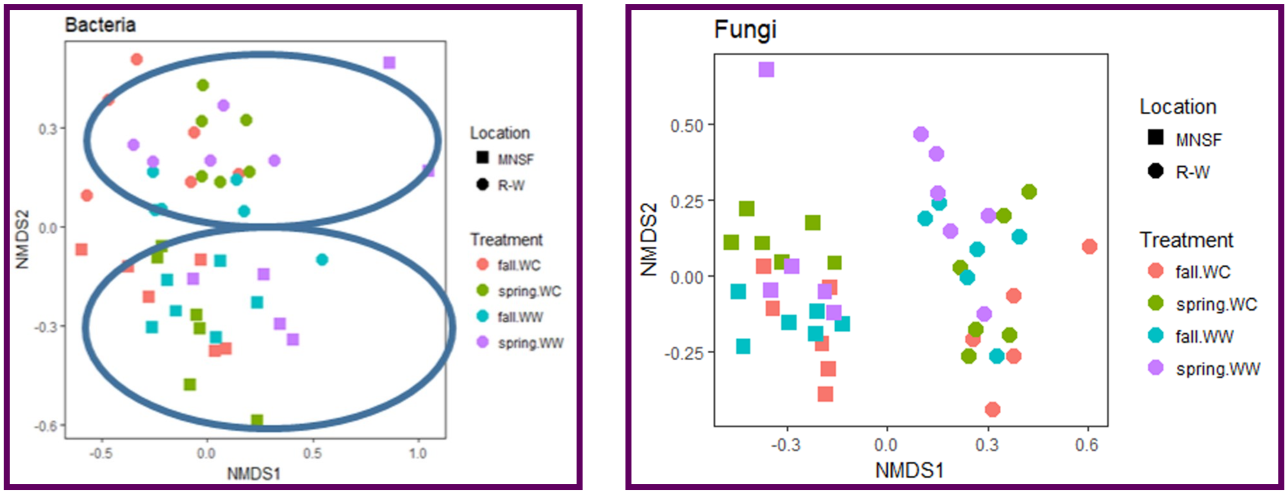
Davenport, WA

				June 27, 2017 *40 DAP*	*August 22, 2017*
Trt	**Seeding Rate**			**Stand Counts**	**Yield**
	seed/m	**seed/ft**	**lb/A**	***plants/m***	***lb/A***
1	26	8	4	12 a	819
2	32	10	5	13 a	919
3	39	12	6	15 ab	908
4	46	14	7	19 bc	890
5	52	16	8	23 cd	925
6	66	20	10	26 d	932
7	73	22	11	32 e	794
8	79	24	12	38 f	841
			LSD	*4*	*NS*

The Rhizosphere Microbiome of Wheat and Canola in Eastern Washington

DANIEL SCHLATTER[1], JEREMY HANSEN[1], WILLIAM SCHILLINGER[2], TARAH SULLIVAN[2], AND TIMOTHY PAULITZ[1]
[1]USDA-ARS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

In a series of replicated field trials over 6 years in the Davenport area, spring wheat grown after winter canola had an average of a 17% yield decrease, compared to when grown after winter wheat. Diseases, water use, and nutrient use could not explain this reduction (see article on page 40). We explored the potential role of microbial communities in explaining this yield decline (see articles on page 54). With samples from a related study (see article on page 45), we used next-generation sequencing (Illumina MiSeq) to look at fungal and bacterial communities to examine the differences in microbial communities between crop species. Six fields were sampled, three in Douglas County and three in Adams County. The soil around the roots (rhizosphere) was sampled on winter canola and winter wheat in fall and spring. Community analysis showed that location was a primary driver of both fungal and bacterial communities, with the three locations in Douglas County clustering together, and the Adams County sites similar to each other (Fig. 1, 2). Season had the next strongest effect, followed by the crop. Differences between the two crops was more evident in the spring than the fall. A more detailed comparison of bacteria showed that *Pseudomonas*, *Flavobacterium* and *Pedobacter* were more abundant on the wheat rhizosphere compared to canola. A few genera including *Opitus* and *Sporocytophaga* were more abundant on canola. Many groups highly abundant in the rhizosphere of both crop species, especially *Janthinobacterium* and *Kaistobacter.* Another interesting finding was that the bacterial community on winter wheat in the fall was dominated by Actinomycetes and Acidobacteria. These are slow growing bacteria that can survive the hot, dry summer. But in the spring, these communities were dominated by fast growing bacteria adapted to high levels of nutrients coming off the root and wetter conditions, including *Pseudomonas*, Oxalobacteraceae, and Sphingobacteriaceae. We identified almost 1,000 groups of fungi. Some fungi were very abundant on both crops- *Ulocladium*, *Mortierella, Cryptocccus, Chaetomium, Penicillium* and *Trichoderma*. These are very abundant in soils as saprotrophs and decay residue. The only distinct differences were the identification of wheat root pathogens in higher levels in winter wheat- *Rhizoctonia, Ceratobasidium*, *Typhula,* and *Microdochium.* The latter two are snow molds. In conclusion, we did not find a "smoking gun" of a group that was increased by canola. Most of the community of fungi and bacteria are not "host specific" but colonize around the roots of both wheat and canola.



Figures 1 (left) and 2 (right). Non-metric multidimensional scaling (NMDS) of bacterial and fungal communities. MNSF= Douglas County, R-W = Adams County. WC= winter canola, WW= winter wheat

Understanding and Management of Black Leg Disease of Canola in Northern Idaho

JUSTIN PICKARD, JIM B. DAVIS, JACK BROWN, AND KURTIS SCHROEDER
DEPT. OF PLANT SCIENCES, UI

Black leg (also known as stem canker, or Phoma stem canker) is the most damaging disease of *Brassica* crops worldwide. However, until recently this disease had not been found in the Pacific Northwest, and the state of Idaho was considered black leg free. The most common symptom of black leg are dull-white lesions on stems and leaves with small dark spots. Once plants are infected, the pathogen may progress down to the base of the stem where it creates stem lesions and cankers. The cankers restrict vascular flow of water and nutrients to the upper plant and can result in crop lodging and yield loss.

The black leg pathogens, *Leptosphaeria maculans* and *L. biglobosa*, can be introduced into a field through infected seed or airborne spores (ascospores) that can travel long distances from infected debris in adjacent fields. Spread can occur within the field and on plants in close proximity by rain splashed spores (conidia). The conidia are responsible for most of the in-season spread of the disease and are produced by tiny black fungal structures known as pycnidia (Fig. 1). A second important source of inoculum is from infected plant debris; light tillage or harrowing of infected residue to increase contact with the soil and accelerate decomposition can reduce disease spread. Initial efficacy studies in the PNW have shown that foliar fungicides do not increase winter canola yield when symptoms are observed, but they may be important in preventing infection of pods and seed in certification fields.

Figure 1. Typical black leg lesion under field conditions showing white lesion with black pycnidia, and pink colored spore masses exuding from pycnidia in lesions after being placed in a high humidity laboratory environment.

A survey of black leg symptoms was conducted from 2014 to 2016 across Idaho, Latah, Lewis and Nez Perce Counties in northern Idaho. Over the course of this study, 46 canola fields were sampled with 83% testing positive for black leg. Included in the survey were fields of winter canola, spring canola, mustard and a variety of related weed species. Most infections were found in winter canola that appeared to have initiated in the fall, with some progression of the disease into the spring. However, canker symptoms and severe leaf spotting were not observed. Evaluation of the sample material resulted in a collection of 130 *L. maculans* and 10 *L. biglobosa* isolates. All isolates were confirmed by pathogenicity testing on canola, with *L. maculans* resulting in severe leaf lesions while *L. biglobosa* caused mild infections. Species designation also was confirmed by using DNA sequencing.

Isolates were characterized by specific PCR tests to identify the race structure. In total, 7 individual avirulence genes were tested, and they indicated that at least 15 distinct races are present in northern Idaho. Efforts are currently underway to conduct differential screening using canola lines and varieties that each have unique resistance genes. This will allow for 13 potential avirulence genes to be identified in *L. maculans,* and the number of races is likely to increase as the plant differential data is added.

Resistance genes are deployed in some of the winter and spring canola varieties currently grown in northern Idaho, but the resistance of many varieties is unknown. Unfortunately, seedling resistance can be readily overcome by mutations in the pathogen within just a few years. Therefore, efforts are underway to identify multigenic, durable mechanisms of resistance in a diverse collection of canola germplasm.

Cabbage Seedpod Weevil Insecticide Trial in Winter Canola

DALE WHALEY[1], DAVID CROWDER[2], AND AARON ESSER[3]
[1]WSU EXTENSION-DOUGLASS COUNTY; [2]DEPT. OF ENTOMOLOGY, WSU; [3]WSU EXTENSION-ADAMS COUNTY

Winter canola acreage in Washington continues to increase as more producers learn about the rotational benefits and potential profitability of canola. With the increase in production, comes the potential of encountering problems with insect pests that are common in other canola-growing regions of the U.S. and Canada. One such insect pest, the cabbage seedpod weevil, *Ceutorhynchus obstrictus* (Marsham) (Fig. 1), is becoming a problem in some areas of Washington state. The cabbage seedpod weevil (CSPW) is an introduced insect pest from Europe and causes damage to members of the Brassicaceae or mustard family, including cultivated crops such as canola and brown mustard. When left unmanaged, the CSPW can cause significant damage to ripening canola seeds and impact overall yields by as much as 50% (Fig. 2). Unfortunately, there is a lack of fundamental knowledge on which insecticide provides the greatest control in order to make sound management recommendations for this pest in our region. An insecticide trial was developed to compare several known insecticides to determine which one will work the best at managing this pest. Five insecticides: Bifenthrin (Tailgunner), Chlorantraniliprole (Altriset, Besiege, Voliam Express), Imidacloprid (Gaucho 600), Lambda-Cyhalothrin (Warrior II) and Zeta-cypermethrin (Mustang Max) were selected for this study. First year data suggests that there was no significant difference between treatments. However, a clear difference was observed between the insecticide treatments and the control plots. Those treated with insecticides yielded (23 lbs/A) on average more than the non-treated control. This data suggests that CSPW should be controlled when pest densities reach treatment or action thresholds of 30 to 40 adults per 10 sweeps. Year two of the trial will be put out the Spring/Summer of 2018.

Figure 1. Adult Cabbage Seedpod Weevil. Photo by Josef Dvořák.jpg

Figure 2. Cabbage Seedpod Weevil larval feeding damage. Photo by Green Thumb Photography.

Management of Fresh Wheat Residue for Irrigated Winter Canola Production

BILL SCHILLINGER[1], TIM PAULITZ[2], JEFF SCHIBEL[3], JOHN JACOBSEN[1], AND STEVE SCHOFSTOLL[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS; [3]COLLABORATING GROWER

We concluded a 3-year irrigated winter canola (WC) field study in 2017 at the Jeff Schibel farm near Odessa, Washington. The two major objectives of this experiment were: (i) to understand the physiological mechanism(s) governing health when planted soon after the harvest of winter wheat (WW), and (ii) to learn how to effectively and profitably produce irrigated winter canola without burning or excessive tillage of wheat stubble. Our hypothesis was that fresh wheat stubble is not phytotoxic to WC and that WC can be successfully produced in a direct-seed system after wheat harvest as a viable alternative to field burning plus heavy tillage.

Five winter wheat stubble management treatments were established in August and September each year. The experiment was embedded in a circle of irrigated WC. Irrigated WW stubble in the plot area was burned in treatments 1 and 3 (below) in late August and irrigation water immediately applied to promote germination of volunteer wheat. Glyphosate was applied to the entire plot area (except for treatment 5, see below) at a rate of 24 oz/acre in early September. Land was prepared as required by protocols for each treatment (see list of treatments in next paragraph). Winter canola was planted in treatments 1 to 4 in early September using a no-till hoe drill with 12-inch row spacing and openers staggered on four ranks. In treatment 5, WC was broadcast into the WW crop before WW harvest in early August.

Treatments established at the Schibel site were: (1) stubble burned + disked, (2) stubble chopped + moldboard plowed, (3) stubble burned, then direct seeded (4) direct seeding into standing and undisturbed stubble, and (5) broadcast WC into WW before WW harvest. Experimental design was a randomized complete block with four replications of each treatment for a total of 20 plots. Application of irrigation water, which totaled about 15 inches for the crop year, was managed by Jeff Schibel.

Satisfactory stands of WC were established in all treatments each year (Fig. 1). The hypocotyl (i.e., the stem from ground level to the growing point at the first leaves) of WC elongated up to four inches and leaves extended above the 15-inch-tall WC by mid-October (Fig. 2, plant on right). In contrast, in the stubble burned treatment the hypocotyl was only one-inch long in mid-October (Fig. 2, plant on left).

Figure 1. WSU research technician John Jacobsen in a standing residue plot that was successfully direct seeded. The grain yield of this winter wheat field was 147 bu/acre and the stubble cut at a height of 15 inches.

Figure 2. Size of winter canola plants in mid-October. Plant on left was direct seeded after burning winter wheat stubble. The plant on the right was direct seeded into 15-inch tall wheat stubble.

In year 2, WC in both the direct seed into standing stubble and broadcast into standing WW before WW harvest was winterkilled. Winter canola plants in the other three treatments were hurt by the cold but many survived. In year 3, voles infested the two standing stubble treatments during the winter (when snow covered the ground for 75 days) and ate WC plants mostly down to ground level. Voles did not infest the other three treatments. Seed yields during the 3-year experiment are shown in Table 1.

Important take-home messages from this experiment are: (i) We found no evidence that fresh wheat stubble is toxic to WC as evidenced by no foliar or root diseases in any year, and; (ii) an Adams County farmer successfully produces irrigated WC direct seeded into freshly harvested WW stubble after mowing the stubble and, therefore, apparently avoiding extensive WC seedling hypocotyl elongation as experienced in our study.

Table 1. Winter canola seed yields in three years and the 3-year average yield with five wheat residue management treatments at the Jeff Schibel farm near Odessa, WA.

	Seed yield (lbs/acre)			
	Year 1	Year 2	Year 3	3-yr avg.
Stubble burned + disked	3092	2832	2776 ab	2900
Stubble burned + direct-seeded	3020	2678	2795 ab	2831
Stubble chopped + moldboard plowed	3246	1830	3158 a	2745
Direct seeded into undisturbed stubble	2988	**	2218 bc	
Broadcast into standing wheat	*	**	1939 c	
Statistical significance	ns (p = 0.40)	ns (p = 0.06)	p < 0.001	ns (p = 0.52)

* The broadcast into standing wheat before harvest treatment was not present in year 1.
** Canola killed by cold temperatures in 2014.
ns = No significant statistical differences at p<0.05.

Soil Microbial Communities in a Long-Term Dryland Camelina Cropping Systems Experiment

Jeremy Hansen[1], Bill Schillinger[2], Tarah Sullivan[2], and Tim Paulitz[1]
[1]USDA-ARS; [2]Dept. of Crop and Soil Sciences, WSU

Camelina is a potential alternative and oilseed biofuel crop for wheat-based cropping systems of the Inland Pacific Northwest (PNW). We investigated the effect of this relatively new rotational crop on soil microbial communities. Camelina is a brassicaceous crop that contains glucosinolates which, upon cell rupture during the decay of residue, hydrolyze to produce isothiocyanates. Dimethyl-disulphide is a compound that is associated with the roots of camelina. Production of isothiocyanates and dimethyl-disulphide contribute to the "biofumigation effect" which can reduce the inoculum of soilborne pathogens. However, the non-selectivity of these compounds has potential to also impact beneficial soil microorganisms.

An 8-yr cropping systems experiment was initiated in 2009 at Lind, WA, to compare a 3-yr rotation of winter wheat (WW) -camelina (C)-summer fallow (SF) to the typical 2-yr WW-SF rotation. Microbial biomass and community composition were determined using phospholipid fatty acid analysis (PLFA). The abundance of fungi, mycorrhizae, Gram positive and negative bacteria, and total microbial biomass all declined over the 3-yr period in the WW-C-SF rotation. All microbial lipid biomarkers were significantly less in SF compared to WW (Fig. 1). The 2-yr WW-SF rotation demonstrated few differences in microbial lipid abundance and community structure between the rotation phases. Decline in microbial abundance and shift in community structure (Fig. 2) of the 3-yr WW-C-SF rotation was likely due to the combination of a brassica crop followed by a fallow period. The stability of microbial communities in the 2-yr rotation was likely a result of a 140-yr history of the monoculture WW-SF cropping system in the low precipitation (<12-inch annual) zone of the PNW.

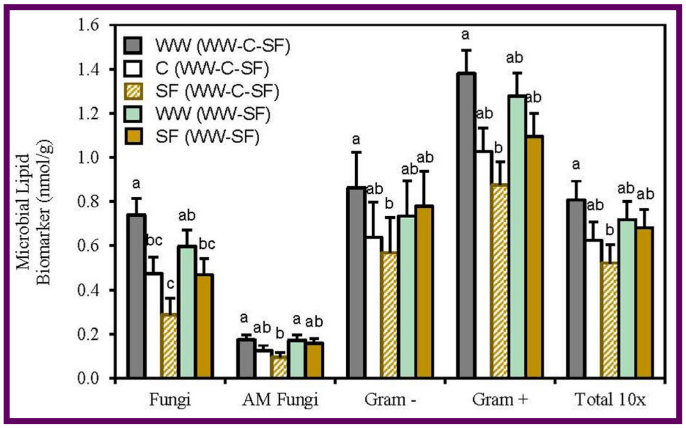


Figure 1. Soil microbial lipid abundance. Biomarker groups and total PLFA (T-PLFA) concentrations (nmol/g) of soil. Values are least square means for crop by rotation treatments. Error bars indicate standard error. Values within each biomarker group with different letters are significantly different (*p* ≤ 0.05).

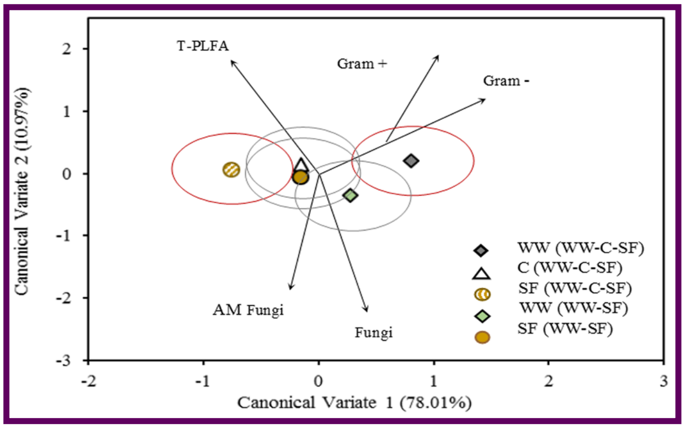


Figure 2. Canonical variates for lipid biomarker groups. Biomarker groups and total PLFA (T-PLFA) of soil from 2011 to 2015. Vectors represent standardized canonical coefficients and indicate the contribution of each biomarker group to each canonical variate. Each point represents the group centroid mean and is accompanied by a mean ellipse at the 95% confidence interval (Treatments groups that differ significantly have confidence ellipses that do not intersect).

Effect of Planting Date on Winter and Spring *Camelina sativa* Biotypes

---

WILSON CRAINE AND SCOT HULBERT
DEPT. OF CROP AND SOIL SCIENCES, WSU

The vast majority of camelina varieties are spring biotypes. However, winter biotypes also exist that require vernalization to flower and consequently exhibit different patterns of growth. These winter types have yet to be evaluated in field trials because camelina traditionally is a spring planted crop. The purpose of this experiment was to evaluate both spring and winter camelina biotypes planted at different times throughout the growing season. Five different planting dates were used, with two fall planting dates, October 5 (F1) and October 24 (F2), and three spring planting dates, April 5 (S1), April 22 (S2), and May 10 (S3). A total of eighteen camelina varieties, consisting of fifteen spring and three winter biotypes, were used in the variety trial, and each of the varieties was replicated three times per planting date. The field trial was located at Cook Agronomy Farm in Pullman, WA.

Although winter biotypes reportedly have superior cold tolerance, we did not observe any significant differences in winter survival between the two biotypes. Despite average temperatures of 26.7°F and temperatures as low as -11°F, negligible rates of winter-kill were observed in both winter and spring types. This result was not surprising, as spring types exhibit cold tolerance comparable to that of winter wheat' and prolonged snow cover likely buffered the plants from the extreme cold. Every fall-planted variety reached the rosette stage before being covered by snow for more than 90 days. All fall-planted varieties flowered before the end of May and were ready for harvest by mid-July. For both S1 and S2, the spring and winter types flowered in synchrony, indicating that the vernalization requirement of the winter types was met by the cool, early spring conditions. S1 reached 50% flowering around June 10, S2 around June 18, and S3 (spring types only) around June 25, and all three were ready to harvest by mid-August. However, the winter varieties in S3 were not thoroughly vernalized and exhibited significant delay in flowering (Photo 1). These varieties did not start flowering until the end of July, had just started seed set by harvest, and ultimately had significantly low yields. This disparity in yields is depicted in Figure 1. Figure 1 also illustrates the differences in yields of winter and spring biotypes across all planting dates. Excluding S3, the winter types out yielded the spring types in every other planting date,

Photo 1. This photo taken August 15 illustrates delayed flowering of winter varieties in S3. Winter varieties (left) are still green and flowering, while spring varieties (right) are ready for harvest.

although this difference was only statistically significant in F2. Figure 2 depicts mean yields of all varieties for each planting. F1 and F2 had highest yields, then S2 and S3, and S1 had the lowest yields overall. It is important to note that S3 was negatively biased by the significantly lower yields of the winter types. Spring types in S3 average yield was 480g/plot, comparable to yields of spring types in F1 and F2. Another interesting trend for spring types is yield increased as planting date got later. Overall, these results demonstrate winter camelina biotypes are capable of performing as well, if not better than, spring types, as long as they are planted early enough to ensure vernalization occurs.

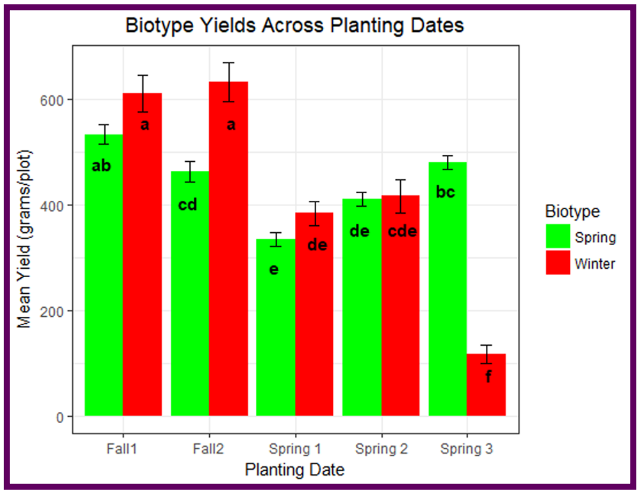


Figure 1. Biotype yields across planting dates. Lowercase letters represent significant differences (Tukey HSD).

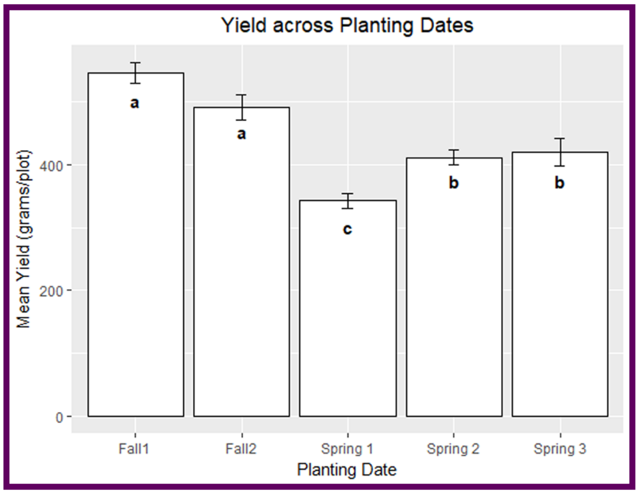


Figure 2. Mean yields across planting dates. Lowercase letters represent significant differences (Tukey HSD).

Recommendations for Growers

Winter varieties: Plant as soon as moisture is available. But if spring planted, be sure to plant early enough to ensure vernalization.

Spring varieties: Spring varieties can be either fall or spring planted. Later spring plantings did not compromise yields in this experiment, so waiting for weeds to emerge for control before planting may be a better strategy in higher rainfall zones. For more comprehensive information on planting dates for spring varieties, please see *Camelina: planting date and method effects on stand establishment and seed yield.*

Integrating Livestock to Dryland System - Grazing on Dual-Purpose Winter Canola

STEVE VAN VLEET[1], DENNIS ROE[2], ISAAC MADSEN[2], STEVE FRANSEN[2], DON LLEWELLYN[1], AND HAIYING TAO[2]
[1]WSU EXTENSION; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Integrated livestock and cropping systems are essential for sustainable farms. Also, alternative feed sources are needed for livestock during the fall on Washington farms/ranches to extend the grazing season and reduce feeding costs. A project was implemented raising winter canola for a harvestable crop the following season while also providing fall grazing forage prior to winter dormancy. Winter canola ("Amanda") was seeded mid-July and cattle grazing introduced to well-developed plants in mid-September prior to frosts and winter dormancy. The cattle grazed the study area for 14 days and were moved to adjacent ungrazed strips of canola after specific levels of grazing impact were observed.

Cattle gained approximately 1.43 lbs/day throughout the canola forage grazing period. Winter canola survival and yield will be determined from ungrazed and grazed areas during the 2018 growing season.

Winter Pea: We Finally Have a Hardy, Stable, and Easy-To-Grow Alternative Crop for the Drylands

BILL SCHILLINGER[1], RON JIRAVA[2], JOHN JACOBSEN[1], AND STEVE SCHOFSTOLL[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]COLLABORATING FARMER

Researchers and farmers in the dry croplands (<12 inches annual precipitation) have experimented with numerous crops and rotations for over 100 years, but none have been found to be as stable, reliable, and profitable as winter wheat-summer fallow (WW-SF). This long wait may finally be over. Winter pea (WP) is a cool-season, nitrogen-fixing pulse crop. Prior to 2012, essentially no edible WP was produced anywhere in the PNW. Winter pea plantings in the WW-SF region of Washington have gone from basically zero to more than 10,000 acres from 2012 to 2017. Although the land area planted to WP currently is still small, the annual increase in planted acres has been exponential.

Field research conducted since 2010 near Ritzville, WA (11.5-inch annual average precipitation) has demonstrated that WP is well suited for the low-precipitation drylands. The objective of our long-term Ritzville study is to determine the yield potential and yield stability of WP and associated rotation benefits to the subsequent crop compared to WW. Two 3-year rotations are evaluated: WP-spring wheat (SW)-SF versus WW-SW-SF. Over the first seven years of the study, WP yields averaged 2275 lbs/acre versus 73 bu/acre for WW (Table 1). No fertilizer was applied to WP whereas 50 lbs N and 10 lbs S/acre were applied to WW. Winter pea used significantly less soil water than WW. Over the winter months, a lesser percentage of precipitation was stored in the soil following WP compared to WW because: (i) very little WP residue remained on the soil surface after harvest compared to WW, and (ii) the drier the soil, the more precipitation is stored in the soil over winter. However, soil water content in the spring was still greater following WP versus WW. Soil residual N in the spring (7 months after the harvest of WP and WW) was greater in WP plots despite not applying fertilizer to produce WP. Spring wheat grown after both WP and WW received the identical quantity of N, P, and S fertilizer each year. Average yield of SW was 34 and 32 bu/acre following WP and WW, respectively (Table 1).

Table 1. Yield of winter pea (WP) and winter wheat (WW) as well as the subsequent yield of spring wheat (SW) following both WP and WW over a 7-year period at Ritzville, WA.

Treatment	2011	2012	2013	2014	2015	2016	2017	7-yr avg.
Winter crop								
Winter pea (lb/ac)	1960	2820	2085	------[*]	1515	2530	2730	2275[**]
Winter wheat (bu/ac)	77	85	87	50	63	73	79	73
Spring crop[***]								
SW after WP (bu/ac)		30	45 a	16	34 a	47	33	34 a
SW after WW (bu/ac)		32	40 b	14	25 b	46	34	32 b

[*] WP was winter killed in 2014 and replanted to Banner edible spring pea, which yielded 775 lb/A.
[**] Winter pea average is for six years (i.e., 2014 not included).
[***] ANOVA is for SW only. Within column means followed by a different letter are significantly different at $p < 0.05$.

Important take-home messages:

- Winter pea has excellent production potential in the typical WW-SF region of east-central Washington.
- Winter pea has unsurpassed seedling emergence from deep planting depths, even when surface soils have been crusted by rain showers before emergence. Excellent WP plant stands were consistently achieved that effectively competed against Russian thistle.
- New WP varieties will soon be available that have cold tolerance similar to that of WW, greater yield potential than 'Windham' (the variety used in our study), and quality traits that will fetch higher prices in regional, national, and international markets.

Three people are largely responsible for the rapid and successful advances in WP production in the PNW drylands. These people are: Howard Nelson, Highline Grain Growers; Kurt Braunwart, ProGene Plant Research; and Rebecca McGee, USDA-ARS. A detailed article on the Ritzville study is available at https://www.frontiersin.org/articles/10.3389/fevo.2017.00043/full

Early and Late Planting Dates for Winter Triticale vs. Winter Wheat at Lind

BILL SCHILLINGER, JOHN JACOBSEN, STEVE SCHOFSTOLL, AND BRUCE SAUER
DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND

Winter triticale (WT) shows excellent agronomic potential as an alternative crop in Washington's low-precipitation (<12-inch annual) zone where winter wheat (WW)-summer fallow is the dominant crop rotation. Since 2014, we have planted the WT variety 'TriMark 099' and the soft white WW variety "Otto" deep into carryover soil moisture at a seeding rate of 50 lbs/acre on 17-inch row spacing in late August. These same varieties are "dusted in" at a shallow depth at a seeding rate of 90 lbs/acre in paired rows on 12-inch spacing in mid-October. Each treatment is replicated six times in a randomized complete block arrangement (total of 24 plots).

Seed-zone water for early planting in 2014 and 2015 (i.e., 2015 and 2016 crop years) were somewhat dry. Trimark 099 does not emerge as well as Otto and this was reflected in some bare areas in WT rows whereas WW had full stands in these years. Averaged over the first three years, grain yields of early early-planted WT and WW were 61 versus 51 bu/acres, respectively (Table 1), with yields of both crops expressed in 60-pound bushels. Although early-planted WT produced an average of 10 bu/acre more grain than early-planted WW, the market price for WT grain is lower than that for soft white wheat. On April 10, 2018, the cash price in Ritzville for WT is $125/ton compared to $5.30/bu for soft white wheat. Thus, 61 bushels of WT is worth $229 compared to $270 for 51 bushels of WW. The 3-year average grain yield for late-planted WT and WW was 45 and 40 bu/acre, respectively, with comparable market-price differences as explained above in this paragraph.

Table 1. Grain yields from a 3-year winter triticale (WT) and winter wheat (WW) planting date study at Lind, WA. 'TriMark 099' WT and 'Otto' WW were planted in both late-August and in mid-October. Both WT and WW yields are reported in 60-pound bushels.

Treatment[b]	2015	2016	2017	3-yr avg.
Early-planted triticale	30 a	63 a	91 a	61 a
Late-planted triticale	26 b	63 ab	47 c	45 c
Early-planted wheat	29 ab	56 ab	68 b	51 b
Late-planted wheat	26 b	55 b	40 c	40 c
Significance (*p*-value)	< 0.05	0.01	< 0.001	< 0.001

[a] Crop-year precipitation for 2015, 2016, and 2017 were 7.61", 12.66" and 14.78", respectively.

[b] Early-planted and late-planted treatments planted at 50 and 90 lb/ac, respectively.

Winter triticale has several excellent agronomic characteristics, including unsurpassed winter hardiness and apparent complete resistance (so far) to stripe rust. Winter triticale produces ample straw but, in our studies (see next article), not significantly more straw than WW. We plan to continue this study at least through the 2019 crop year.

Seeding Rates for Late-Planted Winter Triticale and Winter Wheat

BILL SCHILLINGER[1], JOHN JACOBSEN[1], STEVE SCHOFSTOLL[1], MIKE NICHOLS[2], AND CODY NICHOLS[2]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]FARMER COLLABORATOR

We are conducting field research at Lind (Adams County) and at the Mike and Cody Nichols farm in the Horse Heaven Hills (Benton County) to determine the optimum seeding rate for late-planted winter triticale (WT) and winter wheat (WW). Late planting is defined as seeding at a shallow depth of one-inch in mid-to-late October. Late planting is required when seed-zone moisture is not adequate for deep-furrow planting in late August-early September.

The WT variety 'TriMark 099" was used at both sites. The soft white WW variety 'Otto' was used at Lind and the hard red WW variety 'Arrowhead' at the Horse Heaven site. We had four seeding rates that are approximately equal to 30, 60, 90, and 120 lbs/acre. The same number of WT and WW seeds were used for all seeding rate treatments. An individual WT seed is considerably heavier than a WW seed, thus it is important to use the same number of seeds per unit area planted rather than weight.

Figure 1. WSU research technician John Jacobsen in a 90 lbs/acre winter triticale seeding rate treatment at Lind in 2016. A 30 lbs/acre winter wheat seeding rate treatment is on his right.

Crop-year (Sept. 1-Aug. 31) precipitation at Lind for 2016 and 2017 was 12.66 and 14.78 inches. These were very wet years as the long-term average precipitation at Lind is only 9.61 inches. Crop-year precipitation for 2016 and 2017 at the Horse Heaven site was recorded by a WSU Ag Weather Net device located one mile from our study was 7.29 and 7.07 inches. These amounts were considerably above the long-term annual average of about six inches for the Nichols farm.

We measured all grain yield components (i.e., heads per unit area, kernels per head, and kernel weight) as well as straw weight. Grain yield was determined by harvesting each 100-ft-long plot with a plot combine. Each treatment was replicated four times for a total of 32 plots at each site.

Table 1 shows grain yield, expressed as 60-pound bushels for both WT and WW in 2016 and 2017. At Lind, significantly lower yield for both WT and WW occurred with the 30-pound rate compared to the higher rates. There were no significant differences in yield among the 60, 90, and 120-pound rates for WT. For WW, incremental (but not always statistically significant) increases in yield occurred with each incremental increase in seeding rate. Averaged over the two years, the 120-pound rate produced and average of six additional bushels over the 60-pound rate (i.e., 48 vs. 42 bu/acre) and these differences were statistically highly significant (Table 1). However, one needs to keep in mind that these were both very wet crop years at Lind.

At the Nichols site in the Horse Heaven Hills, there were no differences in either WT or WW grain yields among the four seeding rates in 2016 (Table 1). In 2017, yields for WT at the 60 and 90-pound rates were significantly greater than for the 30 and 120-pound rates. Averaged over both years, the 60-pound seeding rate for WT was the best bet during these two years. For WW, there were no differences in yield in either year or when averaged over both years. Winter wheat grain yields were essentially identical across all four seeding rates (Table 1).

Both WT and WW in the experiment look good at both sites this current (2018) crop year. We plan to continue this study through 2019.

Table 1. Grain yield (bushels/acre) of winter triticale and winter wheat at two locations over two years as affected by four seeding rates. Yields of both winter triticale and winter wheat are expressed in 60-pound bushels.

Treatment	2016	2017	2-yr avg.
	Lind		
Winter Triticale			
30 lb/ac	45 b	34 b	40 b
60 lb/ac	51 ab	42 a	47 a
90 lb/ac	53 ab	45 a	49 a
120 lb/ac	62 a	44 a	53 a
Significance (*p*-value)	0.02	0.001	< 0.001
Winter Wheat			
30 lb/ac	42	32 c	37 c
60 lb/ac	47	37 bc	42 bc
90 lb/ac	51	39 ab	45 ab
120 lb/ac	52	43 a	48 a
Significance (*p*-value)	ns	< 0.001	0.005
	Horse Heaven Hills		
Winter Triticale			
30 lb/ac	17	32 c	25 b
60 lb/ac	17	38 a	28 a
90 lb/ac	18	38 a	28 a
120 lb/ac	17	34 bc	26 b
Significance (*p*-value)	ns	0.003	0.01
Winter Wheat			
30 lb/ac	15	34	25
60 lb/ac	14	35	25
90 lb/ac	14	36	25
120 lb/ac	13	37	25
Significance (*p*-value)	ns	ns	ns

Part 4. Pathology, Weeds, and Insects

Soilborne Wheat Mosaic Virus Post-Harvest Update: Yield Loss and Variety Blends

CHRISTINA H. HAGERTY AND DUNCAN R. KROESE
COLUMBIA BASIN AG. RESEARCH CENTER, OSU

The evaluation of yield loss due to Soilborne wheat mosaic virus (SBWMV) was conducted in Walla Walla county under severe SBWMV conditions. At the severe location, yield was reduced by an average of 37.3 bu/A ($p < 0.001$) (Fig. 1).

Over the course of the spring season, we were consistently impressed with the SY Ovation (SBWMV resistant) and LCS Art Deco (SBWMV susceptible) blends. We documented less than 50% disease in the 50/50 SY Ovation/Art Deco blend, and less than 25% disease in the 75/25 Ovation/Art Deco blend. Preliminary results indicate the resistant/susceptible variety blends do not significantly differ in yield compared to pure stand resistant SY Ovation (Fig. 2). However, susceptible LCS Art Deco yielded 31.2 bu/A less than pure stand resistant SY Ovation (*p=0.003*).

Take home messages from 2017 harvest season: 1) Significant yield loss (37.3 bu/A yield penalty) was documented in association with dryland SBWMV, and 2) Preliminary data suggests resistant/susceptible variety blends may be a good option to prevent yield loss from SBWMV.

Please note all results are preliminary and are based on the 2017 season. A second year of field data is forthcoming. Many thanks to the Oregon Wheat Commission for funding this work, and to the farmers who hosted trials.

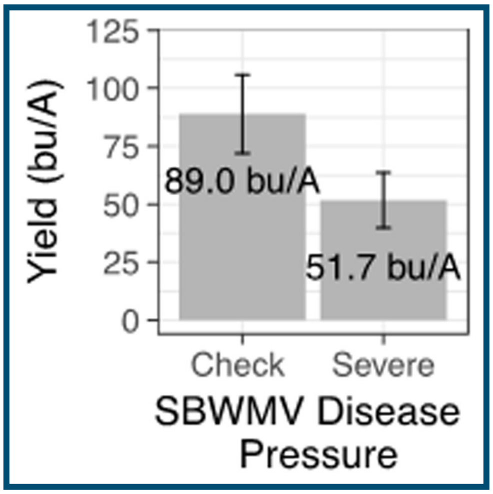


Figure 1. Estimate of winter wheat yield loss associated soil borne wheat mosaic virus (SBWMV) from 24 replicate plots under severe SBWMV disease pressure +/- standard deviation. Yield loss compared to non-SBWMV infested check plots. Bu/A estimates extrapolated from 40x30in bundles.

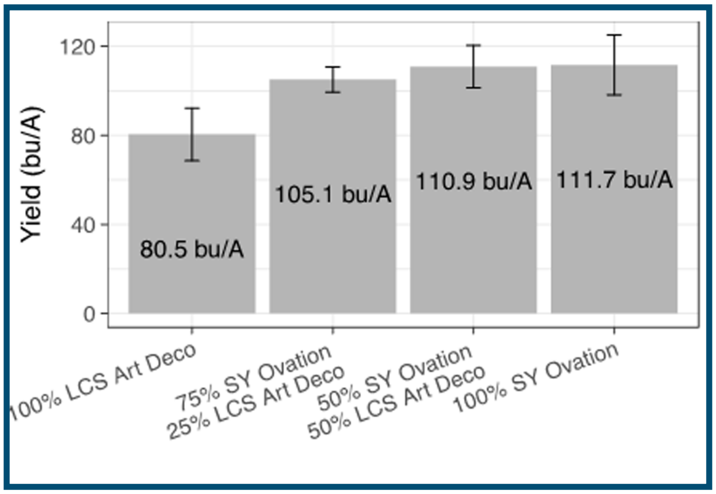


Figure 2. Yield of winter wheat cultivars (SY Ovation and LCS Art Deco) in blends and pure stands grown under heavy soil borne wheat mosaic virus conditions. Bars represent the mean yield of four replicate plots +/- standard deviation. Bu/A estimates extrapolated from 5x45ft plots.

Expression of Defense Enzymes and mRNAs in Wild Oat and Wheat Seeds Challenged with the Pathogen *Fusarium avenaceum*

PAT OKUBARA[1,2], ANNE POLLARD[3], AND PAT FUERST[3]
[1]USDA-ARS, WHEAT HEALTH, GENETICS AND QUALITY; [2]MOLECULAR PLANT SCIENCES PROGRAM AND DEPT. OF PLANT PATHOLOGY, WSU; [3]DEPT. OF CROP AND SOIL SCIENCES, WSU

Dormant weed seeds in the soil actively sense the environment in readiness to germinate. Prior to germination, however, they also mount active chemical and enzymatic defense responses to protect their food reserves from decay-inducing microbes and herbivores. Prior studies of the interaction between dormant wild oat isoline M73 and the pathogen *Fusarium avenaceum* isolate *F.a.*1 indicate that the pathogen causes in vitro decay of the caryopsis (kernel or de-hulled seed) at a rate of 50% over 8 days. Our studies showed that extrinsic activities of the defense enzymes polyphenol oxidase, exochitinase and peroxidase were induced in whole wild oat caryopses incubated with *F.a.*1 for 3 days. In contrast, caryopses of the dormant hexaploid wheat cultivar RL4137 sustained almost no decay in the presence of *F.a.*1, yet showed defense enzyme induction upon pathogen challenge, although to a lesser degree than in wild oats. To evaluate whether defense enzyme activities were released from the caryopsis surface, caryopses were washed with buffer and enzyme activity was measured in the leachate. Polyphenol oxidase, exochitinase and peroxidase were detected in caryopsis leachates, and relative to non-challenged controls, were induced to a greater degree in leachates compared to whole caryopses. The defense enzyme oxalate oxidase displayed a differential response to *F.a.*1, with reduction rather than induction in caryopses of both wild oat and wheat, and absence of activity in the leachate fractions. Our findings indicate that *F.a.*1-triggered activities were enzyme-specific, and these particular enzymes were not key factors in protection from decay, since wild oat showed a higher degree of enzyme induction and greater decay susceptibility, compared to wheat. The findings support the hypotheses that dormant weed and crop seeds are capable of mounting complex enzymatic responses to soilborne pathogens, and that fungi capable of selective decay of weed seeds without damage to crop seeds have potential for weed management in the field. Current research is directed toward quantifying *F.a.*1-mediated decay and defense enzyme and defense gene expression induction in soil.

Weed Control in Chickpea Affected by Incorporation

JOAN CAMPBELL AND TRACI RAUCH
DEPT. OF PLANT SCIENCES, UI

A study was initiated at the University of Idaho Parker Farm east of Moscow, Idaho to evaluate herbicides for control of broadleaf weeds and the effect of rolling after application. Incorporation by rainfall is required for the activation of most soil applied herbicides. This study was to determine if mechanical incorporation might be substituted for rainfall. Herbicides were applied May 5, 2016 the day after planting Billy Bean chickpea. Half the plot was incorporated with a roller packer after herbicide application. The study was arranged in a split block design with four replications. Common lambsquarters was evaluated visually on June 7 and 27, and plants were counted on July 5. Chickpea seed was harvested at maturity.

Weed control and chickpea yield were lower with Sharpen+metribuzin compared to other treatments (Table 1). Weed control on June 27 was highest with Lorox+Spartan although not statistically different from other herbicide treatment combinations with Lorox.

Table 1. Common lambsquarters control and chickpea seed yield averaged over rolling treatment.

	Common lambsquarters control			
Herbicide treatment[1]	Visual June 6	Visual June 27	Plant number	Chickpea yield
	%	%	plant/m^2	lb/A
Nontreated	-	-	213 ab[2]	1722 a
Sharpen + metribuzin	72 a	53 a	45 b	3697 b
Lorox + Valor	95 b	88 bc	3 b	5295 c
Lorox + Pursuit	97 b	88 bc	10 b	5273 c
Outlook + Spartan	95 b	83 b	6 b	5420 c
Lorox + Spartan	98 b	93 c	3 b	5938 c

[1] Herbicide rates are Lorox 0.625, Pursuit 0.031, Sharpen 0.044, metribuzin 0.375, Valor 0.064, Outlook 0.984, and Spartan 0.25 expressed as lb ai/A.

[2] Means followed by the same letter within a column are not statistically different P<0.05.

Incorporation with rolling reduced weed control and did not affect chickpea yield (Table 2). Mechanical herbicide incorporation is not recommended at this time to improve herbicide performance.

Table 2. Lambsquarters control and chickpea seed yield averaged over herbicide treatment.

	Common lambsquarters control[1]			
Treatment	Visual May	Visual June	Plant number[2,3]	Chickpea yield[3]
	%	%	plant/m^2	lb/A
Rolled after application	87 a	75 a	19 a	4858 a
Rolled before application	96 b	86 b	8 b	5177 a

[1] Means followed by the same letter within a column are not statistically different P<0.05.

[2] Data was square root transformed for statistical analysis.

[3] Nontreated plots are not included.

Rush Skeletonweed Control in Winter Wheat

Mark E. Thorne[1], John F. Spring[2], Henry C. Wetzel[1], Ian C. Burke[1], and Drew J. Lyon[1]
[1]Dept. of Crop and Soil Sciences, WSU; [2]Colorado State University Extension

A two-year study evaluating control of rush skeletonweed in winter wheat, with five different synthetic auxin herbicides applied in the fall and early spring, was completed in 2017 at a field site near LaCrosse, WA on the RR Dorman Farm. Rush skeletonweed is a perennial weed that has persisted on farmland across eastern Washington since the land was taken out of the Conservation Reserve Program (CRP) and put back into winter wheat production. Wheat yield is reduced in areas where rush skeletonweed has depleted soil moisture during the fallow year and where it competes during the crop year. Herbicides applied were Stinger® (clopyralid) at 8 oz/A, Milestone® (aminopyralid) at 0.6 oz/A, DPX-MAT128 (aminocyclopyrachlor) at 1.7 oz/A, Clarity® (dicamba) at 4 oz/A, and 2,4-D LV6® (2,4-D) at 8.7 oz/A. Fall applications were applied when the wheat was tillering; spring applications were made when the wheat was well tillered with nodes present 1 inch or less above the crown. At both application times, rush skeletonweed rosettes ranged from one to nine inches in diameter. Winter wheat 'ORCF-102' was planted at 60 lb/A during September of each year with a John Deere HZ616® grain drill. Fall-applied herbicide control was rated visually in March before the spring applications. Both fall and spring applications were rated visually in early April two weeks following spring applications, in June just after bolting, and in July before harvest.

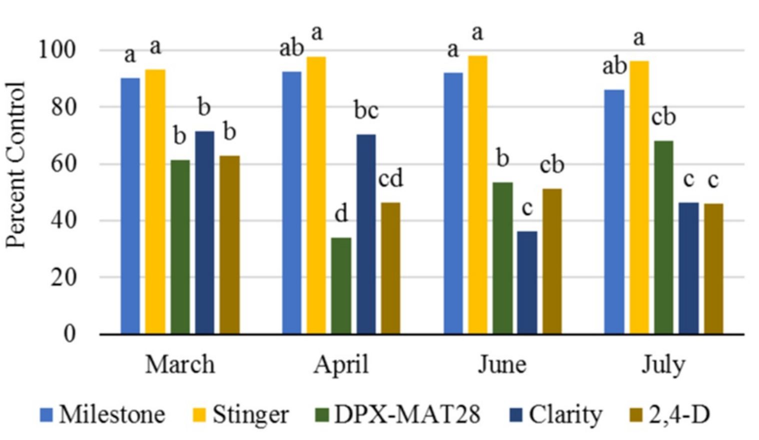


Figure 1. Fall-applied herbicide control of rush skeletonweed in winter wheat averaged across 2016 and 2017. Columns with the same letter within each rating time (month) are not statistically different (p≤0.05).

In both years, fall-applied Stinger provided the greatest control, averaging over 90% control at each rating (Fig. 1). Fall-applied Milestone was not statistically different from Stinger but averaged slightly less than Stinger. Both herbicides resulted in high skeletonweed mortality. Spring-applied Stinger and Milestone exhibited good control by the June rating, but lost some control by harvest (Fig. 2). At the harvest rating, a few plants had bolted that earlier appeared dead. Traditional treatments using 2,4-D LV6, Clarity, or the experimental DPX-MAT128 resulted in only a few dead skeletonweed plants and injury symptoms primarily of reduced growth and suppression of bolting. Furthermore, wheat yield was considerably reduced by the spring-applied DPX-MAT128. Overall, Stinger and Milestone were superior in controlling rush skeletonweed in winter wheat. Stinger is currently labeled for winter wheat, while Milestone is not yet labeled for this use in the U.S. Currently, we have ongoing research investigating herbicide treatments for control of rush skeletonweed in winter wheat fallow.

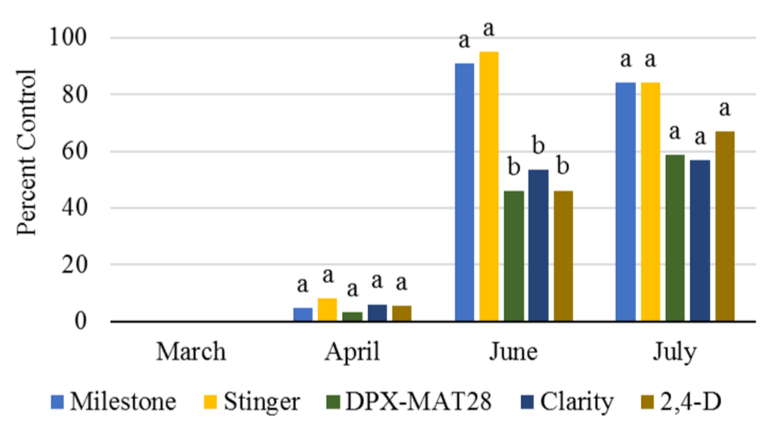


Figure 2. Spring-applied herbicide control of rush skeletonweed in winter wheat averaged across 2016 and 2017. Columns with the same letter within each rating time (month) are not statistically different (p≤0.05).

Fallow Management Determines the Influence of Grassy Weeds in Dryland Wheat

---

Carolina San Martín[1], Dan Long[2], and Judit Barroso[1]
[1]Oregon State University; [2]USDA-ARS

A two-year rotation of winter wheat (WW)/summer fallow (SF) is the most common cropping system in low precipitation areas of the U.S. Pacific Northwest (PNW). In SF, multiple tillage operations are used to manage weeds to maximize soil water storage and potential WW yield. Reduced tillage fallow is an alternative to SF that leaves >30% of the previous crop's residue on the surface. A three-year field study was conducted to evaluate the influence of SF and RTF on weed species density, cover and composition in dryland WW; and determine if changes in these weed infestation attributes have any influence on crop density and yield. The experimental design was a randomized complete block with four replications where each phase of WW/SF and WW/RTF rotations was present every year. Individual plots of WW (100 ft × 20 ft) were divided into a weedy area with no weed control, general area with chemical weed control, and weed-free area where weeds were removed by hand. Environmental conditions and fallow management affected weed infestation. The highest impact of RTF on weed management compared to SF was obtained in grass weed cover, which mainly consisted of downy brome (*Bromus tectorum* L.), and total weed cover. Though significant differences in yield were not detected, weeds were less competitive in RTF/WW than SF/WW as indicated by higher crop density and yield of WW following RTF (Fig. 1). Reduced tillage fallow can help suppress seedling emergence and growth of grassy weeds in WW/fallow cropping systems of the PNW compared to SF.

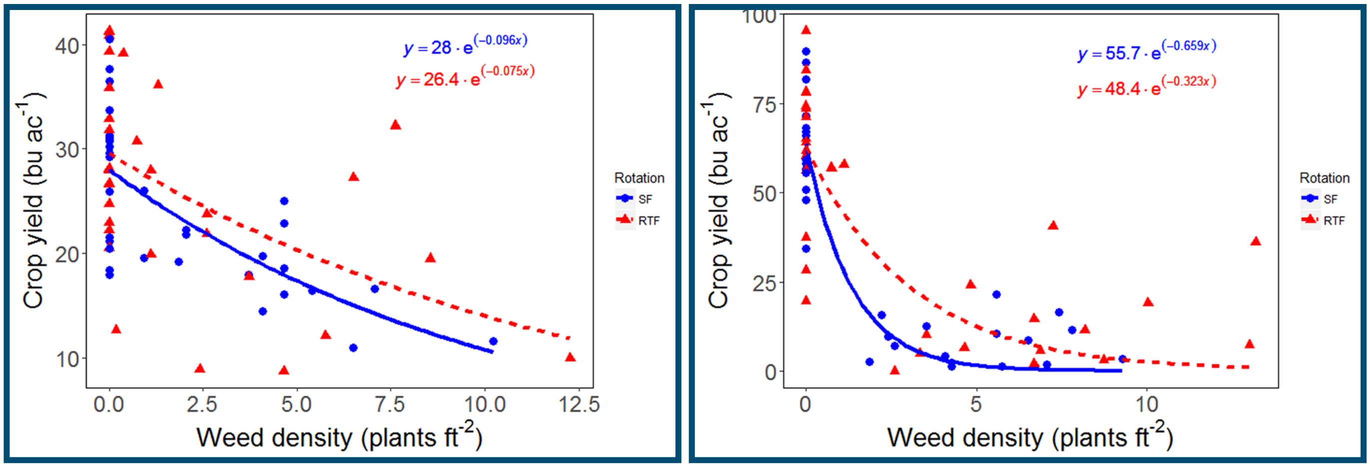


Figure 1. Relationship between crop yield (bu ac^{-1}) and weed density (plants ft^{-2}) in 2016 (left) and 2017 (right).

Downy Brome and Rattail Fescue Control in Winter Wheat with Osprey Xtra

---

Joan Campbell and Traci Rauch
Dept. of Plant Sciences, UI

Osprey Xtra is a herbicide premix that will soon be registered in winter wheat to control grass weeds, including rattail fescue and downy brome. Rattail fescue is a significant problem in direct seed wheat cropping systems in the Pacific Northwest and is difficult to control with glyphosate. Currently, few postemergence herbicide options exist or provide effective rattail fescue control. Downy brome is troublesome in low precipitation production areas where crop rotations are limited and can reduce winter wheat yield. Osprey is a currently registered grass herbicide that suppresses downy brome but not rattail fescue.

Winter wheat injury and grass weed control with Osprey and Osprey Xtra was determined in four studies established in winter wheat between 2015 and 2017. Herbicides were applied postemergence with a CO_2 backpack sprayer. Winter wheat injury and weed control were evaluated visually where 0% represented no injury or control and 100% represented complete plant death. PowerFlex and Everest were included as standards for downy brome and rattail fescue, respectively.

Table 1. Winter wheat injury and grass weed control in winter wheat with Osprey and Osprey Xtra near Moscow, ID in 2017.

Treatment	Rate	Wheat injury	Downy brome control	Rattail fescue control
	lb ai/A	%	%	%
Osprey	0.013	1 a[1]	66 b	54 d
Osprey Xtra	0.018	2 a	79 ab	89 abc
Osprey +	0.013	0 a	81 ab	70 cd
Huskie	0.217			
Osprey Xtra+	0.018	2 a	88 ab	98 a
Huskie	0.217			
Osprey +	0.013	6 a	92 a	82 abc
Huskie +	0.217			
Bromac Advanced	0.5			
Osprey Xtra+	0.018	2 a	84 ab	98 a
Huskie +	0.217			
Bromac Advanced	0.5			
Osprey +	0.013	4 a	68 b	71 bcd
Huskie +	0.217			
Widematch	0.188			
Osprey Xtra+	0.018	2 a	79 ab	92 ab
Huskie +	0.217			
Widematch	0.188			
Everest +	0.027	2 a	32 c	50 d
Huskie	0.217			

[1] Means followed by the same letter within a column are not statistically different P<0.05.

Winter wheat crop safety and downy brome control with Osprey Xtra alone or in combination with broadleaf herbicides were similar to Osprey treatments. Rattail fescue control was greater with Osprey Xtra alone or in combination with broadleaf herbicides compared to Osprey treatments. Downy brome control was enhanced when Osprey or Osprey Xtra was combined with broadleaf herbicides in 2015 and 2016 (data not shown), but not in 2017. Rattail fescue control was enhanced by the combinations in 2015 (data not shown) and 2017.

Rattail fescue control in 2017 winter wheat is shown for non-treated check (left), Osprey (middle), and Osprey Xtra (right).

Osprey Xtra will add a good postemergence option for rattail fescue control. However, both active ingredients are Group 2 herbicides. Everest, also a Group 2 herbicide, has been the only other consistence postemergence choice. Incorporation of Group 15 herbicides applied fall preemergence will be necessary to delay Group 2 herbicide resistant rattail fescue populations. Osprey Xtra (mesosulfuron/thiencarbazone) will not be registered until late 2018. Mesosulfuron (Osprey) and thiencarbazone (Varro) are registered as single activity ingredient herbicides. Osprey allows planting of chickpea, pea, and lentil (90 days) and canola (10 months) in the next cropping season. Varro allows planting the above crops after 9 months. This information along with previous research (2017 Dryland Field Day Abstract, page 15) suggests rotational crop restrictions on the label should be minimal for northern Idaho crops.

Table 2. Grass weed control means and orthogonal contrast for Osprey and Osprey Xtra treatments for all site by year locations.

	Downy brome			Rattail fescue		
Treatments	2015	2016	2017	2015	2016	2017
Weed control means	--------------- % ------------			--------------- % ---------------		
Osprey	76	14	77	77	15	69
Osprey Xtra	76	25	82	92	82	94
Orthogonal contrast (Pr>F)	NS	0.0541	NS	0.0001	0.0001	0.0002
Osprey and Osprey Xtra alone	62	12	72	69	46	72
Osprey and Osprey Xtra plus broadleaf herbicides	80	23	82	90	49	85
Orthogonal contrast (Pr>F)	0.0162	0.0537	NS	0.001	NS	0.0564

Eyespot, Cephalosporium Stripe, and Snow Mold Diseases of Winter Wheat

TIM MURRAY AND HONGYAN SHENG
DEPT. OF PLANT PATHOLOGY, WSU

Eyespot and Cephalosporium stripe diseases are most common in the high-rainfall regions of Washington, but also occur in the low- and intermediate-rainfall wheat-producing areas and have potential to cause loss in grain yield up to 50% for eyespot and 80% or more for Cephalosporium stripe. In contrast, snow mold diseases historically have been a problem on about 200,000 acres in the north-central wheat-producing area of Washington near the Waterville Plateau, and can cause complete yield loss when a susceptible variety is grown and disease is severe.

Planting a resistant variety is the best control for all of these diseases. Our research has focused on identifying new and effective resistance genes to these three diseases and testing new varieties for resistance. Over the past 10 years, we have tested new varieties and advanced breeding lines for eyespot and Cephalosporium stripe resistance in inoculated field trials and used that information to provide variety ratings available on the WSU Extension Small Grains Team website (http://smallgrains.wsu.edu) and the Washington State Crop Improvement Seed Buyer's Guide. Several varieties are available with effective resistance or tolerance to these diseases. We recommend consulting the results of the WSU Variety Testing plots near you and selecting the most resistant variety that does well in your area.

During the past three years, two doubled-haploid populations with a new source of snow mold resistance, PI 173438. These populations are in the second year of field testing this year. The goal of this project is to identify molecular markers that will make it easier for breeding programs to combine several resistance genes and develop varieties with more effective snow mold resistance.

Mixing resistant and susceptible varieties together is one strategy for improving disease control and yield that has received renewed attention in the past few years. Field studies to determine whether there is a benefit to mixing eyespot and Cephalosporium stripe resistant and susceptible varieties on disease severity and yield are in their third year. Two eyespot or Cephalosporium resistant/tolerant and susceptible varieties are grown in field plots alone and all possible combinations, inoculated with the respective pathogens, and then disease severity and yield are measured to determine their effectiveness in controlling disease. Averages of the mixtures are compared against those of pure lines to determine whether there is a benefit. Results from the first two seasons have demonstrated some positive results from mixtures, but additional testing is needed before we can draw any conclusions.

Fungicide application in spring is another option for eyespot control, and several fungicides are now registered for eyespot control: Tilt 3.6EC + Topsin-M 4.5FL; Alto 100SL + Topsin-M 4.5FL; Priaxor 4.16SC; Quilt Xcel 2.2SE + Topsin-M 4.5FL; and, Nexicor EC. Results of our field trials with variety ratings and fungicide trials are available on the WSU Wheat and Small Grains website (http://smallgrains.wsu.edu/disease-resources/research-reports/).

Cropping System Intensification Reduces Weed Pressure in Dryland Wheat

---

Carolina San Martín[1], Dan Long[2], and Judit Barroso[1]
[1]Oregon State University; [2]USDA-ARS

Fallow (F), the practice of keeping a field out of production during the growing season, is commonly used in the semi-arid Pacific Northwest to conserve soil water for the following crop. Studies have demonstrated that cropping intensification has a negative effect on weeds. A three-year study was conducted to determine if intensifying winter wheat (WW)-F by growing spring barley (SB, *Hordeum vulgare* L.) or spring oilseed (SO, *Brassica carinata* L.) after winter wheat (WW) could benefit weed management. The experimental design was a randomized complete block design with four replications where each phase of the rotation was present every year for the three cropping systems (WW-F, WW-SB-F, WW-SO-F). Weed density and cover per species were evaluated in early-, mid- and late- season. Crop yield was also measured at physiological maturity. Differences in community biodiversity due to cropping system rotation were only found in 2017 in WW-SB-F and WW-SO-F compared to WW-F. Grass cover and density in 2017 were significantly lower in WW-SB-F (1.3% and 0.18 plants ft^{-2}) and WW-SO-F (1.8% and 0.33 plants ft^{-2}) compared to WW-F (4.1% and 1.23 plants ft^{-2}). Winter wheat yield was not affected by intensifying the rotation but was negatively affected by weed presence in 2016 and 2017. In 2017, this negative effect was significantly larger in WW-SO-RTF than in WW-F and WW-SB-F (Fig. 1).

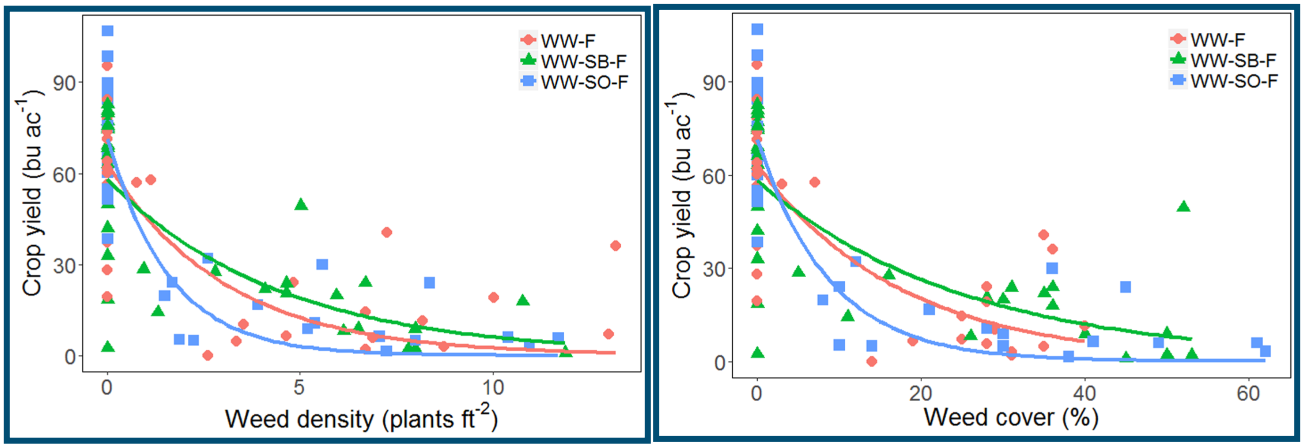


Figure 1. Relationship between (left) crop yield (bu ac^{-1}) and weed density (plants ft^{-2}), and (right) crop yield and weed cover (%) in 2017.

Broadleaf Weed Control in Wheat with Quelex

TRACI RAUCH AND JOAN CAMPBELL
DEPT. OF PLANT SCIENCES, UI

Two studies were established to evaluate broadleaf weed control and crop response with Quelex combined with PowerFlex in winter wheat near Culdesac and in spring wheat near Moscow, Idaho. These studies were arranged in a randomized complete block design with four replications and included an untreated check. All herbicide treatments were applied using a CO_2 pressurized backpack sprayer calibrated to deliver 10 gpa at 32 psi and 3 mph (Table 1). Treatments included the appropriate adjuvants. At Culdesac, the study was oversprayed with Quilt Xcel at 0.24 lb ai/A to control stripe rust and Axial XL at 0.54 lb ai/A to control grass weeds on May 2, 2017. The study was resprayed with Priaxor at 0.10 lb ai/A and Tilt at 0.11 lb ai/ for stripe rust control on June 5 by the grower. At Moscow, the study was oversprayed with Axial XL at 0.54 lb ai/A to control grass weeds and Quilt Xcel at 0.24 lb ai/A for stripe rust control on June 17, 2017. Crop response and weed control were evaluated visually during the growing season.

Table 1. Application data.

Location	Culdesac	Moscow
Application date	4/21/17	6/2/17
Winter variety	Magic	WB 6121
Growth stage		
Spring wheat		4 leaf
Winter wheat	4 tiller	--
Catchweed bedstraw	4 node	--
Common lambsquarters	--	4 to 6 leaf

At Culdesac, all treatments injured winter wheat 0 to 12% but did not differ among treatments at 32 days after treatment (DAT) (Table 2). All treatments controlled catchweed bedstraw 84 to 98% at 18 DAT. By 32 DAT, Quelex treatments and PerfectMatch controlled catchweed bedstraw 94 to 99%.

Table 2. Catchweed bedstraw control in winter wheat with Quelex near Culdesac, ID in 2017.

		Wheat injury	Catchweed bedstraw control	
Treatment	Rate	32 DAT	18 DAT	32 DAT
	lb ai/A	%	%	%
Quelex +	0.0096			
PowerFlex	0.0163	12	92	96
Quelex +	0.0096			
PowerFlex +	0.0163			
WideMatch	0.188	0	97	99
Quelex +	0.0096			
PowerFlex +	0.0163			
2,4-D ester	0.344	1	95	94
Quelex +	0.0096			
PowerFlex +	0.0163			
Talinor	0.19	6	98	98
PowerFlex +	0.0163			
Huskie	0.217	5	84	90
Osprey +	0.0134			
WideMatch	0.188	11	95	90
PerfectMatch				
	0.252	9	96	98
LSD (0.05)		NS	NS	5

At Moscow, Quelex plus PerfectMatch injured spring wheat 5% (Table 3). By 12 DAT, spring wheat was not injured visually by any treatment (data not shown). All treatments, except Quelex alone, controlled common lambsquarters 80% or better at 12 DAT. By 46 DAT, all treatments controlled common lambsquarters 95 to 99%.

Table 3. Common lambsquarters control in spring wheat with Quelex near Moscow, ID in 2017.

		Wheat	Common lambsquarters control	
Treatment	Rate	injury	12 DAT	46 DAT
	lb ai/A	%	%	%
Quelex	0.0096	0	66	95
Quelex +	0.0096			
Widematch	0.188	1	85	99
Quelex +	0.0096			
Widematch	0.25	1	94	99
Quelex +	0.0096			
2,4-D ester	0.0163	1	92	98
Quelex +	0.0096			
MCPA ester	0.0163	0	86	99
Quelex +	0.0096			
Curtail M	0.69	0	94	99
Quelex +	0.0096			
PerfectMatch	0.201	5	80	99
Quelex +	0.0096			
Huskie	0.217	1	99	99
Quelex +	0.0096			
Bromac Advanced	0.5	2	99	99
LSD (0.05)		2	11	NS

Cereal Rust Management and Research in 2017

X.M. CHEN[1,2], K.C. EVANS[1], M.N. WANG[2], J. SPROTT[1], Y.M. LIU[3], C.J. XIA[2], Y. LIU[2], AND L. LIU[2]
[1]USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT; [2]DEPT. OF PLANT PATHOLOGY, WSU; [3]DEPT. OF CROP AND SOIL SCIENCES, WSU

In 2017, wheat stripe rust started early and developed to a severe epidemic in the Pacific Northwest (PNW). Yield losses up to 75% were observed on susceptible checks and 0-49% (average 14%) on commercial varieties of winter wheat; and up to 48% on susceptible checks and 0-22% (average 7%) on commercial varieties of spring wheat in our experiment fields without fungicide application. The severe stripe rust epidemic was accurately forecasted using prediction models in March and monitored in fields throughout the crop season. Rust updates and advises were provided on time to growers for implementing appropriate disease management based on the forecasts and field surveys. The timely application of fungicides kept stripe rust under control, which saved 19 million bushels of wheat grain, about 95 million dollars at the cost of about 25 million dollars in Washington State alone. Nationally, wheat stripe rust occurred through all wheat-growing regions, similar to 2016, but damage was less due to the dry conditions in the central Great Plains. Barley stripe rust occurred at low levels. Wheat leaf rust occurred in western, but not in eastern Washington. Barley leaf rust occurred in western Washington and for the first time appeared in eastern PNW along the Oregon and Washington border. Stem rust of wheat and barley was absent in Washington. From stripe rust samples collected throughout the country, we identified 62 races (29 new) of the wheat stripe rust pathogen and 14 races (4 new) of the barley stripe rust pathogen. In Washington alone, 35 races (14 new) of the wheat stripe rust pathogen and 11 races (4 new) of the barley stripe rust pathogen were identified. Using the advanced sequencing technology, we obtained near-complete genome sequences for both wheat and barley stripe rust pathogens and identified genomic basis for the host adaptations of the different stripe rust forms. We developed more than 700 molecular markers based on secreted protein genes and used them to study virulence genes of the stripe rust pathogen. We evaluated more than 35,000 wheat and 3,000 barley 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 related programs. Using our stripe rust data, we collaborated with breeders in pre-releasing, releasing, and registering eleven wheat and two barley varieties. We mapped 10 genes for stripe rust resistance in two wheat lines and identified molecular markers for all mapped genes. We developed wheat lines with pyramided *Yr15* and *Yr64* resistance genes on the short arm of chromosome 1B, which should be useful in breeding for wheat varieties with high level, durable resistance to stripe rust. We advanced 40 winter wheat by winter wheat crosses to the F_4 generation for identifying and mapping new stripe rust resistance genes. We tested 23 fungicide treatments in fields for control of stripe rust; and 24 winter and 24 spring wheat varieties for their yield loss and fungicide response. In 2017, we published 27 journal articles and the first book (titled *Stripe Rust*) summarizing research and management of stripe rust over past 100 years. The results and resources from our research have been used to develop stripe rust resistant varieties, registering new fungicides, and guiding the management of stripe rust.

Seed Retention of Major Grass Weed Species at Harvest in the PNW

Judit Barroso and Carolina San Martin
Oregon State University

Global wheat production is threatened by the escalating selection of herbicide resistant weed populations. The continuing evolution of herbicide resistance in major crop weeds is a driving force to develop new weed control strategies in field crops such as harvest weed seed control (HWSC). The potential of HWSC practices is dependent on having a significant proportion of total weed seed retained at crop maturity. The objective of this study was to evaluate seed production, height, and retention at harvest of important weed species in wheat-production systems of the semi-arid region of PNW such as, downy brome (*Bromus tectorum* L.), feral rye (*Secale cereale* L.), and rattail fescue (*Vulpia myuros* L.) (Fig. 1). Seed production, height, and retention were evaluated before and during harvest season in 2016 and 2017 in several locations. In general, seed shedding patterns followed a negative exponential model ($Y = Y_0 * e^{-bX}$) better than a linear model. Once the seeds were mature, a larger amount of seeds was shed early in the harvest season than later. However, the percentage of seed retained at harvest (parameter Y_0) and the rate of seed shedding (parameter b) depended on the weed species, year, and site. On average, the rate of seed shedding was similar for downy brome and rattail fescue and a little bit slower for feral rye. The percentage of seed retention at the beginning of harvest season was lower in 2016 (59% on average) than in 2017 (77% on average) for the three species.

Figure 1. Picture of the inflorescence for downy brome (panicle) (left), feral rye (spike) (middle), and rattail fescue (spike-like panicle) (right).

Efficacy of Biological Control Against Sugar Beet Wireworms is Affected by Soil Type

POORIA ENSAFI[1], DAVID CROWDER[2], AARON ESSER[3], JULIET MARSHALL[1], AND ARASH RASHED[1]
[1]DEPT. OF ENTOMOLOGY, PLANT PATHOLOGY AND NEMATOLOGY, UI ABERDEEN; [2]DEPT. OF ENTOMOLOGY, WSU; [3]WSU EXTENSION

Wireworms, the larval stage of click beetles (Coleoptera: Elateridae), are a threat to both dryland and irrigated cereal production in the Pacific Northwest region of the USA. Neonicotinoid seed treatments, the only class of insecticides registered for application in cereals, have failed to provide acceptable levels of protection against wireworms. Therefore, there is a need for evaluating and developing alternative control options that would lead to a relatively more sustainable management of wireworms. Wireworms are continuously exposed to a wide range of underground organisms that are pathogenic to insects (i.e., entomopathogenic orgasnisms). Identifying these natural enemies and determining their efficacy against wireworms would be important steps toward developing a biological control approach. In a greenhouse study, we evaluated the effectiveness of two commercially available entomopathogenic organisms, the nematode *Steinernema carpocapsae* (Fig. 1) and the fungus *Metarhizium anisopliae* (Fig. 2) in protecting wheat plants against wireworms. We also examined whether the addition of diatomaceous earth (DE) would improve the effectiveness of our biocontrol treatments. All evaluations were conducted in sand-dominated and peatmoss-dominated soil media. Treatments containing the entomopathogenic fungus resulted in the highest rates of wireworm mortality, indicating that the fungus may be more effective than the nematode at reducing population. However, results were impacted by soil media. In sand-dominated medium, treatments containing the entomopathogenic nematodes were more effective in reducing feeding damage than treatments containing the fungus. However, in peatmoss-dominated medium, treatments with the entomopathogenic fungus provided relatively better seedling protection. No consistent effect of diatomaceous earth was detected. Our results suggest that the effectiveness of wireworm biological control agents depends on soil media, such that the application of biological control against wireworms must be made with a knowledge of field soil type.

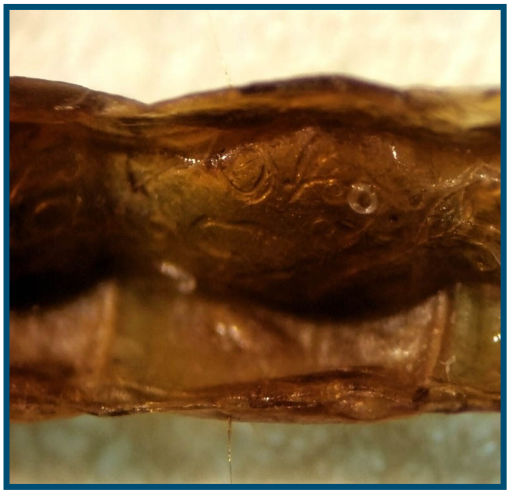


Figure 1. A sugar beet wireworm infested with the entomopathogenic nematodes, *Steinernema carpocapsae*.

Figure 2. A sugar beet wireworm infested with the entomopathogenic fungus, *Metarhizium anisopliae*.

Insects in Fall-Seeded Legumes

JAKE HENNESSEY, SANFORD EIGENBRODE, AND YING WU
DEPT. OF ENTOMOLOGY, PLANT PATHOLOGY, AND NEMATOLOGY, UI

In the inland Pacific Northwest, dry pea is often used as a rotational crop with winter wheat to break disease cycles, improve soil water content and fix nitrogen. The planting of dry peas and other legumes are restricted to higher rainfall regions, but due to genetic advances and changing climates, fall-sown dry peas are expanding across acreage in the

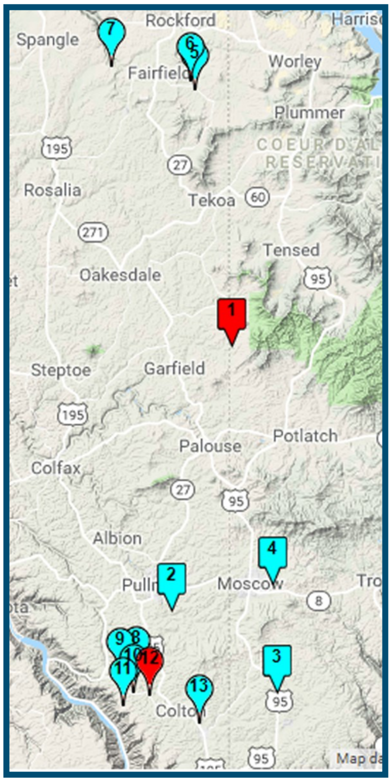


Figure 1. Map showing the sites where fall-planted pea (square markers) and spring planted pea (round markers) were monitored for insects and virus during the 2017 growing season.

region. Fall-sown peas offer much higher yield potential along with other advantages compared to spring-sown pea. Successful management of fall-sown peas will require the study of agronomic and plant protection issues. Spring peas are subject to yield loss from the pressure of multiple insect pests, including the pea leaf weevil (*Sitona lineatus*), pea weevil (*Bruchus pisorum*), and the pea aphid (*Acyrthosiphon pisum*). The earlier maturation of fall-sown peas could change their vulnerability to these insect pests. Starting in the fall of 2016, we have assessed the abundance and injury caused by insect pests and the prevalence of aphid-transmitted viruses in experimental and commercial plantings of fall-sown pea and spring-sown pea. Aphids were trapped after emergence of the crop at locations shown on the map below (Fig. 1). The number of aphids trapped each week (Fig. 2) and the percentage of aphids trapped that week that was carrying virus (Fig. 3) were compared between fall-sown and spring-sown peas. Although the total seasonal number of aphids trapped in fall-sown and spring-sown peas did not differ, the peak abundance occurred earlier in spring-sown pea (Fig. 2). The total percentage of infectious aphids was similar for both planting regimes, but it is noteworthy that pea aphids arriving early in the spring, prior to emergence of spring pea, are already arriving carrying virus, which could be a concern for virus management.

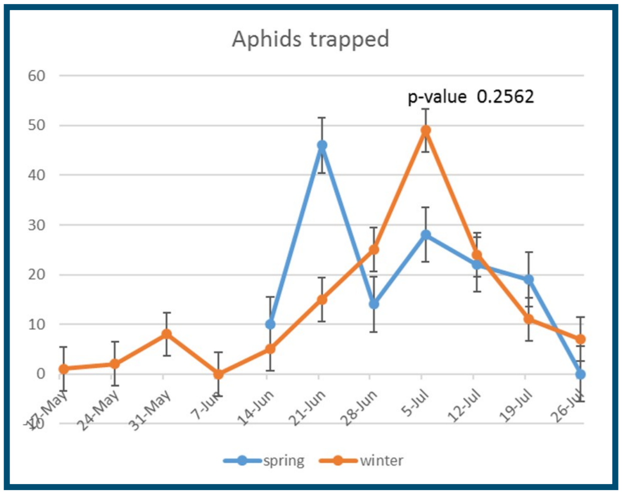


Figure 2. The total number of aphids trapped each week during the spring and summer of the 2017 growing season. Total aphids trapped through the season did not differ between fall and spring planted fields (p = 0.2562). Peak aphid trap density occurred two weeks earlier in spring planted pea.

In the fall of 2016 and 2017, few aphids were trapped after the emergence of fall-sown peas. None of these aphids was carrying virus, but *Pea enation mosaic virus* (PEMV) and *Bean leaf roll virus* were detected in tissue samples from the pea crop collected from both years in the fall. This indicates that fall-planted peas can be infected prior to overwintering. Impacts of these infections on pea yield are therefore being measured this year to inform virus management. We have two field trials currently in operation in which we have manually infected plants with viruses using viruliferous aphids at three dates after plant emergence in the fall and at three subsequent dates after green-up in the spring. Yield parameters will be measured to see if the timing of infection at a plant's growth stage will have an effect on its productivity.

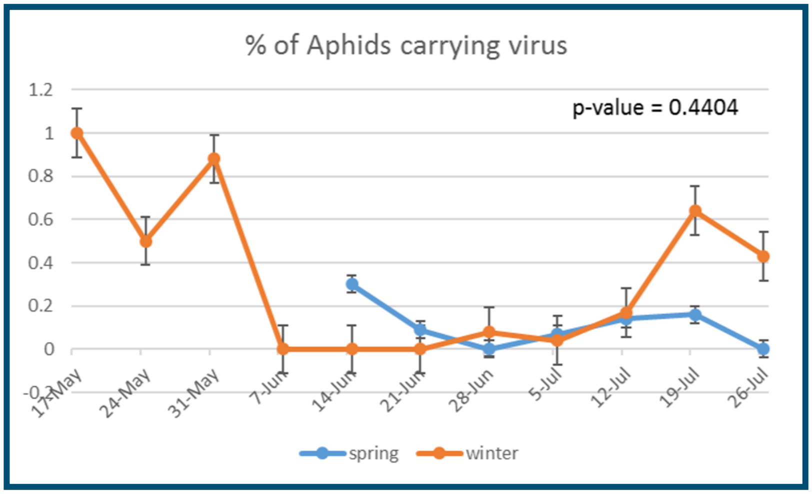


Figure 3. The percentage of aphids trapped each week that were carrying virus. Although a significant difference was found for virus prevalence in aphids trapped in fall-sown and spring sown pea (p = 0.4404), aphids arriving before spring pea emergence were already carrying virus.

Photo by OSU EESC

Photo Credits

Front Cover #1 —Drew Leggett
#2 —Lynn Ketchum
#3 —Wilson Craine

Back Cover #1 —Doug Finkelnburg
#2 —Lynn Ketchum
#3 —Karen Sowers

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. Dept. of Agriculture, and the Dept. of Crop and Soil Sciences. Extension programs and employment are available to all without discrimination.

159821.5.18