2016
Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS

1

2

3

University of Idaho

Oregon State University OSU

Washington State University

Editors:

WASHINGTON STATE UNIVERSITY
Samantha Crow
Bill Schillinger

UNIVERSITY OF IDAHO
Dianne Daley Laursen
Amy Pendegraft
Kurt Schroeder
Doug Finkelnberg

OREGON STATE UNIVERSITY
Mary Corp
Susan Philips
Kathleen Dumont

Welcome to our 2016 Field Days!

2016 Dryland Field Day Abstracts: Highlights of Research Progress

---

WASHINGTON STATE UNIVERSITY,
DEPARTMENT OF CROP AND SOIL SCIENCES
TECHNICAL REPORT 16-1

OREGON STATE UNIVERSITY,
DEPARTMENT OF CROP AND SOIL SCIENCE
TECHNICAL REPORT OSU-FDR-2016

UNIVERSITY OF IDAHO,
IDAHO AGRICULTURAL EXPERIMENT STATION
RESEARCH BULLETIN 189

Field Days:
OSU Pendleton Field Day—Pendleton, OR, June 14, 2016
OSU Moro Field Day—Moro, OR, June 15, 2016
WSU Dryland Research Station Field Day—Lind, WA, June 16, 2016
WSU Cook Farm Field Day—Pullman, WA, June 22, 2016
WSU Wilke Farm Field Day—Davenport, WA, June 23, 2016
UI Limagrain/Parker Farm Field Day—Moscow, ID, July 6, 2016

Climate Science Farmers Can Use

SANFORD EIGENBRODE[1] AND DIANNE DALEY LAURSEN[2]
[1]REACCH PROJECT DIRECTOR; [2]REACCH PROJECT MANAGER

Farmers are the world's original integrators. Successful modern farming requires a good understanding of bio-geophysical, social and economic systems. Changes in weather trends and variability (climate change) add more complexity into agricultural systems and efforts towards sustainable management. Interest in climate change and the importance of being able to communicate it to land owners is increasing. REACCH has made progress in identifying and addressing research questions, knowledge gaps, adaptation and mitigation strategies and developing tools for producers in our region.

Thank you for visiting the AgBiz Logic™ web site. This site is an economic, financial and environmental accounting decision tool to assist agribusinesses that grow, harvest, package, add-value, and sell agricultural products.

Follow up to 2012 Survey of Inland Pacific Northwest Wheat Producers

The Inland Pacific Northwest region of Idaho, Oregon and Washington is agriculturally one of the most productive places in the world. This follow-up survey will assess how social, economic, and climatic factors affect your on-farm decisions as part of a larger study funded by the USDA

1. So we can use the survey results in conjunction with other project results, please provide the zip code of the largest parcel you currently farm (for the 2015 production season).

_______________ zip code of largest parcel I farm

2. How many acres of wheat did you farm for the 2015 production season? Please choose only one option.

_______________ zip code of largest parcel I farm

NOTE If you do not farm wheat, please stop here and return the survey in the envelope provided. Thank you!

Photo credit: Brad Stokes

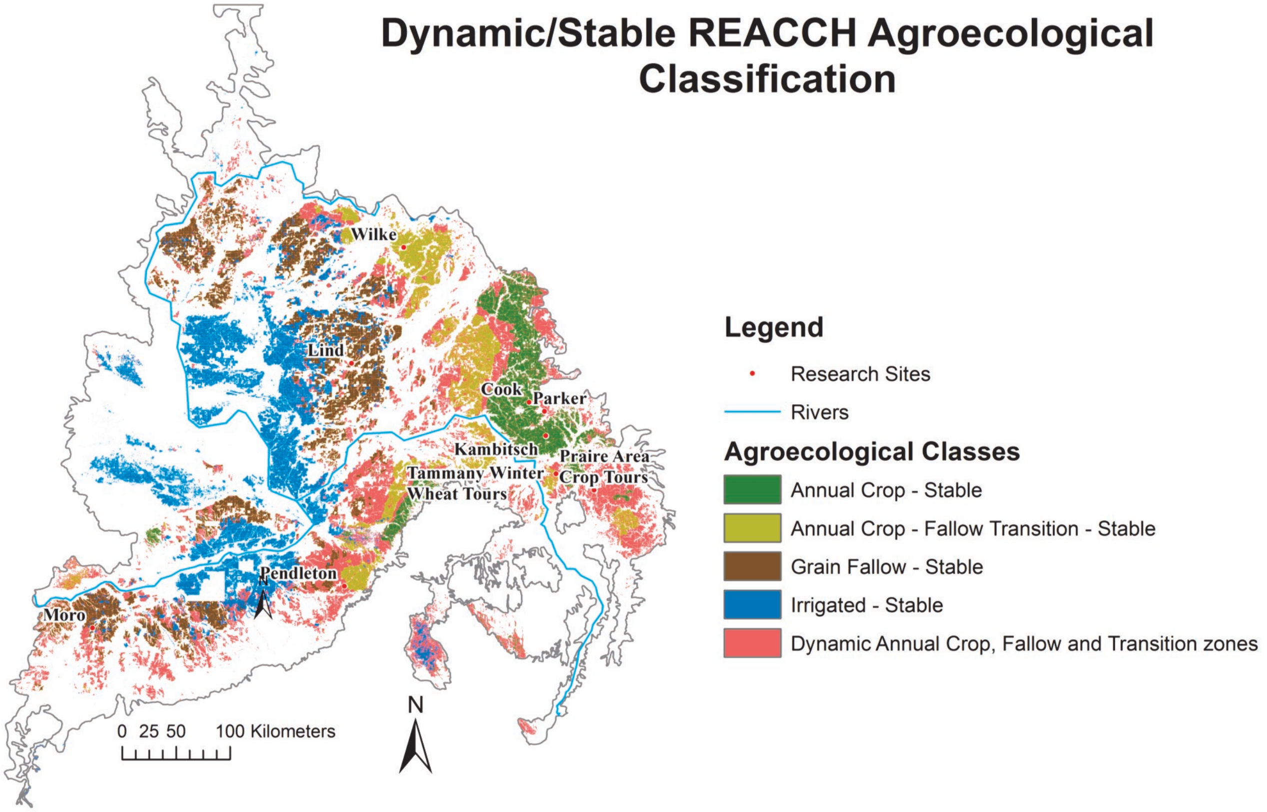
REACCH has worked to increase integrated understanding of a variety of factors that influence agricultural systems, including cropping systems, biotics, socioeconomics, climate modeling, technological advances, and to make the information relevant and accessible to regional cereal farmers and policymakers. In addition to our research and extension teams, our education team trains future scientists, undergraduate through post-doctoral fellows, and delivers K-12 curriculum on agriculture and climate science.

Regional Approaches to Climate Change for Pacific Northwest Agriculture (**REACCH**) was initiated in 2011, and is currently in its sixth and final year. The REACCH project considers wheat production holistically across disciplines integrating research, extension and education. The project was designed to enhance the sustainability of cereal production systems in the Inland Pacific Northwest under ongoing and projected climate change, while contributing to climate change mitigation by reducing emissions of greenhouse gases. Some of the most productive wheat land in the world can be found in the REACCH region of northern Idaho, north-central Oregon and eastern Washington. REACCH is a comprehensive response to the implications of climate change for the already challenging task of managing cereal production systems for long-term profitability.

Changing climates will affect all components of Pacific Northwest agricultural production systems, including technology, management practices, biological, economic and social aspects. Achieving adaptation to changing climate and mitigation of activities that can affect climate and benefit producers requires coordinated efforts in research, education and extension. In Figure 1 below, Agroecological Classes (AECs) attempt to delineate relatively homogenous areas where constraints and capabilities result in common production systems. The map indicates land use changes (in pink), influenced by a variety of biophysical and socioeconomic factors, which are highly relevant to climate science agricultural sustainability.

REACCH is a joint project of University of Idaho, Oregon State University, Washington State University and the USDA Agricultural Research Service (ARS). We are always interested in hearing your questions, concerns and ideas. Look for our Conservation Agriculture Handbook, mobile applications tools, high school and elementary school curriculums and technical reports in the months ahead. We strive to help you build capacity for increased climate resiliency into the future by building tools to identify and predict climate change impacts. As one regional producer reflected, "Just think about all of the farmers in the '30s Dust Bowl, if they had had a project like REACCH going on in the '20s preparing them for what was going to happen. Now we just have so much more technology on our side to do that for us. That is greatest value of the REACCH grant."

More information about the REACCH project may be found at https://www.reacchpna.org/.



Agroecological classification (AEC) for REACCH study region, where stable cells (30 m) had the same AEC for 8 years and dynamic had same AEC for 4, 5, 6, 7 years during the period (2007-2014).

Table of Contents

Part 1. Oilseeds and Other Alternative Crops

Part 2. Pathology, Weeds, and Insects

Part 3. Breeding, Genetic Improvement, and Variety Evaluation

Part 4. Agronomy and Soils

Part 5. Farm Economics

Regional Approaches to Climate Change (REACCH) material in this publication is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2011-68002-30191.

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), and USDA NIFA Award no. 2011-68002-30191 (REACCH).

Washington State University
Cooperative Personnel and Area of Activity

Kirk Schulz	President-elect, Washington State University
Daniel J. Bernardo	Interim President, Washington State University
Ron C. Mittelhammer	Interim Co-Provost
Erica Austin	Interim Co-Provost
Kimberlee K. Kidwell	Acting Dean of the College of Agricultural, Human, and Natural Resource Sciences
Richard T. Koenig	Interim Chair, Department of Crop & Soil Sciences, Associate Dean, and Director, WSU Extension
James W. Moyer	Associate Dean for Research and Director, Agricultural Research Center

Agricultural Economics

K. Painter	509-432-5755	kpainter@uidaho.edu
D.L. Young	509-335-1400	dlyoung@wsu.edu

Agronomy, Conservation Systems, Soil Fertility, and Biofuels

D. Brown	509-335-1859	dave.brown@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
W.L. Pan	509-335-3611	wlpan@wsu.edu
T. Maaz	509-335-3475	tai.mcclellan@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
B. Sharratt, USDA	509-335-2724	brenton.sharratt@ars.usda.gov
H. Tao	509-335-4389	haiying.tao@wsu.edu

D. Appel, B. Barry, D. Bikfasy, R. Bolton, J. Braden, J. DeMacon, S. Higgins, C. Hoffman, J. Jacobsen, I. Madsen, J. Morse, L. Port, M. Reese, R, Rupp, S. Schofstoll, R. Sloot

Breeding, Variety Testing, and Culture of Legumes

Dry Peas, Lentils, Chickpeas

S.O. Guy	509-335-5831	sguy@wsu.edu
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,

Dry Beans

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

Cereal Breeding, Genetics, and Physiology

Wheat Breeding & Genetics

K.G. Campbell, USDA	509-335-0582	kgcamp@wsu.edu
A.H. Carter	509-335-6198	ahcarter@wsu.edu
K.S. Gill	509-335-4666	ksgill@wsu.edu
S. Hulbert	509-335-3722	scot_hulbert@wsu.edu
S.S. Jones	360-416-5210	joness@wsu.edu
C.F. Morris, USDA	509-335-4062	morrisc@wsu.edu
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, P. DeMacon, V.L. DeMacon, T. Harris, E. Klarquist, J. Kuehner, W. Nyongesa, P. Reisenauer, S. Rynearson, G.B. Shelton, R. Sloot, N. Wen

Barley Breeding & Genetics

K. Murphy	509-335-9692	kmurphy2@wsu.edu
S. Rustgi	509-335-3036	rustgi@wsu.edu

N. Ankrah, J. Matanguihan, X. Ou, P. Reisenauer, Y. Sun, 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
R.F. Line, USDA	509-335-3755	rline@wsu.edu
H. Pappu	509-335-3752	hrp@wsu.edu
A.M. Wan	509-335-8715	awan@wsu.edu
M.N. Wang	509-335-1596	meinan_wang@wsu.edu

J.I. Coffey

Soil Microbiology

L. Carpenter-Boggs	509-335-1533	lcboggs@wsu.edu
A.C. Kennedy, USDA	509-335-1554	akennedy@wsu.edu
T. Sullivan	509-335-4837	t.sullivan@wsu.edu

J. DeAvila, J.C. Hansen, S. Higgins

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

R. Boydston, USDA	509-786-9267	rick.boydston@ars.usda.gov
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
F.L. Young	509-335-4196	youngfl@wsu.edu

C. Libbey, L. McGrew, L. Molsee, J. Nelson, H. Wetzel

Wheat Quality and Variety Evaluation

Wheat Quality

C.F. Morris, USDA	509-335-4062	morrisc@wsu.edu

M.L. Baldridge, J. Boehm, P.K. Boyer, D.A. Engle, E.P. Fuerst, Ibba, G.L. Jacobson, K. Jernigan, D. Jiwan, W.J. Kelley, J. Kinkaid, A.M. Kiszonas, M.J. Lenssen, J. Luna, J. Murray, L. Pierantoni, E. Stout, S. Sykes, S. Vogl, E. Wegner, G. Wu

WSU Extension Cereal Variety Testing

R. Higginbotham	509-335-1205	rhigginbotham@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		
M. Dymkoski	509-335-3475	mike.dymkoski@wsu.edu
WSU Spillman Farm and WSU Cook Farm		
M. Dymkoski	509-335-3475	mike.dymkoski@wsu.edu
WSU/USDA-ARS Palouse Conservation Field Station		
M. Dymkoski	509-335-3475	mike.dymkoski@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	Interim Associate Dean of Research & Interim Director of Idaho Agricultural Experiment Station
Barbara Petty	Interim Associate Dean & Director of Extension
Paul McDaniel	Department Head Plant, Soil, and Entomological Sciences

Agronomy and Cropping Systems

J. Brown	208-885-7078	jbrown@uidaho.edu
X. Liang	208-397-7000 x110	xliang@uidaho.edu
A. Moore	208-736-3629	amberm@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
S. Singh	208-423-6609	singh@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

J. Davis, M. Wingerson, S. Pristupa, D. White, R. Roemer, C. Centeno, J. Hatch, C. Lowder, L. Schroeder, R. Portenier, K. Belmont, J. McClintick

Cereal Breeding, Physiology, and Variety Testing

J. Chen	208-397-4162 x229	jchen@uidaho.edu
D. Fu		dlfu@uidaho.edu
J. Kuhl	208-885-7123	jkuhl@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

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

Crop Diseases

N. Bosque-Perez	208-885-7544	nbosque@uidaho.edu
A. Karasev	208-885-2350	akarasev@uidaho.edu
K. Kinzer	208-529-8376	kkinzer@uidaho.edu
G. Knudsen	208-885-7933	gknudsen@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

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

Integrated Pest Management

J. Barbour	208-722-6701 x250	jbarbour@uidaho.edu
E. Bechinski	208-885-5972	edb@uidaho.edu
L-M. Dandurand	208-885-6080	lmd@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. Schwarzlaender	208-885-9319	markschw@uidaho.edu
E. Wenninger	208-423-6677	erik@uidaho.edu

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

Soil Fertility and Management

J. Hammel	208-885-2135	jhammel@uidaho.edu
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
A. Moore	208-736-3629	amberm@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

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

Weed Management

J. Campbell	208-885-7730	jcampbell@uidaho.edu
P. Hutchinson	208-397-7000 x109	phutch@uidaho.edu
D. Morishita	208-423-6616	don@uidaho.edu
T. Prather	208-885-9246	tprather@uidaho.edu
M. Schwarzlaener	208-885-9319	markschw@uidaho.edu

T. Rauch, B. Beutler, K. Frandsen, T. Keeth, L. Lass, B. Harmon

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

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 Sciences
Mary Corp	CBARC Director

Agronomy

V. Jeliazkov	541-737-5877	valtcho.jeliazkov@oregonstate.edu
S. Machado	541-278-4416	stephen.machado@oregonstate.edu

R. Awale, E. Jeliazkova, L. Pritchett, K. Rhinhart

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 Agents

M. Flowers	541-737-1589	mike.flowers@oregonstate.edu
L. Lutcher	541-676-9642	larry.lutcher@oregonstate.edu
J. Maley	541-384-2271	jordan.maley@oregonstate.edu
S. Macnab	541-565-3230	sandy.macnab@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. Mundt	541-737-5256	mundtc@science.oregonstate.edu
R. Smiley	541-278-4397	richard.smiley@oregonstate.edu

Weed Management

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

J. Gourlie

Part 1. Oilseeds and Other Alternative Crops

Expanding Camelina Adaption and Marketability by Breeding

SCOT HULBERT[1,2] AND IAN BURKE[2]
[1]DEPT. OF PLANT PATHOLOGY, WSU; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Camelina has potential as a rotation crop in dryland farming areas of the Pacific Northwest. Several genetic traits have been identified that either make the crop more adaptable to our wheat-based cropping systems or expand its marketing potential. One problem with currently available varieties is the extreme sensitivity to sulfonylurea and imidazolinone herbicides, which prevents their use in crop rotations using these chemistries, especially in rotations with Clearfield wheat varieties. We used a mutagenesis approach to identify lines with reduced sensitivity to these herbicides. One line carried a mutation that provided resistance to residual levels of both types of herbicides (Walsh et al. 2012). Lines carrying the gene showed no herbicide injury when planted into soils where the herbicide Beyond was applied at four times the recommended rate the previous season. The mutation has been bred into a high yielding, high oil background and is being amplified for release in 2016.

A second breeding objective is a variety that will be more widely accepted for edible oil purposes. Although this market is already expanding, camelina oil has not been approved by the FDA partly due to the erucic acid content. Current camelina varieties have erucic acid contents of approximately 3% while canola and other oils are less than 1%. Our cooperator at Montana State University, Dr. Chaofu Lu, has identified a mutation causing low (~0.5%) erucic acid. This trait is being bred into our highest performing lines for release as a low-erucic, herbicide tolerant variety for cooking/salad oil.

Variation in seed size in different Camelina breeding lines.

A third focus of the breeding program is larger seed size for better emergence and stand establishment. Camelina's small seed requires a very shallow seed depth at planting which can make stand establishment difficult under dryland conditions. We have begun a recurrent selection program for large seeds after crossing our advanced lines to the largest seeded camelina germplasm available. The objective is to determine if it is possible to make larger seeded varieties that have similar or better yields and oil contents.

Walsh, D.T., E.M. Babiker, I.C. Burke, and S.H. Hulbert. 2012. Camelina Mutants Resistant to Acetolactate Synthase Inhibitor Herbicides. Molecular Breeding: Volume 30:1053-1063

Canola-Wheat Integration in the Inland Pacific Northwestern U.S.

WILLIAM L. PAN[1], FRANK L YOUNG[2], TAI M. MAAZ[1], AND DAVID R. HUGGINS[2]
[1]DEPT OF CROP & SOIL SCIENCES, WSU; [2]USDA-ARS

The inland Pacific Northwestern U.S. (iPNW) has a diversity of environments and soils, but lacks crop diversity, and is one of the few global wheat growing regions without significant oilseeds in rotation. Although major interest in regional energy crops and rotational diversification spurred feasibility research on iPNW canola food, feed and fuel production as far back as the 1970s, canola adaptation has lagged behind other semi-arid wheat regions for various socioeconomic, ecophysiological and agronomic reasons. Global dietary changes, biofuel demand, genetic advances and public/private investments in regional processing facilities have increased iPNW canola acreage from 7,000 in 2011 to 31,000-43,000 over the past two years.

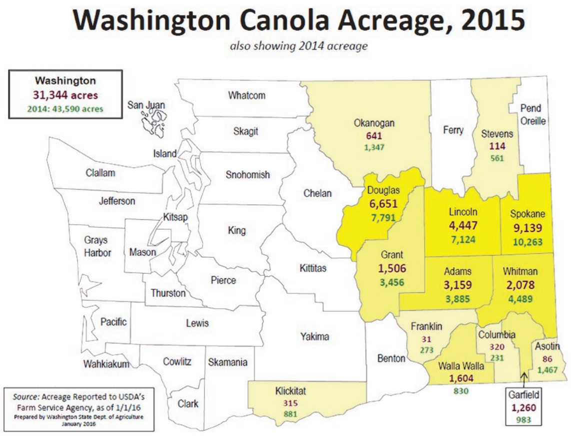


Figure 1. Courtesy of M.B. Lang, WSDA

While canola management largely relies on wheat farm equipment, agronomic approaches require strategic adjustments to account for physiological differences between canola and cereals including seed size, seedling morphology and responses to temperature extremes. Climate change predictions for the region threaten to exacerbate current hot and dry summers and research aims to develop and adapt flexible winter and spring canola-based systems to regional water and temperature stressors in each zone. The iPNW is challenged with having the lowest annual precipitation percentage (20 to 40%) during the growing season of any of the major semi-arid canola producing global regions. The WA Oilseed Cropping Systems Project, funded by the WA State legislature, is conducting research on planting, fertilization, pest control strategies, variety performance, and cropping systems to successfully establish improved winter canola integration in the dry zones and spring canola in the wet zones.

The adaptation of winter and spring canola will somewhat mirror the rotational placement of winter and spring cereals within each zone, with some spring canola potentially replacing fallow during wet years in the intermediate rainfall, flex crop zone. Economic analysis of oilseed break crop benefits such as weed and disease control will help to demonstrate the medium-term economic benefits of crop diversification to support the growth of a regional canola industry in the iPNW. Projected acreage required to match existing Washington processing capacity is around 700,000 acres, far below the 1:1 wheat to canola production levels being approached in the western Canadian Prairies.

Pan, W.L., F.L. Young, T.M. Maaz, and D.R. Huggins. 2016. Canola Integration into Semi-Arid Wheat Cropping Systems of the Inland Pacific Northwestern U.S. An invited submission to a special issue in Journal of Crop and Pasture Science. Accepted for publication.

Improving Economics and Sustainability of Winter Wheat/Fallow Rotation with Oilseed Crops

VALTCHO D. JELIAZKOV (ZHELJAZKOV)
DEPT. OF CROP AND SOIL SCIENCE, OSU

Dryland winter wheat production in large areas of the Palouse region is under a wheat-fallow rotation cropping system. In this system wheat is grown once in a 2 year period; 10 months of fall sown wheat and 14 months in fallow to conserve moisture and store winter precipitation necessary for the wheat crop during the next season. The system could potentially be improved by adding an additional cash crop and converting a 2-year rotation into a 3-year rotation: winter wheat/cash crop/fallow. For growers to use a 3-year rotation, the cash crop would need to provide equal or greater value than 33% of the wheat crop. Some oilseed crops for biodiesel production show promise as cash crops in this 3-year rotation, but there has been no side by side comparison of novel biodiesel crops alongside more traditional ones.

This field trial will provide a side by side comparison of traditional and novel oilseed biodiesel crops in eastern Oregon's semiarid climate. The objective of the project is to evaluate the agronomic, environmental and economic feasibility of growing, processing and co-product utilization of thirteen crops (canola, oriental mustard, camelina, safflower, sunflower, flax, coriander, caraway, cumin, anise, dill, and fennel) following winter wheat. The overall economics of the 3-year rotation winter wheat/oilseed crop/fallow will be assessed. The field trial was established in 2015 at two locations: the Columbia Basin Agricultural Research Center at Pendleton and at Moro, OR. Due to lower precipitation and unsatisfactory results in Moro, the field trial in 2016 and 2017 will be conducted at Pendleton only. Data collected over three growing seasons will provide information about the production costs and returns as well as the agronomic feasibility of the selected crops for Oregon and the surrounding states.

Characterizing Nitrous Oxide Emissions Over a Canola Crop in the Inland Pacific Northwest Using Automated Static Chambers and the Flux Gradient Technique

Sarah Waldo[1], Patrick O'Keeffe[1], Shelley Pressley[1], Brian Lamb[1], Kirill Kostyanovsky[2], David Huggins[3], and Claudio Stockle[4]
[1]Dept. of Civil and Environmental Engineering, WSU; [2]Dept. of Crop and Soil Sciences, WSU; [3]USDA-ARS; [4]Dept. of Biological and Agricultural Engineering, UI

The addition of fertilizer nitrogen (N) makes agricultural soils the main anthropogenic source of N_2O, a greenhouse gas and ozone-depleting substance. Furthermore, gaseous losses of N from the field (in the form of both N_2O and N_2) constitute an economic loss for the grower: less N is available for the crop, reducing nitrogen use efficiency. N_2O emissions are difficult to characterize at the local and regional levels because of their high degree of both spatial and temporal variability. In this study, we used both static chambers and the flux gradient technique to monitor N_2O emissions at two agricultural fields both growing canola in the inland Pacific Northwest of the US. One field was under no-tillage management and nitrogen fertilizer was applied at a rate of 87 kg N/ha (CAF-NT), while the other used conventional tillage and received 101 kg N/ha of fertilizer (CAF-CT). The chamber results indicated that total annual emissions were 2.7 ± 1.6 kg N_2O-N/ha from CAF-NT (and 4.4 ± 3.2 kg N_2O-N/ha from CAF-CT. The flux gradient results agreed with the chamber measurements at CAF-NT, but indicated much lower emissions at the CAF-CT site. The total emissions determined via the flux gradient method were 2.1 ± 0.4 and 1.7 ± 0.3 kg N_2O-N/ha from the CAF-NT and CT sites, respectively. Given typical relationships between N_2O and N_2 emissions, the total gaseous N losses (excluding other N species) from CAF-NT were 16% to 20% of the applied fertilizer N, and from CAF-CT accounted for 11% to 29% of the applied fertilizer N.

Spatial variability was investigated as a contributing factor to the discrepancies between methods, and it was found that the resolution of the spatial variability may explain the lack of agreement at CAF-CT. Despite the lack of agreement in the overall emissions estimates, the two methods captured similar patterns in emissions. Maximum emissions occurred following the first rainfall event after fertilization at both sites, and other rainfall events also spurred emissions. Higher temperatures were associated with higher emissions at both sites. Continued monitoring coupled with the use of models will be necessary to determine defensible field-scale and regional estimates of annual N_2O emissions from cropping systems in the inland PNW, and to investigate how changing climate will affect emissions.

Comparison of Rhizosphere Soil Microbial Communities for Winter Canola and Winter Wheat at Paired Field Sites

Jeremy Hansen[1], Tarah Sullivan[2], Bill Schillinger[2], and Ann Kennedy[1]
[1]USDA-ARS Northwest Sustainable Agroecosystems Research Unit; [2]Dept. of Crop and Soil Sciences, WSU

Canola as a rotation crop in the inland Pacific Northwest has expanded in recent years with the increased demand for canola-based products. Market prices, a major crushing facility at Warden, WA and reported rotational benefits have attributed to canola acreage expansion. Suppression of fungal root pathogens is one of the reported rotational benefits. Canola plants contain glucosinolates (GSLs), which upon cell rupture and during the decay of residue hydrolyze to produce isothiocyanates (ITCs). The production of ITCs is the mechanism responsible for what is referred to as the “biofumigation effect”. The biofumigation effect is largely considered positive; however, the non-selectivity of ITCs has potential to impact beneficial soil organisms. Canola root GSLs and ITCs often have greater concentration and toxicity in the root. Toxicity, and close proximity of ITCs to soil microorganisms, would potentially create changes in the rhizosphere soil microbial community. Preliminary data from a related field study near Reardan, WA (see article on page 19) suggest that winter canola may suppress mycorrhizal fungi associations of wheat following canola. The objective of this research is to determine the differences and similarities in the rhizosphere microbial communities of canola and wheat. To accomplish this, canola and wheat rhizosphere soil (Fig. 1) is being collected from six farms located in Adams and Douglas Counties. Each farm is a paired site with winter canola and winter wheat grown in adjacent fields having similar soil properties, landscape position, and crop history. Samples from the farms of Derek Schafer, Rob Dewald, and Curtis Hennings near Ritzville, WA and Doug Poole, Tom Poole, and Denver Black near Mansfield, WA have been collected. Rhizosphere microbial community composition will be determined using phospholipid fatty acid (PLFA) analysis, and polymerase chain reaction (PCR) based community profiling techniques focused on the bacterial (16S), and fungal (18S) rRNA regions. This study will determine the influence of canola on soil rhizosphere microorganisms, and deliver information to supplement the findings of the winter canola rotation benefit study at Reardan. Collectively, these studies will provide research-based information to growers, scientists, and industry personnel of the influence that brassica crops have on soil microbial communities.

Figure 1. Field collection of rhizosphere samples and separation of rhizosphere soil from roots for analysis. Rhizosphere soil is defined here as soil adhering to canola or wheat roots after extraction.

Exploring Early Planting Dates for Winter Canola to Improve Seedling Establishment

JIM B. DAVIS, MEGAN WINGERSON, AND JACK BROWN
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Drier than average summers and falls during the past 10 years have caused dryland winter canola growers to have difficulty establishing their crops due limited soil moisture during mid to late August. Since seed zone moisture is available earlier in the summer, winter canola could be planted earlier to achieve better crop establishment. To investigate this potential, we initiated a four-year time-of-planting trial in 2010. Sites throughout the inland Pacific Northwest were chosen to represent the wide variety of micro-climates found in the region and included Kalispell, MT, Moscow, ID, LaCrosse, WA, and Pendleton, OR. Three well adapted cultivars (Athena, Baldur and Amanda) were tested in mid to late June, mid to late July, and mid to late August. A variety trial with 40 entries was planted in mid-June for two years at Moscow and LaCrosse.

The results of the variety trial showed that some cultivars are not adapted to early planting and will bolt and flower before fall, which nearly always results in complete winter kill. Some cultivars don't flower but have some stem elongation, which raises the main growing point well above the ground and reduces winter hardiness. Other cultivars do not flower and have stems that remain compact when planted early, making them good candidates for this approach.

The yield of canola planted at different dates varied considerably from year to year, with no planting date showing a distinct advantage; although the July planting was the most consistent (Table 1). Low yields from August plantings were typically due to poor establishment. The low yields of the June and July plantings in 2014 appeared to be due to increased winter damage compared to the August planting. Winter damage reduced plant vigor and delayed flowering.

Table 1. *Winter Canola yields at different planting times in the Pacific Northwest.*

			Planting Time	
Year	**Sites**	**June**	**July**	**August**
		---------------- *lbs. per acre*		---------------
2011	Kalispell - Moscow - Pendleton	2,550 a[1]	2,433 a	1,983 b
2012	Kalispell - Moscow - Pendleton	3,114 ab	3,324 a	2,878 b
2013	Moscow - Pendleton - LaCrosse	2,041 b	2,313 a	767 c
2014	Moscow[2]	1,713 c	2,209 b	2,992 a
Mean		**2,604** a	**2,773** a	**2,083** b

[1] Means within rows with different letters are significantly ($p<0.05$) different.

[2] The LaCrosse site had severe winter damage to all planting dates.

Determining an optimum planting date has proven to be difficult, since the weather is somewhat different each year. Some years favor earlier planting, while others favor traditional planting times. We are exploring other management practices with early planted winter canola, such as mowing and grazing, to increase its reliability. Currently, our best recommendation is to monitor soil moisture levels, pay attention to weather forecasts, and plant as close to a traditional date as possible but before seed zone soil moisture is lost. This approach requires regular field monitoring and a flexible schedule for planting.

Twenty Years of Canola Variety Performance and Improvement in the Pacific Northwest

JACK BROWN, JIM B. DAVIS, AND MEGAN WINGERSON
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Researchers at the University of Idaho established the Pacific Northwest Spring and Winter Variety Trials in 1992 and 1993, respectively. Over the next 20 years, spring canola cultivar testing was conducted at an average of four sites in Idaho, three sites in Washington, and two sites in Oregon. Winter canola varieties were evaluated at an average of four sites in Idaho, two sites in Washington, and two sites in Oregon.

The trials contained cultivars and advanced breeding lines from the University of Idaho and commercial seed companies. After 20 years of trials, 266 cultivars from 25 companies and breeding programs have been tested in the spring trial, and 160 different cultivars from 20 companies and breeding programs have been tested in the winter trials. 'Westar' spring canola was included in all spring trials as a control, and 'Bridger' winter rapeseed was included in all winter trials as a control. These controls were used to determine what proportion of the observed yield improvement can be attributed to advances in crop genetics or to improved agronomics.

The winter rapeseed cultivar 'Bridger' had a yield increase from 2,601kg/ha to 3,070 kg/ha, a rate of 23 kg/ha per year (Fig. 1). The observed yield increase can be attributed to improvements in agronomic practices such as new pesticides and better fertility management. The yields of the best winter canola cultivars (top three each year) have increased from 3,400 kg/ha to over 4,400 kg/ha, an average increase of 52 kg/ha each year resulting from both agronomic and genetic improvements. Comparison of the genetic and non-genetic yield gains show that genetic improvements in winter canola were responsible for yield increases of 604 kg/ha (55% of the gain), while agronomics contributed 483 kg/ha (45% of the gain).

The yields of the best spring cultivars have also increased considerably, from 1,950 kg/ha to over 2,500 kg/ha (Fig. 2). The yield of 'Westar' spring canola increased from 1,665 kg/ha to 1,844 kg/ha due to improved agronomics. Comparing genetic with non-genetic yield gains, spring canola cultivars showed a yield improvement from genetics of 470 kg/ha (70% of the gain), while agronomic improvements accounted for an increase of 188 kg/ha (30% of the gain).

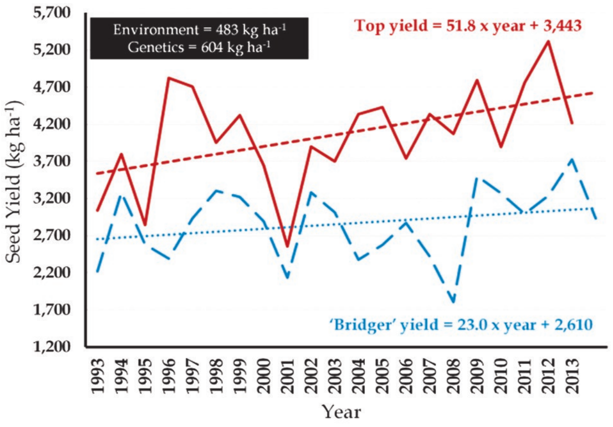


Figure 1. Yield increases in winter canola.

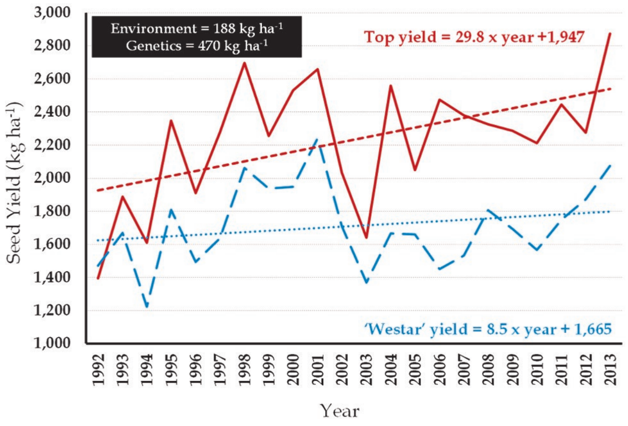


Figure 2. Yield increases in spring canola.

Two New Long-Term Winter Canola Cropping Systems Studies Established Near Ritzville, WA

BILL SCHILLINGER[1], RON JIRAVA[2], JOHN JACOBSEN[1], AND STEVE SCHOFSTOLL[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND; [2]GROWER COLLABORATOR, RITZVILLE, WA

Two long-term winter canola cropping systems studies were recently initiated at the Ron Jirava farm five miles west of Ritzville, WA. Annual precipitation at the site averages 11.5 inches. The soil is a deep Ritzville silt loam with uniform texture throughout the profile.

Study 1 commenced in September 2014 and includes four winter crop species. These crops are winter canola (WC), winter pea (WP), winter triticale (WT), and winter wheat (WW). There are two 4-year crop rotations involving no-till summer fallow (NTF) that are compared to the "check" treatment of 2-year WW-undercut tillage fallow (UTF). The experimental design is a randomized complete block with four replicates. Individual plot size is 32 x 100 feet. Each phase of all rotation sequences is present each year for a total of 40 individual plots covering 2.94 acres. Crop rotation treatments are: (1) WC-NTF-WT-NTF, (2) WP-NTF-WT-NTF, and (3) WW-TF. Winter canola is planted from late July to mid-September depending on surface soil moisture conditions in the NTF and predicted air temperatures for the ensuing week. If adequate seed-zone moisture for planting WC is not present, spring canola is planted in late March. Winter pea is planted deep into moisture (no N fertilizer) with a deep-furrow drill into NTF during the first week of September. In the first author's experience, emergence of WP from deep planting depths has never been a problem. Winter triticale is planted deep into NTF during the first week of September if seed-zone moisture is adequate. If moisture is not adequate, WT seed is "dusted in" to NTF in mid-October. Winter triticale yields are much higher than those of WW with late planting. With the use of NTF, the two 4-year rotation sequences hold promise as stable, profitable, and ecologically-friendly crop rotations for the low-precipitation zone.

Study 2 was initiated in September 2015 following the completion of the 6-year safflower experiment (see article on page 28). The previous 3-year WW-safflower-UTF rotation was replaced by a 3-year WC-spring wheat-UTF system. Individual plot size in this study is 30 x 500 feet. The study site contains 56 plots covering 20 acres and has been the focus of cropping systems research for the past 20 years. As seed-zone moisture is generally greater in UTF (Study 2) compared to NTF (Study 1), WC will be planted in late August, if possible. If planting of WC is not possible, spring canola will be planted in late March. Excellent WC stands were achieved during this first year from an August 25, 2015 planting into UTF (Fig. 1). Due to widespread cold damage to *Brassica napus* WC varieties in recent years we, collectively, decided to use a *Brassica rapa* WC variety in this study due to improved cold tolerance and despite reduced seed yield potential compared to *Brassica napus* types. Long time Ritzville area WC grower Curtis Hennings suggested and provided the variety "Largo" for this study (Fig. 1).

Figure 1. Stand of 'Largo' *Brassica rapa* winter canola on the Ron Jirava farm near Ritzville, WA. This crop was planted with a deep-furrow drill on August 25, 2015. Photos were taken on April 5, 2016. Note the flowers are already well initiated on this date.

Based on experience of regional WC growers, only phosphorus is applied at time of planting WC in both Study 1 and Study 2. Nitrogen and sulfur is stream jetted in a Solution 32 formulation with a sprayer in a split application during the fall and again in early spring.

Rotational Effects of Winter Canola on Subsequent Spring Wheat as Related to the Soil Microbial Community

JEREMY HANSEN[1,2], BILL SCHILLINGER[2], ANN KENNEDY[1], AND TARAH SULLIVAN[2]
[1]USDA-ARS NORTHWEST SUSTAINABLE AGROECOSYSTEMS RESEARCH UNIT; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Inclusion of canola as a rotational crop in the inland Pacific Northwest has expanded in recent years with the increased demand for canola-based products. Wheat grown after canola is generally reported to have greater grain yield compared to wheat grown after wheat. In a 7-year on-farm winter canola (WC) rotation study conducted near Reardan, WA, yields of spring wheat (SW) following WC were reduced compared to yields following winter wheat (WW). The objective of this research is to determine the differences and similarities in the soil microbial communities associated with WC and WW. If a shift in the microbial community between crops exists, we want to determine if the changes are connected to SW yield response. β-Glucosidase (BG) enzyme activity in WW was significantly greater compared to WC (Fig. 1A) in the first year (CS1), with the effect carrying over to the subsequent SW (CS2) in 3 of 5 crops years (CY). The BG enzymes are widely distributed among soil fungi and involved in the degradation of cellulose providing energy for soil microorganisms. Differences in BG activity could suggest alterations in the soil fungal community. Results of phospholipid fatty acid (PLFA) analysis indicate that fungal groups of the soil microbial community in WC were suppressed. In particular, mycorrhizal fungi (MF) were significantly suppressed in WC compared to WW in 4 of the 5 CY for CS1and CS2 demonstrating carry over to the subsequent SW crop (Fig. 1B). Preliminary data from this work suggest the preceding canola crop may have suppressed MF associations with the subsequent SW crop, which could explain the reduction in the observed SW yields. This study will provide research-based information of the influence brassica crops have on soil microbial health and crop yields to growers, scientists, and industry personnel.

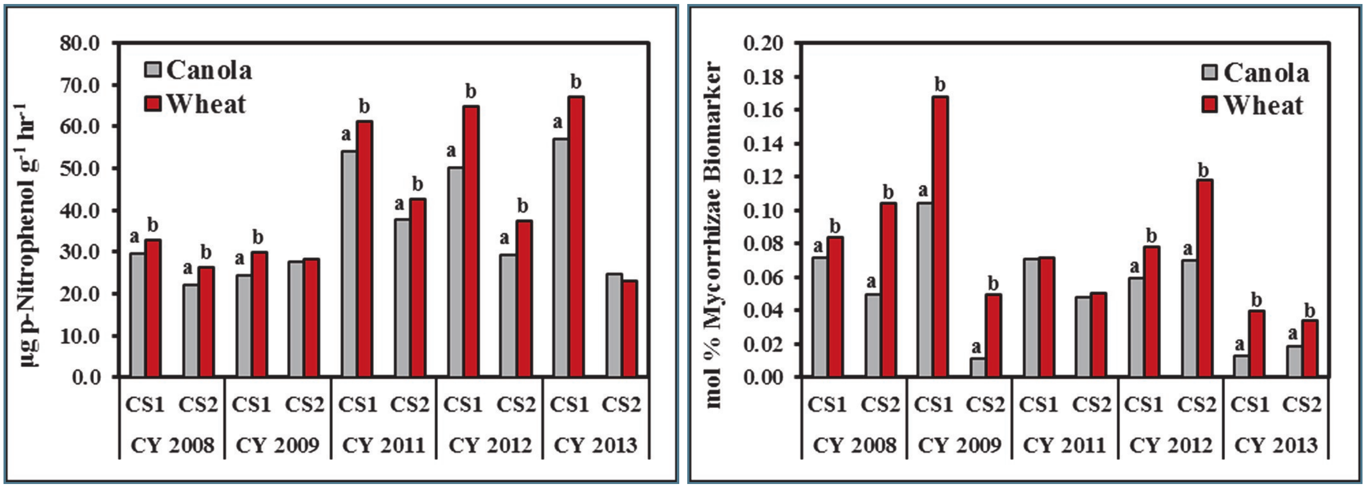


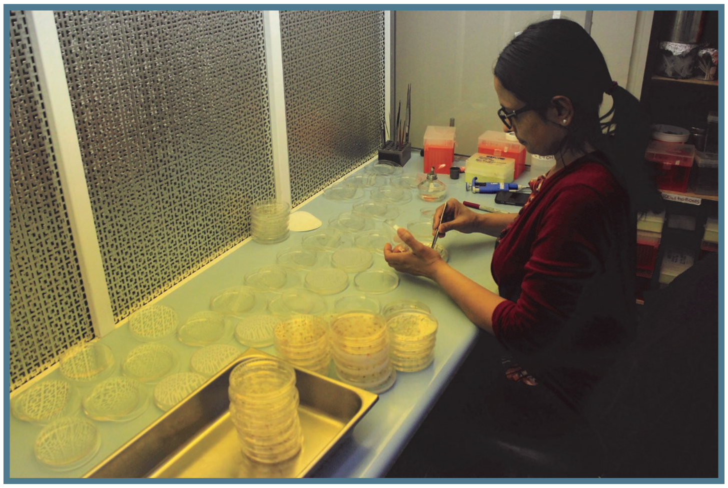
Figure 1. A) Difference in soil microbial enzyme activity in WC and WW treatments as determined by β-Glucosidase. B) Difference in biomarker indicators for soil mycorrhizal fungi in WC and WW treatments as determined by PLFA. Cropping sequence (CS) 1 represents data from the initial canola and wheat plots in the first year. CS2 represents data from the SW treatment following the WC and WW treatments. Different letters indicate significance @p<0.05.

Manipulating the *AT-hook Motif Nuclear Localized* (*AHL*) Gene Family for Bigger Seeds with Improved Stand Establishment

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

MICHAEL M. NEFF, PUSHPA KOIRALA, DAVID FAVERO, AND REUBEN TAYENGWA
DEPT. OF CROP AND SOIL SCIENCES, MOLECULAR PLANT SCIENCES GRADUATE PROGRAM, WSU

In low rainfall dryland-cropping areas of eastern Washington, stand establishment can have a major impact on yields of camelina and canola. During dry years these seeds need to be planted in deep furrows so that the developing seedling has access to water in the soil. One approach to facilitate stand establishment is to develop varieties with larger seeds and longer hypocotyls as seedlings while maintaining normal stature as adults. Few mechanisms, however, have been identified that uncouple adult stature from seedling height. The Neff lab has identified an approach to improve stand establishment by uncoupling seedling and adult phenotypes through the manipulation of members of the *AHL* family. When these genes are over-expressed, the result is seedlings with shorter hypocotyls. When the activity of multiple genes is disrupted, the result is seedlings with taller hypocotyls, demonstrating that these genes control seedling height in a redundant manner. In the Brassica *Arabidopsis thaliana,* we have identified a unique allele (*sob3-6*) for one of these genes, *SOB3/AHL29*, that over-expresses a protein with a disrupted DNA-binding domain and a normal protein/protein interaction domain. In *Arabidopsis*, this mutation confers normal adult plants that produce larger seeds and seedlings with hypocotyl stems that can be more than twice as long as the wild type. The goal of this project is to enhance camelina and canola seedling emergence when they are planted deeply in low-rainfall dryland-cropping regions (generally less than 12"/year) or in wheat stubble. This can be achieved by manipulating *AHL* gene family members to develop varieties that have long hypocotyls as seedlings yet maintain normal growth characteristics as adult. The current aims for this project are: 1) Analyze seed size of *AHL* mutations in *Arabidopsis*; 2) Identify, clone and characterize *AHL* gene family members from camelina and canola; 3) Generate transgenic camelina and canola expressing *AHL* genes; 4) Use CRISPR/Cas9-based genome editing to modify *AHL* genes; 5) Characterize seedling morphology in canola varieties previously



used in stand establishment studies. During this funding period, the Neff Lab has used a combination of molecular, genetic, biochemical, and biotechnological approaches to understand the role of *AHL* genes in plant growth and development. Our primary goal has been to characterize *AHL* genes from *Arabidopsis* and camelina, while also establishing a canola transformation system. The picture is of Pushpa Koirala using tissue culture to generate transgenic canola using *Agrobacterium*-mediated transformation as a part of her Ph.D. training. We have used the camelina draft genome sequence to identify 81 camelina *AHL* genes, eight of which have been cloned. We have transformed camelina and *Arabidopsis* with some of these camelina genes. We have also generated putative transgenic canola, though these still need to be verified. Using *Arabidopsis AHL* mutants, we have now demonstrated that the long hypocotyl seedling phenotypes are regulated by plant hormones including the auxins and brassinosteroids. This work is part of David Favero's Ph.D. dissertation. The auxin-related work has been accepted for publication: Favero, D.S., C.N. Jacques, A. Iwase, K.N. Le, J. Zhao, K. Sugimoto, and M.M. Neff. 2016. *SUPPRESSOR OF PHYTOCHROME B4-#3* Represses Genes Associated with Auxin Signaling to Modulate Hypocotyl Growth in *Arabidopsis thaliana*. Plant Physiology (accepted).

First Report of Horned Lark Damage to Pre-emerged Canola Seedlings

Bill Schillinger[1], Scott Werner[2], John Jacobsen[1], Steve Schofstoll[1], Bruce Sauer[1], and Brian Fode[1]
[1]Dept. of Crop and Soil Sciences, WSU, Lind, WA; [2]National Wildlife Research Center, USDA APHIS Wildlife Services, CO

Winter canola is considered the most promising, domestically-produced oilseed feedstock for the biodiesel industry and for diversifying wheat based cropping systems in the inland Pacific Northwest (PNW). Winter canola field experiments conducted in east-central Washington were completely destroyed, and commercial fields were damaged, over several years by large flocks of horned larks (*Eremophilia alperestis* L.) that ate the cotyledon leaves of pre-emerged and newly-emerged seedlings (Fig. 1). Horned larks are permanent year-round residents of the PNW. Through the years, several measures were attempted to control horned lark damage in newly-planted winter canola fields. These were:

(i) A loud propane-powered noise cannon (such as that used in fruit orchards) was placed inside the plot area and set to explode at one-to five-minute intervals. Explosions initially caused the birds to take flight, but they soon returned to feeding. Horned larks soon became accustomed to the cannon booms, after which they fluttered briefly about a meter off the ground before resuming feeding.

(ii) Bird netting such as used to protect cherry trees was spread on the surface a 0.5-acre irrigated winter canola experiment the day after planting. Segments of netting were connected with plastic ties. Horned larks wedged themselves underneath the netting in small gaps where netting segments were attached and travelled under the netting to eat pre-emerged cotyledon leaves. Several dozen horned larks died after becoming trapped in the netting. The sight of dead horned larks did nothing to deter their companions. Essentially all canola seedlings in the experiment were destroyed.

(iii) Concurrent with placing bird netting on the soil surface, a life-size great horned owl replica was mounted on a 5-ft-tall perch in the plot area two days after planting. This appeared to have little to no effect on deterring horned larks.

(iv) A large quantity of garlic was mixed with canola seed in the drill before planting. Immediately after planting, additional garlic was then mixed with water and applied uniformly on the soil surface with a plot sprayer. A light water irrigation of 0.1 inch was then applied to incorporate garlic into the surface soil. A very strong odor of garlic was emitted from the plot area following these treatments. This had little to no effect as horned larks completely destroyed the plot before seedlings emerged from the ground.

Repellent seed treatments can be used to protect newly-planted crops from bird depredation. In 2016, we will field test a non-toxic anthraquinone-based seed treatment for the protection of pre-emerged and newly-emerged canola seedlings from horned lark depredation.

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

Figure 1. The horned lark is a ground-dwelling bird commonly found in open areas and in fallow fields throughout North America. Photos by Terry Sohl (with permission) and S.J. Werner.

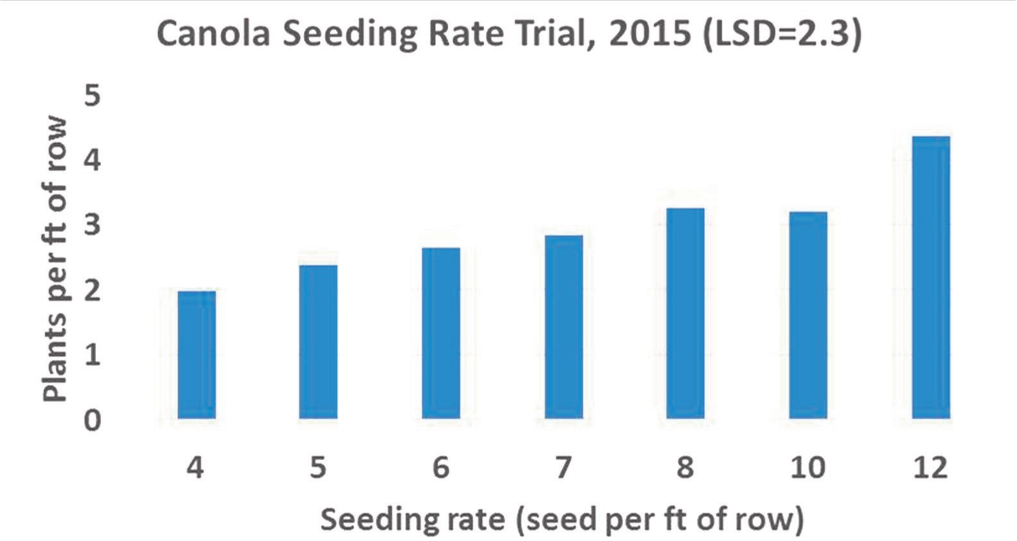
Evaluation of a Precision Double-Disk Planter for Spring Canola

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

IAN BURKE
DEPT. OF CROP AND SOIL SCIENCES, WSU

Growers typically use a seed drill and a lot of seed to produce an adequate stand of canola. In general, approximately 50 to 60% of the 4.5 to 6 lbs of seed per acre planted actually germinates and emerges. Canola stands for production can be quite variable, but there needs to be a minimum of 4 plants per ft of row, and populations can be as high as or higher than 10 per ft of row. When high variation in seedling establishment is coupled with the wide variability in seed lots (canola seed can vary between 80,000 and 120,000 seeds per pound) and the expense of transgenic canola seed, a significant amount of money is wasted just planting canola. Precision vacuum plate planters offer a potential solution to minimize seed expense in canola production. Unlike seed drills, which are calibrated by flow (using weight of seed per unit time), precision vacuum plate planters are calibrated by seed number – instead of lbs to the acre, growers calibrate by the desired seed number per foot of row. By uniformly distributing seed in the row, greater numbers of seed could potentially establish and seeding rate could be reduced.

A study was conducted in 2015 to evaluate canola stand establishment using a precision vacuum plot planter. Eight seeding rates were selected: 4, 5, 6, 7, 8, 10, or 12 seed per ft. The study design was a randomized complete block with 3 replications. Plots were 8 ft wide by 75 ft long. HyCLASS® 955 Roundup Ready® canola was seeded May 7, 2015 into a smooth seedbed 1.5 inch deep, and into moisture. Stand counts were recorded June 16, 2016. Two 1-meter sections of row were counted per plot. Canola stands ranged from 1.9 to 4.4 plants per ft of row, and increased incrementally with seeding rate (Fig. 1). Percent of seed that produced plants increased with planting rate, and at 10 seeds per ft, only 32% of seed failed to emerge. Percent establishment was much lower at lower planting rates, and at 4 seeds per ft ~50% of seed failed to emerge. Conditions were dry, and bloom began not long after the stand assessments were recorded. As a consequence, yield was not recorded.



Canola Seedling Root Damage Caused by Ammonium Fertilizers

Isaac Madsen and William Pan
Dept. of Crop and Soil Sciences, WSU

Toxicity to crops due to banding ammonium-based fertilizers below the root is well documented. Tap-rooted crops such as canola are more susceptible to toxicity than wheat, which has a fibrous root system. Because of the increased susceptibility of canola it is important to carefully consider the rate, source, and placement of ammonium-based fertilizer applications when including canola in a primarily wheat rotation. Symptoms of halted apical growth, premature lateral root emergence, taproot shrinkage, and necrosis have been observed by growing canola seedlings along the face of an office scanner (Fig. 1). While these symptoms do not necessarily lead to seedling death, they may be responsible for increasing seedling vulnerability to other stresses as well as reducing the potential for a strong tap root.

When banding fertilizers at planting, it is important to consider rate, place, and source. **Rate:** The rate can increase the size of the toxic zone (Fig. 1). Note that while the seedlings growing above the medium rates suffered damage to their tap roots they were able to recover and able to avoid the toxicity zone with lateral roots. **Source:** The ammonium source may also influence the size of the toxic zone. Forms of ammonium-based fertilizers which have higher pH cause an increase in ammonia gas movement through the soil. Ammonia gas is more deadly to plant roots and causes an expanded toxic zone. **Place:** Ideally fertilizer should be placed to the side or to the side and below the seed. However, this will infrequently be an option as it requires adjustments to seeding drills. If changing the fertilizer placement is not an option, split applying fertilizer may be the best approach.

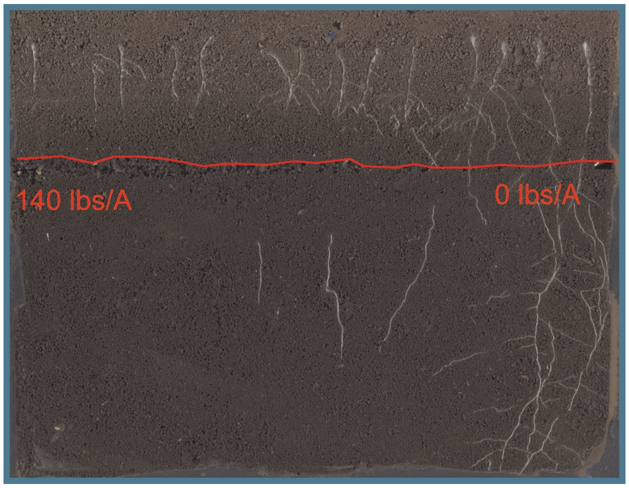


Figure 1.

Conclusion: If banding ammonium-based fertilizer at planting, consider adjusting rate, place, and source to reduce damage to seedling root systems. It is preferable to place the fertilizer below and to the side of the seed; decreasing the N rates may decrease the potential for damage; the source, and specifically the pH of the source fertilizer, can influence the distance at which toxicity symptoms may be observed from the seed.

Effect of Insecticide Applications on Early-Planted Winter Canola in Northern Idaho

JIM B. DAVIS, MEGAN WINGERSON, AND JACK BROWN
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Recently, some dryland Pacific Northwest (PNW) winter canola growers have been planting their crops earlier than is traditional to improve establishment by planting before soil moisture is lost to evaporation later in the season. To assess the need for summer insecticide applications in early plantings, we conducted a four-year trial at Moscow, ID. Early-planted canola was subjected to four different treatments; (1) seed treated with the label rate of Helix Xtra® plus a late summer foliar application of Warrior II®, (2) the seed treatment alone, (3) the late summer application of the foliar insecticide alone, or (4) no seed or foliar insecticide treatment.

In each year of the trial, insects damaged the canola during the late summer and early fall. Untreated plots were devastated by flea beetle and aphid infestations during the summers of 2010 and 2011 (Table 1). Despite the impact of insect infestation on the untreated plots, no yield loss was seen from not controlling insects in those years. This is likely because favorable growing conditions in late September and October allowed the plants to recover after insect populations had decreased. A yield loss was seen in the no-control plots in the 2013-2014 crop, likely due to less favorable fall conditions that did not allow for recovery. No differences in seedling emergence, establishment, or disease due the presence or absence of the seed treatment were observed.

Table 1. *Insect damage and yield of canola with insecticide treatments.*

	Insecticide Treatment			
Crop Year	**No Insecticide**	**Seed Trt Only**	**Foliar Only**	**Seed Trt and Foliar**
	------------------------ *score*[1] ---------------------			
2010-11	1.2 c[2]	5.3 b	5.7 b	7.7 a
2011-12	1.4 c	6.1 b	6.0 b	8.3 a
	--------------------- *lbs./acre* ----------------------			
2010-11	3,425	3,424	3,451	3,348
2011-12	4,276 ab	4,499 a	4,143ab	3,925 b
2012-13	1,503	1,592	1,648	1,652
2013-14	1,251 b	1,474 ab	1,666 a	1,676 a

[1] A score of 1 indicates severe damage and a score of 9 indicates no damage.
[2] Means within rows with the different letters are significantly ($p<0.05$) different.

Based on this data, winter canola can recover from severe insect damage in appropriate fall growing conditions. In some years, such conditions will not occur and canola will benefit from late summer insecticide applications. Since growers cannot accurately predict weather conditions six to eight weeks in advance, controlling summer insect infestations is recommended in case good growing fall conditions do not occur. In addition, the use of a seed treatment with an insecticide-fungicide package should be strongly considered to reduce the risk of unexpected seedling damage from insects as well as from seedling diseases and black leg disease. A fungicidal seed treatment to control black leg is often required by state law in the PNW, and adding an insecticide to it is a simple and routine matter.

Feral Rye Control in Winter Canola

FRANK YOUNG, DALE WHALEY, NEVIN LAWRENCE, AND IAN BURKE
DEPT. OF CROP AND SOIL SCIENCES, WSU

Feral rye is a problematic winter annual grass weed in the low-rainfall, winter wheat-summer fallow rotation of the Pacific Northwest. The inclusion of winter canola into the crop rotation provides additional herbicide options to control feral rye. A study was conducted for three years in north central Washington to determine the efficacy of Select 2EC, Assure II, and Roundup on feral rye control and winter canola yield. In 2011, when all three herbicides were applied in the spring, weed control ranged from 64% to 98% and yield increased more than 40% compared to the nontreated control (see table below). Fall plus spring applications of Assure II and Roundup were the most effective treatments for increasing canola yield and controlling rye (>95%) during the last two years of the study. Data from these experiments indicate that Roundup in Roundup-resistant winter canola (Fig. 1a and 1b) and Assure II in conventional or Roundup-resistant winter canola can effectively control feral rye.

Effect of three herbicides on feral rye control and winter canola yield.[a]

		Bridgeport 2011		Bridgeport 2012		Okanogan 2014	
Treatment	Rate	Control	Yield	Control	Yield	Control	Yield
	oz/A	%	lbs/A	%	lbs/A	%	lbs/A
Nontreated	-	-	1300	-	270	-	0
Select (F)	6	-	-	67	700	69	750
Select (F+S)	6+6	-	-	83	770	89	740
Select (S)	6	64	1880	60	600	35	90
Assure II (F)	9	-	-	63	680	96	860
Assure II (F+S)	9+9	-	-	96	1070	100	780
Assure II (S)	9	74	1920	93	840	83	430
Roundup (F)	22	-	-	69	780	96	740
Roundup (F+S)	22+22	-	-	99	1030	99	1040
Roundup (S)	22	98	1930	99	860	100	350

[a] F=fall; S=spring. Select and Assure II contained nonionic surfactant in 20011 and cropoil concentrate in 2012 and 2014. Roundup contained 2.5% ammonium sulfate. Control ratings recorded May of harvest year.

Figure 1a. Feral rye stand in 2013 before fall Roundup application.

Figure 1b. Feral rye control in spring 2014 after fall Roundup application.

Components of Improved Canola Nitrogen Use Efficiency with Increasing Water and Nitrogen

TAI MCCLELLAN MAAZ[1], WILLIAM L. PAN[1], AND W. ASHLEY HAMMAC[2]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS WEST LAFAYETTE, IN

Spring canola is being adapted as a rotational crop for the high rainfall and transitional fallow zones of the PNW. Our nitrogen (N) fertility trials indicate that water stress lowers nitrogen use efficiency (NUE) of spring canola (Pan et al., 2016). An NUE component analysis was performed in 2011 and 2012 to identify the soil and plant processes that attribute to lower yield potential under low water availability of spring canola following wheat.

Our NUE component analysis indicated that differences in water-limited yields were associated with lower N uptake efficiency from soil (plant N/N supply) and utilization efficiency to produce grain (grain yield/plant N). In particular, most of the reduction in yields were attributed to a lower grain N utilization efficiency (grain yield/grain N-inverse of grain N concentration), followed by a lower N retention in the soil (available N/N supply). Differences in grain N accumulation due to a lower availability of water were mostly attributed to a lower N retention efficiency.

When water availability decreases by an inch, wheat yields and grain N losses are attributed to the various NUE components?

	Yield↓ lb/ac	Grain N↓ lb/ac
Lower N supply=	0	0.1
N retention efficiency=	22	1.4
Available N uptake efficiency=	15	0.7
N harvest index=	15	0.1
Grain N utilization efficiency=	32	
Total=	84	2.3

With decreasing available water and fertilization, spring canola became less efficient at accumulating (1) grain biomass per unit grain N and (2) grain N per unit of available N supply. These results emphasize the need to develop breeding and management strategies to improve water use efficiency and to select canola varieties capable of coping with water stress that limits grain biomass production per unit plant N accumulation.

Pan, W.L., T.M. Maaz, W.A. Hammac, V.A. McCracken, and R.T. Koenig. 2016. Mitscherlich-modeled, semi-arid canola nitrogen requirements influenced by soil N and water. Agron. J. *in press*.

Soil Characteristics and Associated Wind Erosion Potential Altered by Oilseeds in Wheat-Based Cropping Systems

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

Oilseeds are integral to the production of biofuels and diversifying rainfed cropping systems in the Pacific Northwest. However, there is evidence to suggest greater potential for wind erosion when growing oilseeds in wheat-based rotations when tillage is used during fallow. Little is known concerning the impact of growing oilseeds on soil surface characteristics that affect erosion. Soil characteristics were examined during the fallow phase of three crop rotations: (i) winter wheat-summer fallow (WW-SF), (ii) winter wheat-camelina-summer fallow (WW-C-SF), and (iii) winter wheat-safflower-summer fallow (WW-SAF-SF) at Lind and Ritzville, Washington. Crop residue biomass and soil water content, roughness, surface strength, and aggregate size distribution were measured immediately after planting winter wheat. Camelina and safflower did not affect random roughness, penetration resistance, geometric mean diameter, or the erodible fraction. Flat residue biomass and cover, however, tended to be greater in the WW-SF rotation. The Revised Wind Erosion Equation suggested that sediment transport could be from 57 to 212% greater for the WW-C-SF or WW-SAF-SF than the WW-SF rotation due to differences in crop residue characteristics after sowing wheat. These results indicate that crop residue must be carefully managed to minimize the occurrence and intensity of wind erosion from dryland oilseed cropping systems when tillage is used during summer fallow. Specifically, no-tillage may be required to manage crop residue during the fallow phase of a wheat-oilseed-fallow rotation for controlling wind erosion. A newly-published detailed report of this study is available at: Sharratt, B.S. and W.F. Schillinger. 2016. Soil Characteristics and Wind Erosion Potential of Wheat-Oilseed-Fallow Cropping Systems. *Soil Science Society of America Journal* doi:10.2136/sssaj2015.12.0427.

Long-term camelina (left) and safflower (right) cropping systems studies have been conducted at Lind and Ritzville, respectively.

A Survey of Eastern Washington State for Blackleg Disease of Canola Caused by *Leptosphaeria maculans* and *Leptosphaeria biglobosa*

TIMOTHY C. PAULITZ[1], A. JENNY KNERR[2], DAN SCHLATTER[1], KAREN SOWERS[2], MICHAEL L. DERIE[2], AND LINDSEY J. DU TOIT[2]
[1]USDA-ARS WHEAT HEALTH, GENETICS AND QUALITY RESEARCH UNIT; [2]DEPT. OF PLANT PATHOLOGY, WSU

Blackleg caused by the fungi *Leptosphaeria maculans* and *L. biglobosa* is the most important disease of canola worldwide. The pathogen can be seedborne, which is the primary way it can spread into a new area. Blackleg was discovered in canola crops in northern Idaho in 2011, and a widespread epidemic occurred in the Willamette Valley of Oregon (OR) in spring of 2014 and 2015. In spring 2015, the disease was discovered on winter rapeseed and canola in the Camas Prairie of Idaho, with infected fields located from Grangeville to Moscow. In addition, the disease was found in irrigated canola in northcentral OR. Because of these finds so close to Washington (WA), we initiated a survey of winter and spring canola fields in WA in 2015. As a result of the harsh winter of 2014-2015, most of the winter canola was winter-killed, except for some crops in Okanogan and Douglas counties. Fields were surveyed in Asotin, Douglas, Garfield, Columbia, Okanogan, and Whitman counties. In many of the fields, overwintered canola stubble was sampled, or canola leaves were examined for symptoms and pycnidia. Single-spore isolations were made from pycnidia on leaves onto water agar. Stubble samples were incubated at 100% relative humidity to induce production of fruiting bodies and spores, from which single spore isolations were made. Isolates were tested for pathogenicity on the cabbage cv. (Copenhangen Market) by wounding the base of the seedlings with a needle and inoculating with a spore suspension. Isolates were also sequenced with ITS and β-tubulin primers for species identification.

Results: Two isolates from a diseased leaf sampled from a field in Okanogan county collected in April were identified and confirmed as *L. maculans* based on DNA sequencing and pathogenicity testing. Isolates from Okanogan and Whitman county, were identified as *L. biglobosa* subsp. *australiensis.* Common saprophytes identified on stubble that produced black fruiting bodies, and that could be readily confused with the blackleg fungus included *Davidiella tassiana* (the perfect state of *Cladosporium herbarum*), and *Pleospora* spp. (the perfect state of *Alternaria* and *Stemphylium* spp.).

Implications: These results indicate that *L. maculans* and *L. biglobosa* are present in the inland WA, but at a limited incidence. *L. biglobosa* is mildly pathogenic on brassicas, compared to *L. maculans*, and its impact on canola in WA is unknown. In late 2015, the WA State Department of Agriculture modified existing state quarantine regulations to require testing of all brassica seed lots for the pathogen before seeds can be planted in any county east of the Cascade Mountains or in six counties in NW Washington. It is especially important that the blackleg pathogen not become established in the northwest counties of WA and the Columbia Basin, where a significant percentage of the brassica seed for the country and the world is produced. Members of the PNW Blackleg Team gave numerous extension talks in 2014-2016 throughout WA to alert growers and other stakeholders about the disease. The two pictures show the characteristic lesions on leaves, with dead (necrotic) lesions surrounded by a yellow (chlorotic) halo. Inside the lesions are tiny black dots, which are the asexual fruiting bodies of the fungus (pycnidia), which produce spores that can be dispersed by rain or irrigation.

Both show blackleg lesions on canola leaves. Note dead area in center, surrounded by yellow zone. Small black dots in center of lesion are black, asexual fruiting bodies of the fungus. Spores are produced inside of the fruiting bodies, and can be dispersed by rain and splash. Photos courtesy of Lindsey du Toit.

Long-Term Safflower Cropping Systems Experiment Near Ritzville, WA

BILL SCHILLINGER[1], RON JIRAVA[2], JOHN JACOBSEN[1], AND STEVE SCHOFSTOLL[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND; [2]GROWER COLLABORATOR, RITZVILLE, WA

We completed a 6-year experiment in 2015 to evaluate the potential for safflower (SAF) in a long-term dryland cropping systems experiment on the Ron Jirava farm located west of Ritzville, WA. Safflower was grown in a 3-year winter wheat (WW)-SAF-undercut tillage summer fallow (UTF) rotation and was compared to WW-spring wheat (SW)-UTF and WW-UTF rotations. Each phase of all rotations was present each year and there were four replicates. Individual plots were 30 ft x 500 ft. Soil water was measured in all plots after grain harvest in August and again in early April, and from UTF in early September. Treflan, a soil-residual herbicide, was applied in March or April to be rain incorporated into plots that were to be sown to SAF. Safflower was direct seeded into the standing stubble of the preceding WW crop at a rate of 40 lbs/acre + N, P, and S fertilizer in late April or early May. Excellent stands were always achieved. Grain yield was determined with a commercial-sized combine and a weigh wagon in mid-to-late September. Safflower seed yields ranged from 125 to 1130 lbs/acre and averaged 483 lbs/acre over the six years.

Due to safflower's relatively high soil water use, crops grown after SAF sometimes produced lower grain yield than those following wheat. The water shortfall carried through a year of fallow after SAF harvest compared to a year of fallow after SW or WW. At time of planting for WW in early September, fallow in the WW-SAF-UTF rotation contained an average of

1.35 inches less soil water in the 6-ft profile compared to the WW-SW-UTF and WW-UTF rotations. Figure 1 shows WW grain yield at the Ritzville site in three rotations for four cycles. By far the highest average WW grain yield of 68 bushels/acre was in the WW-SW-TSF rotation. The next highest average WW grain yield was 60 bushels/acre in the WW-TSF rotation. The lowest average WW grain yield of 55 bushels/acre occurred in the WW-SAF-TSF rotation.

Although the 4-cycle average WW grain yield is lowest in the WW-SAF-TSF rotation, the only statistically significantly within-year WW yield differences between the WW-SAF-TSF and WW-TSF rotations occurred in 2012. Winter wheat yields in these two rotations were not statistically different in 2013, 2104, and 2015 (Fig. 1). This indicates that SAF may be providing a rotation benefit to the subsequent crop that offsets its well-documented high soil water use.

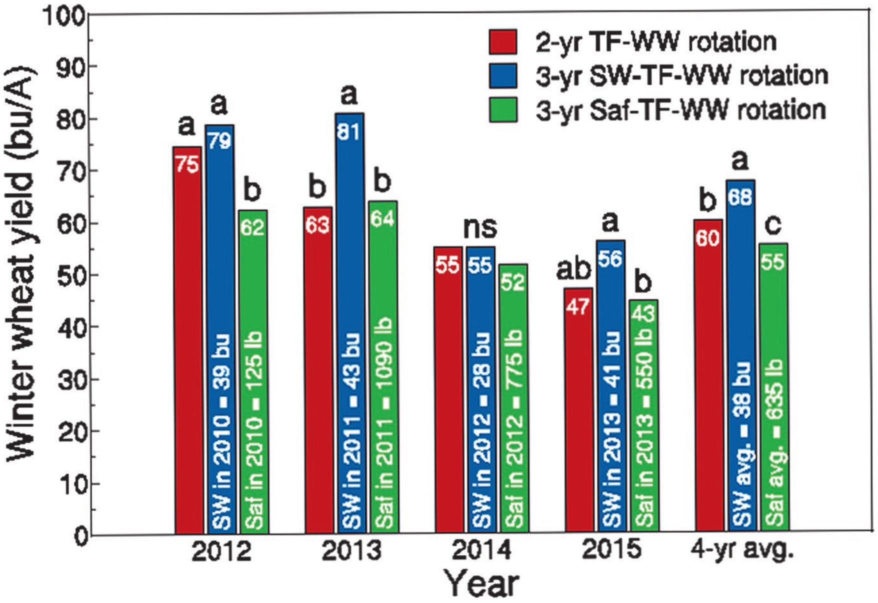


Figure 1. Winter wheat grain yield in three crop rotations at Ritzville, WA during four years and the 4-year average. Some readers may be confused as to why we only have four "cycles" of data shown here despite having grown and harvested safflower for six years. The reason is there is a year of fallow in all three rotations before winter wheat is planted. Thus, we will not have the full data set until after the 2017 winter wheat harvest. Numeric values at the top portion of the data bars are winter wheat yields. Yields of the preceding spring wheat and safflower in the two 3-year rotations are also shown within the data bars. Within-year winter wheat yields followed by a different letter are significantly different at the 5% probability level.

Optimizing Fertilizer Application Timing for Winter Canola in Northern Idaho

JIM B. DAVIS, MEGAN WINGERSON, AND JACK BROWN
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

In Pacific Northwest (PNW) dryland cropping systems, winter canola must be seeded into summer fallow. One approach to avoiding establishment difficulties at traditional mid to late August seeding times is to simply plant at an earlier time when soil moisture in the seed zone has yet to be lost to evaporation. Early-planted winter canola can yield as much, or more, than canola planted at traditional dates, but in some years reduced winter survival and reduced yields have been documented in early-planted winter canola. To see if varying the timing of fertilizer applications would have an effect on winter survival and yield, we examined the effects of five nitrogen application regimes on winter survival and seed yield in both early-planted and traditionally planted winter canola.

Five nitrogen application timing treatments were used (Table 1). As expected, the reduced nitrogen rate resulted in lower seed yield, but winter survival was not affected. Winter survival and seed yield were reduced when all of the recommended nitrogen was applied at planting. The yield reduction associated with applying all of the nitrogen at planting (160 lbs. N per acre) was so great that the two-year mean yield of that treatment was equivalent to the low nitrogen treatment that received only 35 lbs. of N per acre.

Table 1. *Mean seed yield of two canola cultivars with five nitrogen fertility timing regimes.*

Fertilizer Timing Treatment	Winter Survival	Seed Yield		
		2014	2015	Mean
	- -*score*[1]- -	------------ *lbs. per acre* -----------		
Reduced N (40%) at Planting Only	6.5 a	1,680 c[2]	2,695 b	2,154 b
All at Planting	5.4 b	1,978 b	2,405 b	2,178 b
None at Planting, 50% in Fall, 50% in Spring	6.9 a	2,346 a	3,775 a	3,038 a
25% at Planting, 25% in Fall, 50% in Spring	6.7 a	2,306 a	3,594 a	2,929 a
25% at Planting, 75% in Spring	6.8 a	2,360 a	3,257 a	2,794 a

[1] Scored on a scale of 1 to 9 with one equaling no survival and 9 equaling complete survival.
[2] Means within columns with different letters are significantly ($p<0.05$) different.

The numerically best fertilizer timing regime based on the two-year average seed yield was the one with no nitrogen applied at planting and a 50:50 fall-spring split; however, this regime was not significantly different from the 25:25:50 and the 25:0:75 treatments. The worst approach was to apply all the fertilizer at seeding. The decreased winter survival seen in that treatment suggests that extra vegetative growth in the summer reduces cold hardening in winter canola. The yield decrease seen with the all-at-planting treatment could be due to decreased winter survival, loss of nitrogen during the summer from volatilization of the urea, loss of nitrogen and sulfur during the winter from leaching and denitrification, or more likely a combination of all three. We observed no effects from the fertilizer treatments on seedling emergence. To maximize yield, the rate of fertilizer applied at planting should be kept low, especially when planting at dates that are earlier than traditional, and the remaining fertilizer should be split between late fall and early spring applications. A more in depth report can be found at <*www.cals.uidaho.edu/brassica/*>.

Winter Canola Water and Nitrogen Use in Low Rainfall Areas of Eastern Washington

MEGAN REESE[1], BILL PAN[1], FRANK YOUNG[2], AND WILLIAM SCHILLINGER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS

Fertility management of winter canola is more complex than spring canola due to its additional growth stages and potential markets of feed, food and fuel. In addition to the complexities of nutrition management, water use is of paramount concern to growers in the water-limited environment of the Pacific Northwest. Analyzing winter canola water and nitrogen (N) use can be approached throughout three growing seasons: vegetative growth (from planting to winter dieback), winter survival, and harvest season (spring regrowth to seed harvest). In the 2014 season, winter canola water and N use was monitored in variety trial plots seeded around August 20 in Okanogan and Pomeroy.

Fall 2014 water use in Okanogan and Pomeroy varied from 2-7 in., 15-20% of total water use. Canola at Pomeroy extracted water to at least 5 ft in the fall and used nearly all available water by harvest. In contrast, canola water use at Okanogan was relegated to the top 3 ft during fall, but moisture deeper in the soil profile was accessed during spring regrowth. Total water use was 12 in. at Okanogan and 22 in. at Pomeroy. Available water remained in the soil profile after harvest in Okanogan (Fig. 1), possibly due to hardpan layers or subsoil nutrient restrictions. Canola grain yield was 2185 lb/acre at Pomeroy, which had greater soil water and N supplies than at Okanogan, which yielded 795 lb/acre. Water use efficiencies were 65 and 105 lb/ac yield per inch water used for Okanogan and Pomeroy respectively, similar to spring canola in the area. Total season unit N requirements were higher than current regional extension bulletin literature, at 26 lb N per 100 lb yield in Okanogan and 17 lb N per 100 lb yield in Pomeroy. N inefficiencies appeared to occur in the fall and winter seasons to a greater degree than the harvest season. Volatilization, immobilization, and ammonium fixation are potential N loss pathways.

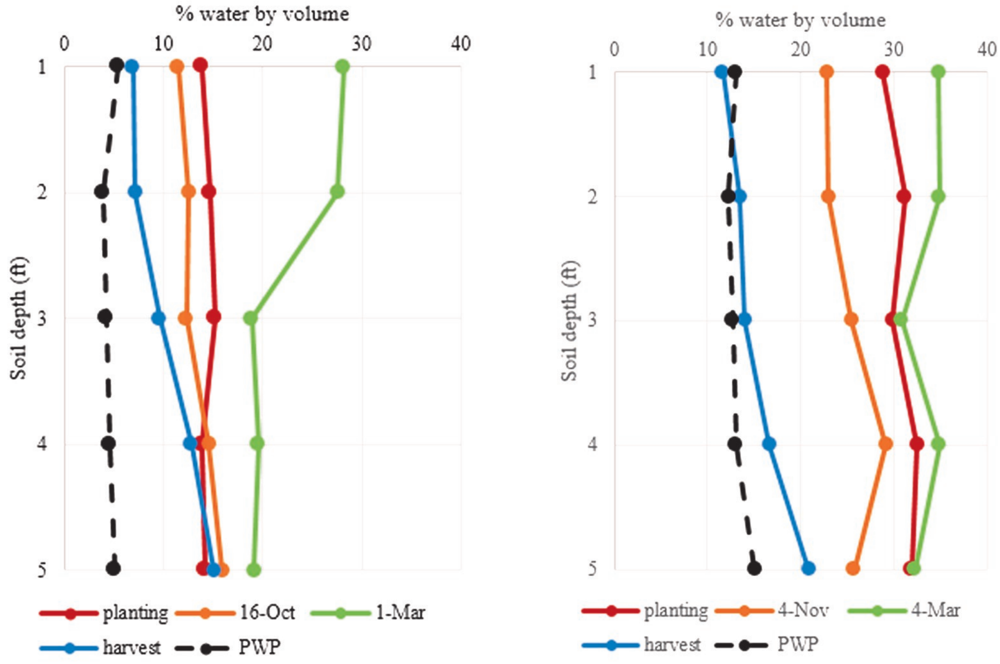


Figure 1. Soil water profiles at Okanogan (left) and Pomeroy (right) in 2014-15 for selected sampling dates, compared to dry soil at permanent wilting point (dashed).

Cropping Systems: Economic Returns to Canola Rotations in Eastern Washington

VICKI A. MCCRACKEN AND JENNIFER R. CONNOLLY
SCHOOL OF ECONOMIC SCIENCES, WSU

Canola growers have observed rotational benefits from growing canola including increased yield in subsequent wheat crops, decreased weed pressure, and improved soil quality. These benefits accrue in crops following canola, impacting total farm returns. Growing canola in traditionally cereal-only rotations also impacts costs due to the use of herbicides that are compatible in rotations with canola, and different tillage needs following canola as a result of canola residue breaking down differently than cereal crops. These impacts affect both costs and returns in the year canola is grown and in years later in a rotation.

Assessing returns for complete rotations gives a more accurate picture of the profitability of canola than assessing returns for a single year. Enterprise budgets have been developed for the low and intermediate rainfall areas of eastern Washington and include expanded features that allow for the rotational impacts of canola. These interactive computer tools are available online and can be used by growers and advisors to growers (e.g. bankers and other agricultural industry personnel) to assess the on-farm economics of growing canola. Each enterprise budget file includes separate tabs for summary, crop calendars, crop budget sheets (differentiated by rotation), and machinery complements and costs. The summary tab presented below (based on 2013 data) provides detailed, interactive summary economic information useful in comparing alternative crops and rotations with and without canola.

Inclusion of canola into crop rotations may offer agronomic benefits to farms that translate into improved overall farm profitability over time. Our research finds favorable economic returns of selected crop rotations that incorporate canola as compared to returns of traditional crop rotations when rotational impacts are considered, under some alternate price and production scenarios.

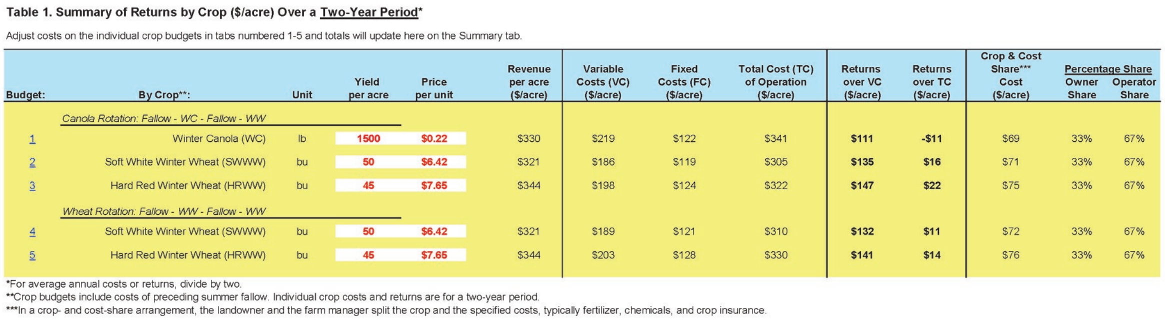


Table 1. Summary of Returns by Crop ($/acre) Over a Two-Year Period*

Adjust costs on the individual crop budgets in tabs numbered 1-5 and totals will update here on the Summary tab.

Budget:	By Crop**:	Unit	Yield per acre	Price per unit	Revenue per acre ($/acre)	Variable Costs (VC) ($/acre)	Fixed Costs (FC) ($/acre)	Total Cost (TC) of Operation ($/acre)	Returns over VC ($/acre)	Returns over TC ($/acre)	Crop & Cost Share*** Cost ($/acre)	Percentage Share Owner Share	Percentage Share Operator Share
	Canola Rotation: Fallow - WC - Fallow - WW												
1	Winter Canola (WC)	lb	1500	$0.22	$330	$219	$122	$341	**$111**	**-$11**	$69	33%	67%
2	Soft White Winter Wheat (SWWW)	bu	50	$6.42	$321	$186	$119	$305	**$135**	**$16**	$71	33%	67%
3	Hard Red Winter Wheat (HRWW)	bu	45	$7.65	$344	$198	$124	$322	**$147**	**$22**	$75	33%	67%
	Wheat Rotation: Fallow - WW - Fallow - WW												
4	Soft White Winter Wheat (SWWW)	bu	50	$6.42	$321	$189	$121	$310	**$132**	**$11**	$72	33%	67%
5	Hard Red Winter Wheat (HRWW)	bu	45	$7.65	$344	$203	$128	$330	**$141**	**$14**	$76	33%	67%

*For average annual costs or returns, divide by two.
**Crop budgets include costs of preceding summer fallow. Individual crop costs and returns are for a two-year period.
***In a crop- and cost-share arrangement, the landowner and the farm manager split the crop and the specified costs, typically fertilizer, chemicals, and crop insurance.

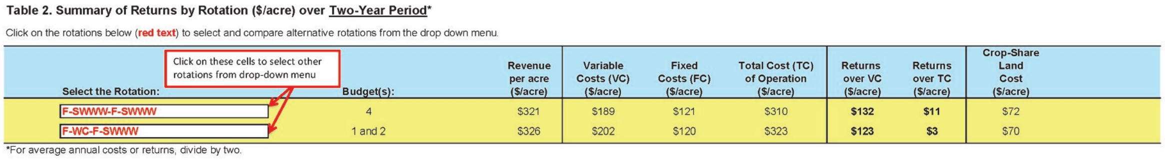


Table 2. Summary of Returns by Rotation ($/acre) over Two-Year Period*

Click on the rotations below (**red text**) to select and compare alternative rotations from the drop down menu.

Click on these cells to select other rotations from drop-down menu

Select the Rotation:	Budget(s):	Revenue per acre ($/acre)	Variable Costs (VC) ($/acre)	Fixed Costs (FC) ($/acre)	Total Cost (TC) of Operation ($/acre)	Returns over VC ($/acre)	Returns over TC ($/acre)	Crop-Share Land Cost ($/acre)
F-SWWW-F-SWWW	4	$321	$189	$121	$310	**$132**	**$11**	$72
F-WC-F-SWWW	1 and 2	$326	$202	$120	$323	**$123**	**$3**	$70

*For average annual costs or returns, divide by two.

Extension and Outreach: Getting Oilseed Information in the Hands of Stakeholders

KAREN SOWERS[1], DENNIS ROE[1], BILL PAN[1], FRANK YOUNG[2], AARON ESSER[1], AND BILL SCHILLINGER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS

As evidenced by the numerous reports in this section of the abstracts, the Washington Oilseed Cropping Systems (WOCS) project continues to crank out a wide range of research results annually. The WOCS team's top priorities is to conduct research to answer production questions from growers, to improve production, and to be applicable in a range of precipitation zones in eastern Washington and the Pacific Northwest. Just as important as the research is finding effective ways to disseminate the data and findings to growers, crop consultants, and other stakeholders. We have found that a variety of formats of outreach is key to effective communication. Methods we use throughout the year are online via the WOCS website (www.css.wsu.edu/biofuels), email updates and notifications, five field days during the growing season, individual farm visits, on-farm trials, Extension publications, presentations at university and industry events, and finally, our annual oilseed production workshops and/or conference. In 2015, 1335 people attended all WOCS events. Ten Farmer Technology breakfast meetings were held in Colfax and Lewiston, all of which had an oilseed component.

After partnering with the Pacific Northwest Direct Seed Association for a large conference in 2014 and 2015 and based on survey results, we returned to our original format of several smaller workshops dedicated specifically to oilseed production, marketing and processing information. The workshops were held in Odessa, Colfax and Dayton, and the response from growers and industry was overwhelmingly positive. Attendees placed the highest value on the presentations being geared toward the production region where each workshop was at, and the interactive format of the breakout sessions. We will be having workshops again in 2017 with the interactive format, potentially a more hands-on approach, and growers and industry involved in the planning.

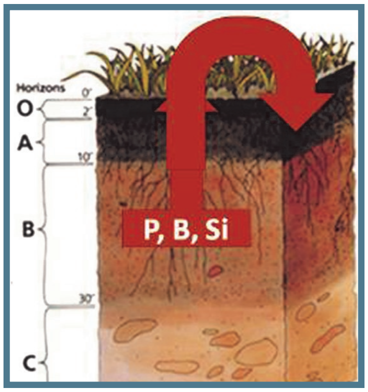
Winter canola plans with growers and WOCS staff were challenged, and in many cases failed, last summer and fall with drought conditions. Additionally, there was a period of time during seeding time when bids were not available for canola and there was uncertainty about the future of a major processor where most growers take their crop. Those factors resulted in planted winter canola acres again being down from the recent high of 51,000 acres in 2014 to 37,000 for 2016 (USDA-NASS, Mar. 31, 2016). Despite the reduced prospective acres, the WOCS team is forging ahead with outreach to continue educating PNW growers and crop consultants about the latest research to improve production. Several fact sheets published to kick off a WOCS-branded Extension publication series.

With a grant from Viterra, the WOCS Extension team has planned on-farm spring canola variety trials that are now being planted at three locations in eastern Washington: Davenport (WSU Wilke Farm), St. John (Eriksen farm), and Fairfield (Emtman Farms). There are six varieties, including Roundup Ready, Liberty Link, Clearfield (including a high-oleic), non-GMO hybrid, and a *Brassica rapa*. We are using grower equipment for most field operations and will be hosting field days at the plots. Stand establishment, soil water and nitrogen use efficiency, weed control, and yield will be measured. Keep an eye on our website calendar for upcoming events!

Do our Subsoils Provide Wheat and Canola Roots with Ample Nutrients During Grain Filling?

BILL PAN, MEGAN REESE, TAYLOR BEARD, ISAAC MADSEN, AND TAI MAAZ
DEPT. OF CROP AND SOIL SCIENCES, WSU

The inland Pacific Northwest (PNW) is blessed with deep soils capable of storing water and nutrients that crops can access throughout their life cycle. But 125 years of producing annual crops has extracted subsoil nutrients, and we now need to ask if there is a problem with subsoil deficiencies in soil-immobile nutrients. Are these deficiencies exacerbated by alkaline subsoil conditions? Typically, routine soil tests are only conducted on surface soil samples. This approach was developed for Midwestern and southern U.S., where summer rains replenish topsoil moisture, thereby sustaining shallow root uptake of topsoil nutrients. The PNW adopted the same approach, but does this make sense for us? Currently we only test for subsoil mobile nutrient forms (nitrate and sulfate), replenished with vertical infiltration of water that carry these anions during soil recharge. We decided to run soil tests on all root zone depths to begin assessment of subsoil fertility status. Here's what we found:



- Most annual dryland crops remove subsoil nutrients, and those that are not removed by grain harvest are returned to the soil surface.
- Many nutrients are not soluble enough to be carried back into the subsoil in high concentrations, and mainly remain in the surface soils that receive these nutrients. **Soil immobile nutrients include P, Zn, Mn, Fe, B.**
- Over years of crop extraction, these soil-immobile nutrients have reached very low levels, and high subsoil pHs render some of them rarer.
- But wheat and canola **root systems rely on subsoil water and nutrients** mid to late season as surface soils dry in our semi-arid climate.
- Topsoils dry out in our region and shallow roots become inactive. **Do our subsoils provide wheat and canola roots with ample nutrients during grain filling?**
- With our unique patterns of winter precipitation and dry summers, **improving subsoil fertility** may be crucial to achieving full soil productivity potential.
- What are ways to improve subsoil fertility? It will be tough. For example, deep phosphorus movement is only achieved when P fixation sites are saturated during P over-fertilization. However, organically bound nutrient forms are more mobile. Green cover crops, animal manures, biosolids, and perennial forages may all provide more organic compounds, such as organic acids, that solubilize soil-immobile nutrients.

Winter Canola Variety Trial in the Low to Intermediate-Rainfall Zone of Washington

FRANK YOUNG[1], DALE WHALEY[2], DENNIS ROE[1], LABAN MOLSEE[1], AND LARRY MCGREW[3]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]WSU EXTENSION; [3]USDA-ARS

In 2014, winter canola variety trials were established at Okanogan and Pomeroy, Washington. Fourteen varieties were planted at 1900′ elevation at Okanogan, and 12 varieties at the Pomeroy site at 4400′ elevation. Annual precipitation was 7″ at Okanogan and 15″ at Pomeroy. Plant establishment was visually evaluated 3 weeks after planting on a scale of 1 (poor establishment) to 5 (excellent establishment). Cold hardiness was determined by recording crop stand counts in the fall before freeze-up and in the spring after dormancy was broken. At Okanogan, the winter was cold, open, and very dry. Highest yielding varieties at Okanogan were Mercedes (Rubisco Seeds), Largo (*B. rapa* variety) (Fig. 1a), and Claremore (imi-tolerant, High Plains Development). At Pomeroy, Griffin (Kansas State University) (Fig. 1b) yielded the highest, followed by Amanda and Claremore. Largo had the highest survivability at both locations.

Winter canola variety trials in the low-intermediate rainfall zones of WA, 2014-2015.

	Okanogan			Pomeroy		
Variety	Yield (lbs/A)	Est.	Survival (%)	Yield (lbs/A)	Est.	Survival (%)
Mercedes	878	4.3	36	2470	4.5	18
Edimax	655	3.0	14	2538	3.6	24
Safran	532	3.5	13	2659	3.4	28
Inspiration	478	4.0	5	1229	4.0	5
Largo	858	3.9	71	1375	4.4	101
Falstaff	544	4.3	12	2286	3.6	25
Cp115	738	4.3	30	2125	4.0	31
Cp125	571	4.5	8	2237	4.3	39
Cp13-26	225	4.0	8	116	4.3	0
Amanda	809	4.3	25	2584	4.4	25
WC-1	555	3.9	26	-	-	-
05.6.33	600	3.6	7	-	-	-
Griffin	684	4.1	40	2923	3.9	39
Claremore	968	4.1	35	2414	4.4	44

Figure 1a. Largo, spring 2015.

Figure 2b. Griffin, summer 2015.

Best Management Practices to Improve Low-Rainfall Oilseed Production

FRANK YOUNG[1], LAUREN PORT[2], AND BILL PAN[2]
[1]USDA-ARS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

Wind erosion continues to be a major problem in the low-rainfall, winter wheat fallow region of the Pacific Northwest. One method to reduce soil loss by wind erosion is to increase residue. Five years ago we initiated a project at Ralston, WA to increase residue to improve winter canola planting conditions into no-till chemical fallow. We are increasing residue by planting tall winter wheat and winter triticale in lieu of semi-dwarf wheat and harvesting them with a stripper header. The tall residue influences the microclimate at the soil surface and seed zone which allows us to plant winter canola in August when we want to compared to when the weather dictates us, i.e. a 5-day post plant temperature of ≤ 85F. In 2013 and 2014, winter canola establishment was 35 to 45% better in stripper header plots compared to reduced-tillage fallow plots. In 2014, stand establishment was zero in the reduced-tillage plots. Unfortunately, cold weather killed all plots each year. In 2015, winter canola was planted into stripper header spring barley stubble and reduced-tillage fallow plots. Winter canola establishment was higher in the stripper header chemical fallow plots compared to reduced tillage plots (Fig. 1a and 1b). This year, plots were covered with snow which protected plants (even very small, 2-leaf plants that emerged late) over winter.

Figure 1a. Spring 2016, reduced tillage.

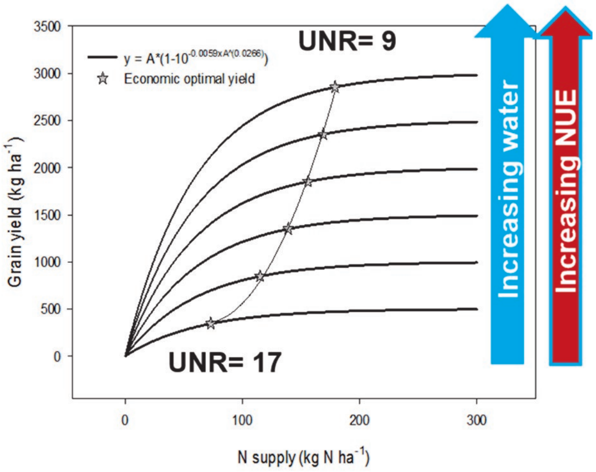
Figure 2b. Spring 2016, stripper header chem. fallow.

Semi-Arid Canola Nitrogen and Water Requirements

WILLIAM L. PAN[1], TAI MCCLELLAN MAAZ[1], W. ASHLEY HAMMAC[2], VICKI A. MCCRACKEN[3], AND RICHARD T. KOENIG[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS WEST LAFAYETTE, IN; [3]SCHOOL OF ECONOMIC SCIENCES, WSU

Spring canola is being adapted as a rotational crop for the high rainfall and transitional fallow zones of the PNW. This agronomic and economic diversification is improving weed control and soil quality, as well as supporting a growing regional oilseed processing and marketing industry. Field experiments were conducted over 12 site-years to define nitrogen (N) and water requirements of spring canola following wheat or fallow. Soil N supply (N_s) availability following wheat was lower than following fallow (77 vs. 205 kg N_s ha^{-1}) leading to higher N fertilizer requirements (47 vs. 0 kg N_f ha^{-1}) for canola following wheat, despite having lower water limited-yield potentials. Unit N requirements (UNRs) at economic optimal yield levels ranged from 9 to 17 kg N_s (kg grain^{-1}) across high to low yielding site-years, respectively.

Higher UNRs and lower N use efficiency (NUE) in water stressed years suggests projected climate change could result in more reactive N remaining in the system. Overall, these UNRs are generally higher than other reported canola recommendations from similar production areas, due to our inclusion of greater residual soil N depths and N mineralization contributions to N supply estimates. Nitrogen fertilizer requirements were low to zero in situations when residual and mineralized N sources and/or water availability limited canola yield potential.



Pan, W.L., T.M. Maaz, W.A. Hammac, V.A. McCracken, and R.T. Koenig. 2016. Mitscherlich-modeled, semi-arid canola nitrogen requirements influenced by soil N and water. Agron. J. in press.

Washington Extension Legume Variety Trails in 2015 and 2016: Performance Information for Superior Variety Selection

STEPHEN GUY AND MARY LAUVER
DEPT. OF CROP AND SOIL SCIENCES, WSU

The WSU Extension Grain Legume Variety Testing (GLVT) program provides growers, the agribusiness industry, university and USDA-ARS researchers, and other interested clientele with comprehensive, objective information on the adaptation and performance of grain legume cultivars across several different climatic growing regions in eastern Washington. The GLVT program conducts comparisons using scientifically sound methodology, produces independent results, disseminates all data to clientele, and uses uniform testing procedures across multiple locations. The replicated dryland GLVT trials in eastern Washington were grown at six locations in 2015 using spring and winter planted varieties of dry pea, lentil, and spring chickpea.

Winter adapted pea and lentil evaluation trials were planted at three locations in the fall of 2015 and will provide performance information on released and experimental lines that produce food quality seed. The release of food quality, winter adapted pea and lentil varieties have the potential to significantly expand the adapted areas, especially in the lower and intermediate rainfall zones, for economical grain legume production. Growing grain legumes in a wheat rotation will increase wheat yield potential. Winter adapted pea and lentil production systems have demonstrated much higher yield potential than spring planted types.

Trial results are available in printed form in: 2015 WSU Extension Variety Testing Grain Legume Program Results (Technical Report 15-4), and comprehensive results for last year, and previous years, can be found on the Variety Testing Web site (http://variety.wsu.edu).

Oral and poster presentations, field days, and industry and extension meetings are traditional means used for delivering research results. Results from the GLVT provide independent assessment of variety performance to support variety selection decisions by growers and other clientele. Growers can realize a timely economic payback using information from yield and variety performance data. This project is made possible by contributions of land and time from farmer cooperators where trials are located. Partnerships with research scientists from state, federal and private sectors are vital to the success of this program. Funding is provided by: The USA Dry Pea and Lentil Council, WSU Agricultural Research Center, and Washington State Crop Improvement Association.

Climate Impacts on Palouse Pea Yields

John Abatzoglou[1] and Sanford Eigenbrode[2]
[1]Dept. of Geography, UI; [2]Dept. of Plant, Soil, and Entomological Sciences, UI

Climate variability can play a significant role on crop yields in dryland farming systems. An analysis of yields (lbs/acre) of dry pea from 1992-2014 across the Palouse region of Idaho and Washington (data from USADPLC) and climate records aggregated across the region reveal a strong positive relationship between summer soil moisture and yield. Specifically, yields of green and yellow pea were on average 20 percent lower for years where June-August soil moisture was below the median than for all other years. Higher soil moisture years resulted when reduced spring-summer evapotranspiration losses and ample soil moisture carryover from winter and spring precipitation allowed for a longer period before drought limitation set in. Although yield data from 2015 was not available at the time of this writing, yields were substantially impacted by moisture limitations during drought conditions concurrent with the 2015 growing season.

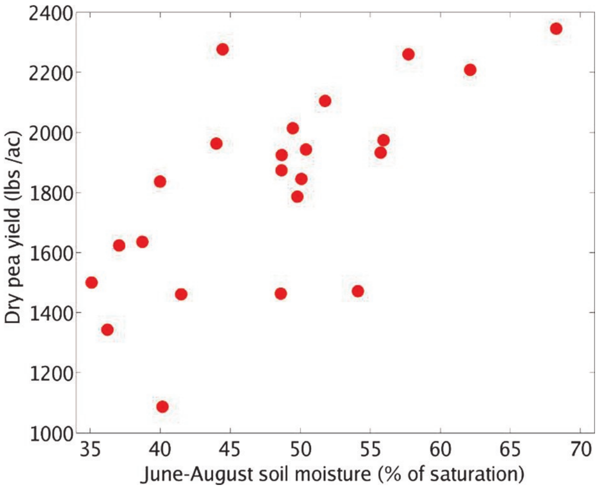


Figure 1. Observed relationship between relative average June-August soil moisture and average annual yield for dry peas (green and yellow) for the Palouse region spanning the years 1992-2014.

Winter Pea Production and Rotation Benefits in the Dryland Wheat-Fallow Region

Bill Schilllinger[1], Ron Jirava[2], John Jacobsen[1], Kurt Braunwart[3], Howard Nelson[4], and Steve Schofstoll[1]
[1]Dept. of Crop and Soil Sciences, WSU, Lind; [2]Grower collaborator, Ritzville; [3]ProGene, Othello; [4]Central Washington Grain Growers, Wilbur

A long-term winter pea (WP) cropping systems experiment was initiated at the Ron Jirava farm near Ritzville, WA in the September 2010. The objective of the experiment is to determine the suitability of winter pea in the low-precipitation zone where winter wheat–summer fallow (WW-SF) is dominant rotation. Two 3-year crop rotations are tested in the experiment: (i) WP-spring wheat (SW)-SF versus (ii) WW-SW-SF. Experimental design is a randomized complete block with four replicates of each treatment. All treatment combinations are present each year for a total of 24 plots, each 100 feet long. The WP variety “Windham” was selected for inclusion in the experiment. Windham is a feed pea with upright growth habit and good cold tolerance that can be direct combined with a regular header (i.e., swathing and/or a pick-up header not required). Winter pea has a large seed that is capable of emerging through five inches or more of soil cover.

Winter pea used significantly less soil water that WW (Table 1). However, over the winter months, a higher percentage of precipitation was generally stored in the soil following WW compared to WP (Table 1). The reason for this is because: (i) very little WP residue remains on the soil surface after harvest compared to WW, and (ii) the drier the soil, the more precipitation will be stored in the soil over winter. The end result, however, was that when SW was planted in late March, soil water following WP was significantly greater than that after WW (Table 1).

In the first five years of the study, WP yields have averaged 2094 lbs/acre versus 72 bushels/acre for WW (Table 1), with similar gross economic returns. Winter pea was killed by cold temperatures during the winter of 2013-2014. We replanted the plots to the edible "Banner" spring pea. The yield of spring pea in 2014 was 778 lbs/acre. The yield of the subsequent SW crop has been significantly greater after WP compared with after WW (Table 1). Based partially on the successful early results of this study, several farmers in the dry region have started planting 20-to 160-acres of WP.

Table 1. *Soil water content at time of harvest of winter pea and winter wheat as well as soil water content in late March following these two crops near Ritzville, WA. The grain yield data is for spring wheat where the previous crop was either winter pea or winter wheat. PSE = overwinter precipitation storage efficiency.*

	Timing in fallow period				
	Beginning (late Aug.)	Spring (mid Mar.)	Over-winter Gain	PSE[†] (%)	Grain yield (bu/A)
	Soil water content (inches)				
			A. 2014-2015		
Rotation					
SW after WP[††] in 3-yr rotation	8.0	12.1	4.1	64	34
SW after WW[†††] in 3-yr rotation	6.0	10.9	4.9	77	25
p-value	0.003	0.006	0.04		0.005
			B. 4-year summary		
Rotation					
SW after WP[††] in 3-yr rotation	7.4	10.9	3.5	56	30
SW after WW[†††] in 3-yr rotation	6.1	10.3	4.2	67	28
p-value	< 0.001	0.04	0.007		0.03

[†] Overwinter precipitation for 2014-15 and 4-yr avg. were 6.4" and 6.24".

[††] Winter pea yields for 2015 and 4-year avg. were 1513 and 2094 lbs/A (does not include 778 lbs/acre spring pea in 2014).

[†††] Winter wheat yields for 2015 and 5-year average were 63 and 72 bu/A.

Biochar Effects on Wheat and Peas in Eastern Oregon

STEPHEN MACHADO AND LARRY PRITCHETT
COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU

Biochar has the potential to increase soil organic matter (SOM) levels, which have declined under the winter wheat-summer fallow cropping systems (WW-SF) predominant in the Pacific Northwest. Biochar is charcoal produced from pyrolysis (combustion at low oxygen levels) and is resistant to decomposition. Adding biochar to soil sequesters C that would otherwise be lost to the atmosphere as CO_2 through burning or natural decomposition, where it would contribute to global warming. Biochar increases soil water holding capacity, cation exchange capacity, nutrient retention capacity, fertilizer use efficiency, and soil microbial populations, all conditions required for sustained crop production. We are evaluating the effects of biochar derived from forest wastes on wheat and pea yields.

The biochar, which contained 90% C, 0.18% N, C/N of 500, and a pH of 10.6, was applied at rates of 0, 10, 20, and 40 tons/acre to a field under winter wheat-spring pea rotation (WW-SP) before seeding winter wheat in fall 2012 at the Betts Farm, Athena. In spring 2014, spring peas were seeded after winter wheat on the same plots. In a second experiment at the Pendleton Station, biochar was applied at rates of 0, 5, 10, and 20 tons per acre to a WW-SP rotation in 2013. Biochar was applied to all phases of the rotation. Grain yield, ears/m^2, test weight, and soil pH were determined at maturity in 2013.

At the Betts farm, increasing biochar from 0 to 40 tons/acre increased grain yield from 45 to 60 bu/acre, an increase of 26% to 33% (Fig. 1). However, applying biochar at rates above 10 tons/acre did not significantly increase yield. Biochar application did not influence ears/m^2 and test weight. Applying biochar increased soil pH by a factor of 0.21. Yields of the following spring pea were increased by 20, 25, and 15% in plots that had received 10, 20, and 40 tons of biochar per acre during the wheat phase, respectively (Fig. 2). At the Pendleton site, amending soil with biochar increased both yields of wheat and peas by 24% and 16%, respectively.

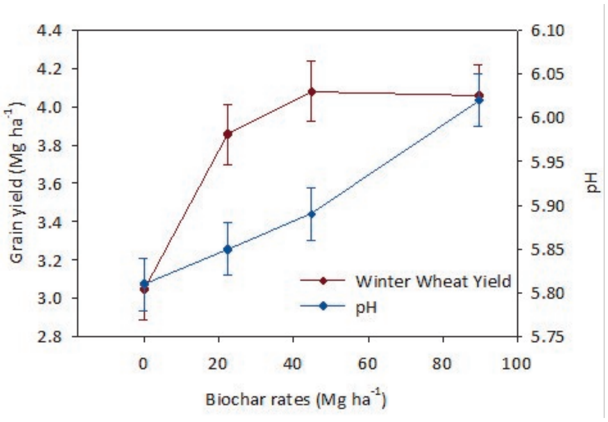


Figure 1. Biochar Effects on Wheat Grain Yield and Soil pH in Athena, Oregon during the 2012-13 Crop-year. Bars represent standard error.

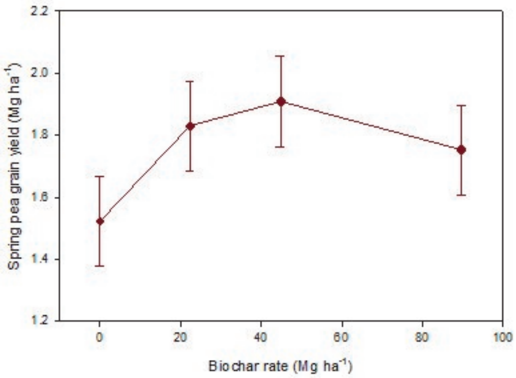


Figure 2. Residual effects of biochar on spring pea grain yield, Athena, Oregon, 2013-14 crop-year. Peas were grown on the same plots that had wheat in the 2012-13 crop–year without further biochar additions. Bars represent standard error.

These results indicated that biochar had the potential to increase grain yield of winter wheat and spring peas. The biochar used was alkaline and may also have the potential to reduce the acidity that is increasingly evident in fields fertilized with N compounds and in no-till systems. This study is on-going.

The Role of Caregiver Communication in Children's Liking and Consumption of Lentils

---

A.J. Roe[1], J. Davis[1], S.A. Ramsay[1], and S.L. Johnson[2]
[1]School of Family and Consumer Sciences, UI; [2]Anschutz Medical Campus, University of Colorado

Children's consumption of lentils supports overall health, and the higher fiber content of lentils could reinforce eating behaviors that help prevent obesity. The use of repeated exposure in fostering development of a child's taste preference for previously disliked foods has been thoroughly examined; however, other techniques such as adult verbal communication have not. Child Centered Nutrition Phrases (CCNP) were developed as part of the Child Care Mealtime and Active Play Partnerships project. The efficacy of adults' use of these developmentally appropriate, nutritionally sound messages to improve children's intake and liking of lentils has not been evaluated. This study was conducted to determine whether repeated taste exposure (RE) and RE + CCNP would increase young children's liking and intake of lentils.

Children (3-6 yr; n=30) were offered lentils twice a week for 5 weeks. Taste preference and consumption were recorded using a visual analogue scale and plate waste, respectively. Repeated measures ANOVA was used to determine within and between group differences. There was a significant main effect of exposure on consumption (p=0.002) as children ate significantly more lentils at exposures 2-5 compared to baseline. The main effect of exposure on taste preference showed a trend to increased liking over time (p=0.07). There was no significant main effect of group on either liking (p=0.13) or consumption (p=0.56). However, there was a trend toward a significant interaction between group and exposure on consumption (p=0.09), but not liking (p=0.12).

Repeated taste exposure resulted in increased liking and intake of lentils in young children, regardless of the use of CCNP. In order to further explore the trend toward a significant interaction between group and exposure, the study will be continued with more exposures to determine if there is a point where the two groups diverge.

Part 2. Pathology, Weeds, and Insects

Wireworms in Idaho Cereals: A Survey of Wireworm Species in Relation to Soil Characteristics and Cultural Practices

A. Rashad, C.W. Rogers, A.T. Gerritsen, M. Marshall, and S.S. Hunter
Aberdeen Research and Extension Center, UI

Wireworms, the larval stage of click beetles, continue to be one of the top concerns of cereal grain producers in the Pacific Northwest region of the United States. This is primarily because the available registered insecticides for wireworm control in cereals (i.e., neonicotinoids) have provided very limited protection, if any at all. Inconsistencies in the effectiveness of seed treatments have been attributed to among-species variations in susceptibility and ecology, highlighting the importance of investigating species diversity to identify the predominant damaging wireworm species.

A two-year survey was conducted to identify wireworm species across southern Idaho and to identify practices and soil characteristics that could be associated with reduced wireworm numbers. To date, a total of nine wireworm species have been identified. Results revealed the sugar beet wireworm, *Limonius californicus*, as the predominant species. In addition, the sugar beet wireworm was active and consistently present following planting and through harvest. Soil bulk density appeared to be the only soil variable negatively correlated with wireworm pressure across southern Idaho. A collaboration was established with the University of Idaho Institute for Bioinformatics and Evolutionary Studies (IBEST) to generate the full sequence of sugar beet wireworm mitochondrial and nuclear genomes, paving the way towards studying population genetic differences with respect to different levels of susceptibility to current neonicotinoid insecticides. In addition to field surveys, greenhouse studies are ongoing to evaluate wireworm response to host plants in different soil media.

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

Tim Murray and Hongyan Sheng
Dept. of Plant Pathology, WSU

Eyespot (strawbreaker foot rot) and Cephalosporium stripe are important diseases of winter wheat in the Pacific Northwest. These 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. Early-seeded winter wheat is at the greatest risk of being affected by these diseases, especially when planted following summer fallow.

Planting an eyespot-resistant variety is the best control, although fungicide application in spring is still important in some areas. Our research focuses on identifying new and effective resistance genes to both of these diseases. As part of that research, we test new varieties and advanced breeding lines from both public and private breeding programs for eyespot and Cephalosporium stripe resistance each year. Results of our field trial data are available on the WSU Wheat and Small Grains website (http://smallgrains.wsu.edu/disease-resources/research-reports/). We also provide ratings of varieties in the Washington State Crop Improvement Winter Wheat Certified Seed Buying Guide (http://washingtoncrop.com). Several varieties are currently available with effective resistance against eyespot including: AP700CL, AP Legacy, ARS Chrystal, ARS Selbu, Brundage 96, Cara, Chukar, Coda, LCS-Azimut, Madsen, Masami, Norwest 553, ORCF-102, Otto, Puma, Rosalyn, Tubbs 06, WB 456, WB 523, WB 528 and WB 1066CL.

True resistance to Cephalosporium stripe doesn't occur in wheat, but varieties differ in their susceptibility and some are tolerant including: Bauermeister, Bruehl, Coda, Curiosity CL+, Eltan, Farnum, LCS-Artdeco, Masami, Mela CL+, ORCF-102, Skiles, Tubbs 06, WB 528, and Xerpha. Data for disease reaction, yield and test weight of winter wheat varieties and breeding lines in response to Cephalosporium stripe was evaluated at the Palouse Conservation Field Station, Pullman, WA, in 2015 and are available online (http://smallgrains.wsu.edu/disease-resources/research-reports/).

Four fungicides are registered for eyespot control; Tilt 3.6EC, Topsin-M 4.5FL, Priaxor 4.16SC, and Alto 100SL. The active ingredients in Tilt and Alto are related and belong to the triazole class of fungicides. Including a half rate of Topsin-M in the mix for both Tilt and Alto is recommended to improve control. Priaxor contains two active ingredients, a carboxamide and a strobilurin, which are very effective in controlling eyespot. We test these and potential new fungicides for effectiveness in controlling eyespot and publish the data on the Wheat and Small Grains website (Table 1). In 2015, we tested foliar fungicides for eyespot control at two locations in commercial wheat fields, one near Ralston and the other near Dayton, WA. Priaxor at 8 oz provided the best disease control at both locations, but yield was not significantly different from the untreated control or other fungicide treatments. The lack of differences in disease control is likely due to below average rainfall at both locations, which limited yield potential.

Table 1. *Effect of foliar fungicides on eyespot disease, yield, and test weight of winter wheat, near Ralston and Dayton, WA, 2015.*

Treatment, application rate/A	Disease incidence%	Disease severity 0 to 4	Disease index 0 to 100	Yield bu/A	Test wt lb/bu
Location: Ralston					
Untreated	87.5	2.2	48.3	46.3	56.3
Priaxor 4.16SC, 8.0 fl oz	64.8	1.9	31.0	47.2	56.6
Tilt 3.6EC 4.0 fl oz + Topsin 4.5FL 20.0 fl oz	79.4	2.1	41.6	50.7	56.8
Alto 100SL, 5.5 fl oz	81.4	2.1	42.6	48.4	56.6
$LSD_{0.05}$	10.8	NS	10.1	NS	NS
Location: Dayton					
Untreated	85.3	1.9	41.1	72.8	55.2
Priaxor 4.16SC, 8.0 fl oz	65.2	1.7	27.5	74.6	54.9
Tilt 3.6EC 4.0 fl oz + Topsin 4.5FL 20.0 fl oz	90.4	2.0	44.3	69.5	54.7
Alto 100SL, 5.5 fl oz	89.6	1.8	39.9	67.4	55.0
$LSD_{0.05}$	15.9	NS	12.4	NS	NS

Disease severity was determined by rating stem bases, 1 to 2 internodes above the crown, for symptom severity using a 0 to 4 scale where 0 = no visual symptoms, 1, 2 and 3 = up to 25, 50 and 75% of the stem circumference colonized by a lesion(s), respectively, and a 4 = a stem with a lesion girdling the base. Disease index, which ranges from 0 to 100, was calculated by multiplying percent infected stems (disease incidence) by disease severity of infected stems and dividing by four.

Speckled snow mold and pink snow mold occur in the north-central wheat-producing area of eastern Washington where snow cover can persist for up to 150 days. These diseases can cause complete yield loss in years when they are severe, but disease-resistant varieties like Bruehl and Eltan are available to limit damage. Planting a resistant variety early is still the best control for the snow molds. In conjunction with the WSU Winter Wheat Breeding program and University of Idaho Extension Plant Pathology program in Idaho Falls, ID, we are testing current and new varieties for snow mold resistance in field plots near Mansfield and Waterville, WA, and Tetonia, ID. In addition to field testing, we are also trying to improve methods of screening for resistance in the growth chamber based on inoculation under simulated winter conditions and by measuring accumulation and depletion of fructan polysaccharides.

Effect of Winter Wheat Row Orientation to Suppress Downy Brome (*Bromustectorum*) in Northeastern Oregon

JUDIT BARROSO
COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU

Light is an important resource for which crops and weeds compete. Using row orientation to increase the amount of light intercepted by winter crops can help to suppress weeds as part of an integrated weed management approach. The effect of row orientation varies with latitude and with the seasonal tilt of the earth in relation to the sun. Winter crops oriented in the east-west direction can potentially shade weeds in the inter-row spaces to a greater extent than crops oriented north to south (Fig. 1). The objective of this study was to examine the effect of winter wheat row orientation to suppress downy brome in the latitude and growth conditions of northeast Oregon.

In agreement with similar studies conducted in other parts of the globe, we observed lower downy brome stands and biomass in the winter wheat subplots oriented East-West compared to subplots oriented North-South (Fig. 2), but the suppression effect was not significant and it did not affect downy brome fecundity parameters or crop yield. It appears that manipulation of crop row orientation in winter wheat is not a useful technique to suppress downy brome in northeastern Oregon.

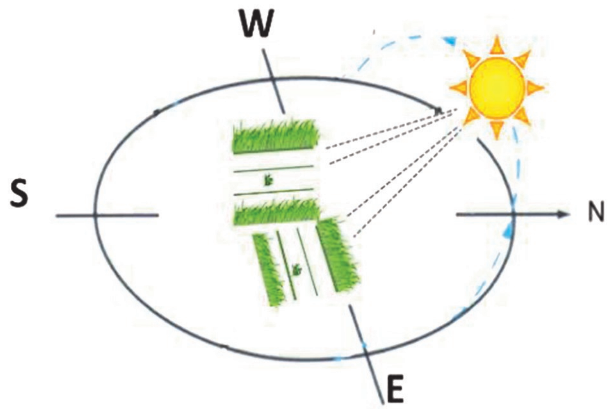


Figure 1. Schema of the project hypothesis

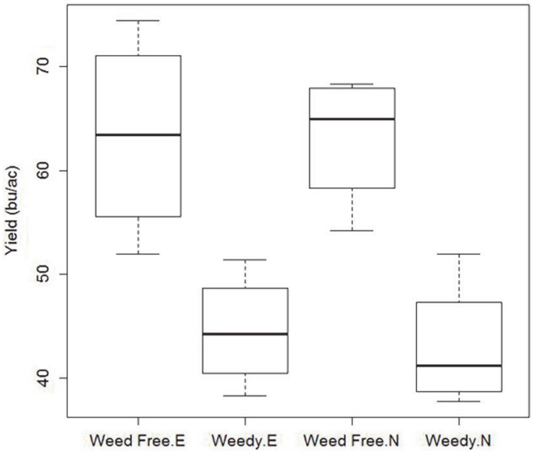


Figure 2. Effect of the crop row orientation and downy brome infestation on the median of winter wheat yield (bu/ac).

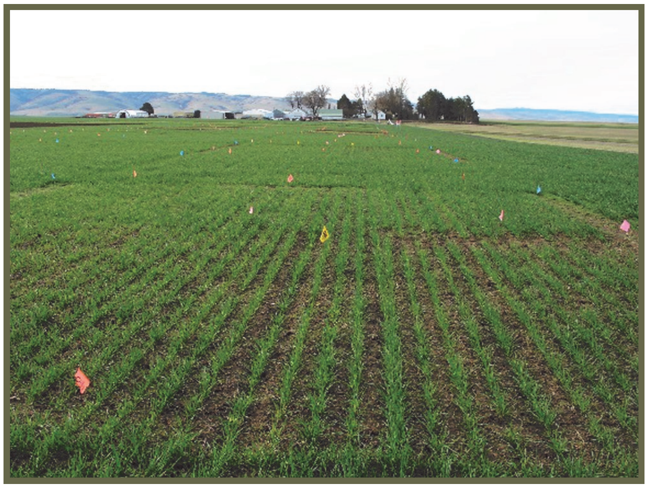


Figure 3. General view of the experiment (left) and a Downy Brome infested subplot (right).

Evaluation of Herbicides and Mowing to Control Smooth Scouringrush in Winter Wheat

DREW LYON, MARK THORNE, DEREK APPEL, JOHN SPRING, AND HENRY WETZEL
DEPT. OF CROP AND SOIL SCIENCES, WSU

A field study was established on the ground of the Spokane Hutterian Brethren near Reardan, WA to evaluate the effects of mowing and herbicides on the control of smooth scouringrush in a direct-seed system. Four of the eight blocks were rotary mowed July 24, 2014. Herbicides were applied on July 25th using a CO_2 backpack sprayer set to deliver 15 gpa at 30 psi and 3.5 mph. On September 10th, Whetstone hard red winter wheat was seeded on a 10-inch row spacing at the rate of 60 lb/acre.

Plants treated with Curtail® M, Glean® XP + Rhonox® and Permit® + Rhonox exhibited the most injury 26 days after treatment. Mowing in combination with the various herbicide treatments did not have a significant effect on smooth scouringrush control, thus treatment means are averaged over the mowing factor. All treatments except Rhonox, Curtail M, Starane® Ultra and RoundUp PowerMax® + Liberty® reduced smooth scouringrush stem counts compared to the nontreated check when evaluated on May 15, 2015. Glean XP + Rhonox was the most effective treatment in reducing smooth scouringrush stems in the spring and on the second evaluation date (August 10th), it was the only treatment that was significantly different from the nontreated check. There were no significant differences among test weight or yield (data not shown) in relation to the herbicide treatments. The average yield was 72 bu/ac.

Visit http://smallgrains.wsu.edu/weed-resources/research-reports/ for further information on this and other WSU weed control studies.

	Rate	Injury (%)	Stem counts per linear meter	
Treatment[1]	Fl oz pr/a	8/20/14	5/15/15	8/10/15
Nontreated check	—	—	38 a	38 a
2,4-D LV6	23.3	33 d[5]	22 b-d	34 a
Rhonox MCPA	34.6	55 c	32 ab	36 a
Curtail M	37.4	70 ab	30 a-c	42 a
Glean XP + Rhonox MCPA	0.5 oz + 34.6	79 a	1 e	2 b
Permit + Rhonox MCPA	1.33 oz + 34.6	67 b	23 b-d	28 a
RoundUp PowerMax[2]	32	17 e	15 d	29 a
RoundUp PowerMax + Sharpen®[2, 3]	32.0 + 4.0	10 e	21 b-d	29 a
Starane Ultra	11.2	29 d	28 a-c	36 a
Paramount®[2, 4]	5.3 oz	19 e	18 cd	30 a
RoundUp PowerMax + Liberty[2]	21.3 + 30.0	46 c	32 ab	32 a

[1] All treatments, except RoundUp PowerMax plus Sharpen, and Paramount, were applied with 90% nonionic surfactant (R-11) at 0.33% v/v.
[2] These treatments were applied with ammonium sulfate at 50 oz/A.
[3] This treatment was applied with a 99% crop oil concentrate (Agri-Dex) ay 1.0% v/v/.
[4] This treatment was applied with a 98.1% modified vegetable oil (Kalo) at 32 fl oz/A.
[5] Means within a column followed by the same letter are not significantly different at P = 0.05.

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

Effect of Volunteer Wheat on Wheat: An Option to Control It

JUDIT BARROSO[1] AND STEWART WUEST[2]
[1]COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU; [2]USDA-ARS SOIL AND WATER CONSERVATION RESEARCH UNIT

Volunteer wheat is a threat to the subsequent wheat crop because it not only may increase the probabilities of diseases and insect pests, but may interfere with the yield components of the seeded crop as well. In this work we studied the effect of volunteer wheat on the yield components of a seeded winter wheat crop. The data were collected in a no till annual winter wheat field at the Pendleton Agricultural Research Center (Fig. 1), from comparison of six places where chaff rows produced a lot of volunteer wheat to areas where there were few volunteers. Our preliminary results, with only one year of data, indicate that the areas with chaff row had, on average, 7.3 volunteer plants per square foot more than the areas without the chaff row (Fig. 2). The higher infestation in the chaff row significantly decreased the yield and yield components of the seeded crop (Fig. 3). We propose chaff collection as a promising practice to increase crop yield in those areas.

Figure 1. View of the experiment area.

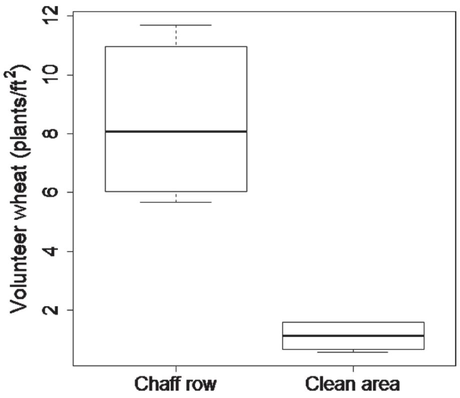


Figure 2. Presence of volunteer wheat plants in the chaff row in comparison with areas outside of the chaff row.

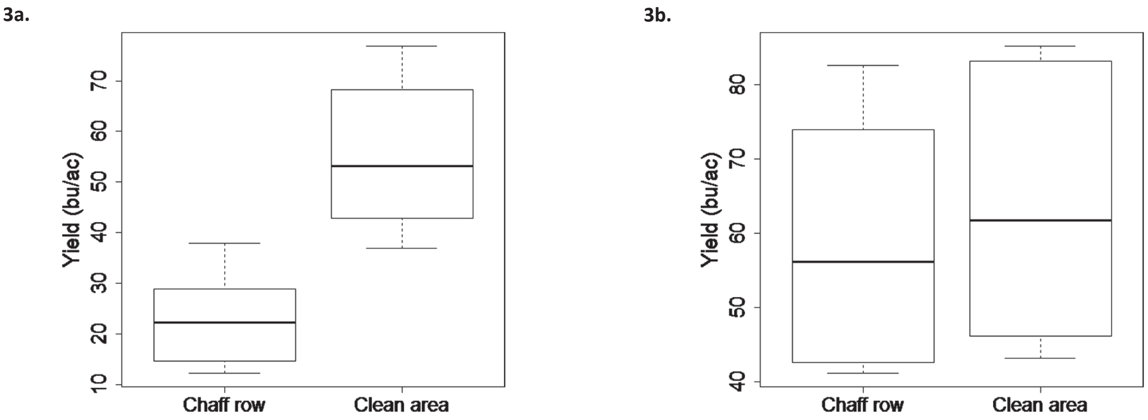


Figure 3. Effect of volunteer wheat density on seeded winter wheat yield (bu/ac).
The higher infestation in the chaff row decreased the yield and yield components of the seeded crop (Figure 3a).
However, if we consider total yield (seeded and volunteer), the difference is not significant (Figure 3b).

Soilborne Pathogen Dynamics in Long-Term Field Trials at Pendleton

Richard Smiley[1], Stephen Machado[1], Karl Rhinhart[1], Catherine Reardon[2], and Stewart Wuest[2]
[1]Columbia Basin Agricultural Research Center, OSU; [2]USDA-ARS

Most information on diseases in wheat and other rainfed field crops have been developed from short-term experiments. Few studies have defined comparative effects of management treatments in long-term experiments where multiple pathogens may have attained equilibrium within a specific cropping system.

Experiments operated continuously for up to 84 years at Oregon State University's Columbia Basin Agricultural Research Center at Pendleton are among the oldest agronomic trials in North America. The four oldest trials include a residue management and fertility trial, an annual cereals trial, a tillage intensity × fertilizer rate trial, and a winter wheat-spring pea rotation with four tillage treatments. Diseases had been monitored visually in the past but there had been no attempt to quantify the density of pathogen inoculum. Natural inoculum of 17 fungal and nematode pathogens were quantified for each of two years on eight trials using DNA extracted from soil.

Crop type, tillage, rotation, soil fertility and year, and their interactions, had large effects on the pathogens. The Fusarium crown rot pathogen *Fusarium pseudograminearum* was more dominant than *F. culmorum* where winter wheat was the only cereal crop, and the opposite occurred when spring cereals were included in a cropping system. The root-lesion nematode *Pratylenchus neglectus* was more dominant than *P. thornei* where only winter wheat was grown, and the opposite occurred when spring crops were included. The common root rot pathogen (*Bipolaris sorokiniana*) and the black root rot pathogen (*Phoma pinodella*) were restricted to the current or recent presence of spring cereals or legumes, respectively. The eyespot (strawbreaker foot rot) pathogens (*Pseudocercosporella* species) occurred in winter wheat-fallow but not in annual winter wheat. The take-all pathogen, *Gaeumannomyces graminis* var. *tritici*, was more prevalent in cultivated than in non-cultivated soils and the opposite generally occurred for the Rhizoctonia root rot pathogen, *Rhizoctonia solani* AG-8. Densities of *Pythium* species were high in many trials but were influenced by treatments. An organic spring wheat experiment with legume intercrops or cover crops had especially high concentrations of *Pythium* and *Rhizoctonia*. We detected a positive interaction between root-lesion nematodes and the fungi that cause Fusarium crown rot and Rhizoctonia root rot, and between the fungi that cause Fusarium crown rot and take-all. Depending upon crop treatment, we detected both positive and negative associations between the two species of root-lesion nematodes, and between these nematodes and the fungi that cause take-all and Pythium root rot. The DNA-based method used in this research also detected the presence of two pathogens not previously known to occur at the research center; the tan spot pathogen *Drechslera tritici-repentis* and the black root rot pathogen *Phoma pinodella*.

Influences of cropping systems on densities of fungal and nematode pathogens are clearly complex and still poorly understood. A greater understanding of pathogens and soil ecosystems is imperative for improving holistic disease management practices in field crops in the Pacific Northwest. A full report of this research is at: cbarc.aes.oregonstate.edu/plant-pathology.

Cereal Aphids, Climate Variability, and Change in the Pacific Northwest

Ying Wu, Ebrahim Sadeghi, Brad Stokes, and Sanford Eigenbrode
Dept. of Plant, Soil, and Entomological Sciences, UI

Like many insects and other cold-blooded organisms, aphids respond to weather patterns and longer-term trends in winter and summer temperatures, precipitation, and wind patterns. The ongoing warming in the Pacific Northwest (PNW), coupled with reduced precipitation in summer, could potentially change the aphid population and movement patterns in the region, influencing their potential as pests in cereal crops.

In the early 1980s, a network of 28 trapping locations was established in cereal grain production regions throughout the PNW. At each location, a suction trap was installed to sample populations of migrating aerial insects (mainly aphids). With historic downscaled climate data, we have been able to relate capture records to weather patterns and trends. This information has allowed us to investigate how intrinsic and extrinsic climatic factors influence year-to-year variation in aerial densities of these aphid species. In summary, we found that the population dynamics of three abundant aphid species (bird cherry-oat aphid, rose grass aphid and Russian wheat aphid) showed evidence of feedbacks. That is, years with high numbers of trapped aphids were regularly followed by years with low aphid numbers, indicating density-dependent mortality to aphids, whether from natural enemies, competition for winter hosts, or both. This illustrates the important point that different insect species, even very similar ones, respond differently to climatic factors.

In addition to suction traps, aphids have also been collected using pan traps across our region. Aphids collected in pan traps can reveal arrival patterns that can help assess risks from these aphids during drop development, with the potential to discern patters related to weather and other trends. We deployed these types of traps for four years as part of REACCH. As examples of these data, we provide data for four years for one site (Pullman, WA) and two aphid species, bird cherry-oat aphid and English grain aphid (Fig. 1). The figures show the continuing region-wide alternation between years in which aphids are abundant (2012 and 2014) and years in which they are less abundant (2011 and 2013). They also illustrates differences in flight phenology between the two species, with late-season flights of bird cherry-oat aphid of particular importance since these aphids are the primary vectors of *Barley yellow dwarf virus*.

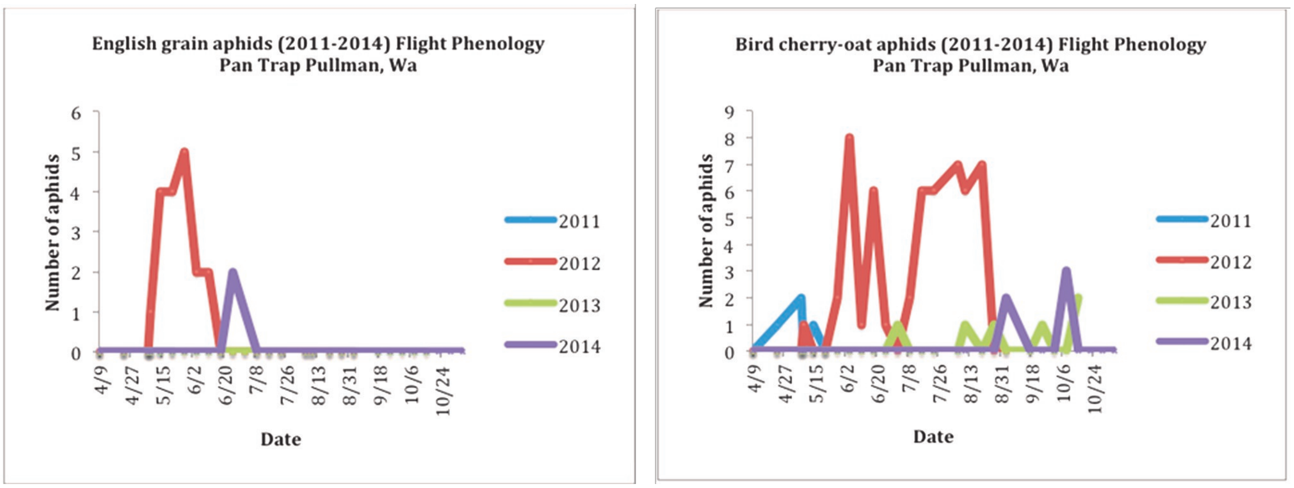


Figure 1. Flight phenology of English grain aphid, *Sitobion avenae* (Left) and bird cherry-oat aphid, *Rhopalosiphum padi*, (Right) from pan trap collections, 2011 to 2014 in Pullman, WA.

Weed Control in Pulse Crops

JOAN CAMPBELL
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Weed control is one of most challenging aspects of pulse crop production in the inland Pacific Northwest (PNW). Chickpea and lentil have short stature, slow early season growth rates and open canopy growth habits, resulting in poor competition with weeds. Weed seeds may emerge before planted crops, giving them a competitive advantage. Shallow crop seeding can hasten emergence, which aids early season competition with weeds but may also result in crop injury from herbicides. Other cultural control methods, such as increased seeding rates and delayed seeding, have shown little promise. Increasing seeding rates alone has not been shown to decrease weed density or biomass in peas and lentils. Delayed seeding can allow for mechanical or chemical control after weed seedlings emerge, but pulse crops grown in the PNW suffer great yield loss if bloom is delayed until the onset of the dry, hot season.

Few broadleaf herbicides are registered for use in chickpea and lentil compared to other legume crops. Most herbicides are pre-emergence and require rainfall for activation. However, sub-surface moisture is high in the spring and weed seeds can easily germinate without additional rainfall; thus weeds can emerge before the herbicides are activated. Most pulse crops are under dryland production where supplementary irrigation is unavailable. While some herbicides benefit from mechanical incorporation when rainfall is insufficient, much of the acreage is under reduced tillage which does not allow for incorporation. Also, some herbicides lose effectiveness under mechanical tillage, such as Lorox, which is applied to about 90% of lentil acreage. Pre-emergence herbicides either do not control weeds once they have emerged or injure emerged crops. Of the three herbicides registered for post-emergence application, all are strictly for grass control. Given the inadequate weed control in many chickpea and lentil crops, chemical desiccation with glyphosate or paraquat is often necessary to dry down weeds and crops for successful harvest.

Figure 1. Italian ryegrass in chickpea

One persistent weed problem in the cereal-pulse rotation is Italian ryegrass. It was kept in check starting in the early 1980's with Hoelon, the first Group 1 (Acetyl Coenzyme A carboxylase inhibitor) herbicide. Hoelon was eventually registered for use on all major crops grown in the rotation and was often used every year. Italian ryegrass biotypes resistant to Hoelon were found in 1992, and biotypes resistant to other Group 1 herbicides followed. Amber (Group 2, acetolactase synthase inhibitor) also was used extensively in wheat for Italian ryegrass control, and biotypes resistant to several Group 2 herbicides have increased. The continual use of Group 1 and 2 herbicides in has led to widespread cross resistance in Italian ryegrass. Resistant biotypes have been reported for Axiom, Group 15, although cross resistance has not yet been reported. Italian ryegrass can be controlled in chickpea with current labeled herbicides if resistant biotypes are not present. Pyroxasulfone (Zidua/Anthem Flex), another Group 15 herbicide, was labeled in wheat recently and may soon be labeled in pulse crops. Great caution must be taken to avoid overuse of group 15 herbicides so that our current resistant weed situation is not repeated.

Genetic Analysis and Root Phenotyping for Root Rot Resistance to *Rhizoctonia* Species

---

AARON MAHONEY[1], PAT OKUBARA[1,2], TIM PAULITZ[2], DEVEN SEE[1,2], AND SCOT HULBERT[1]
[1]DEPT. OF PLANT PATHOLOGY AND MOLECULAR PLANT SCIENCES PROGRAM, WSU; [2]USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT

Soil erosion from wind and water have long been associated with dryland wheat production in the Pacific Northwest (PNW). Efforts to decrease soil erosion have relied on conservation practices to increase crop residues on the surface of the field. This management strategy also helps to facilitate infiltration of winter rain and snow melt. However, yield losses and root rot diseases associated with soilborne pathogens that live on the plant residue have reduced its adoption. To identify wheat germplasm with resistance to these soilborne pathogens, a large screen of CIMMYT synthetic wheat germplasm was conducted in the field and greenhouse. From these screens, five lines showing varying levels of resistance were identified as having improved shoot length reduction to *Rhizoctonia* species.

To determine heritability, phenotypic variation, as well as map the loci onto wheat chromosomes, two segregating populations (Louise x SPCB-3104 and Louise x Synthetic 172) were produced by making two crosses (BC1) into the 'Louise' cultivar. Field and greenhouse screens identified three quantitative trait loci (QTL) in the Louise x SPCB-3104 BC1 population. In 2013-2015 field screens, four QTL were identified in the Louise x Synthetic 172 BC1 population. Efforts are currently under way to identify QTL associated with root morphology traits in the Louise x Synthetic 172 BC1 population.

Our current objectives are to determine the best root rot resistant traits related to shoot length reduction. Through the use of high-resolution scans and root measurement software, correlative root traits will be identified. These correlative traits will provide the necessary insights into improving root rot diseases and the associated yield losses against these economically important soilborne pathogens.

Drought Stress Alters a Host-Vector-Pathogen Interaction

THOMAS SETH DAVIS, BRAD STOKES, NILSA BOSQUE-PÉREZ, AND SANFORD EIGENBRODE
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Figure 1. Wheat seedlings 'JD' following seven days of water scarcity. BYDV-infected plants (L) were visibly more turgid and robust at the end of the experiment.

Barley yellow dwarf virus (BYDV) is a problem in wheat in some parts of the Pacific Northwest (PNW). How does this pathogen interact with another stress that can occur in the region and may become more frequent – drought stress? We tested whether drought stress alters host-virus interactions involving the vector *Rhopalosiphum padi*, bird cherry-oat aphid (BCOA), BYDV and wheat variety 'JD'. We asked: (1) do water quantity and pathogen infection interact to affect host plant growth and seed set over the life of the host plant and (2) are there consequences when plants are challenged by drought and subsequently allowed to recover? For these questions we tested two different types of water stress that climate models suggest may happen in the future: short-term water scarcity and longer-term water withholding.

There were statistically significant interactions between host infection status and water quantity when watering treatments were applied over the lifetime of the plants (e.g. until maturity). Under low water there was no significant difference in the total number of germinating seeds resulting from plant infection status, indicating a pattern consistent with higher seed set by uninfected plants at high water inputs, but no effect of pathogen infection on seed set at low water inputs. When water inputs were low, infected plants retained more water. Under long-term water stress (withholding) followed by recovery, infected plants surpassed control plants in biomass growth, seed set, absolute and relative seed germination frequency and seed mass.

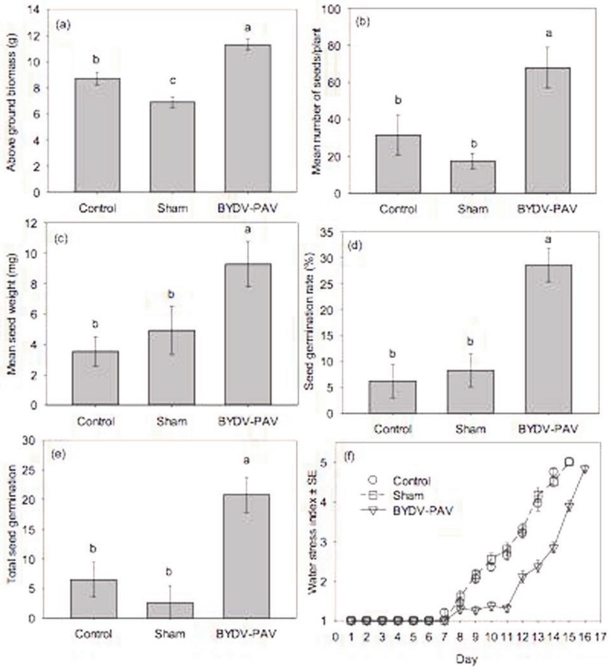


Figure 2. Wheat responses following water withholding and recovery. (1) aboveground biomass, (b) seed set, (C) seed mass, (d) seed germination frequency, and (e) total germination, after water stress. Control = not infected; BYDV-PAV = infected by aphids; Sham = aphid only.

Our results show that there is context dependency in this pathosystem. Drought may mediate disease dynamics in this system, potentially favoring coexistence of hosts, vectors and pathogens in such stressful environments. Barley yellow dwarf disease and drought are both injurious to JD wheat, but together their effects are not compounded. Instead, the infected wheat tolerates water stress better. Practical applications are limited, even if field validated, but the finding suggests that yield projections under the dual stress could be modified upward, influencing decisions about whether harvesting would be justified when these stresses coincide.

An Analysis of Predictor Variables and Sampling Dates in the Estimation of Crop Yield Loss

JUDIT BARROSO[1], ARON BOETTCHER[1], AND DANIEL LONG[2]
[1]COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU; [2]COLUMBIA PLATEAU CONSERVATION RESEARCH CENTER, PENDLETON, OR

Traditionally, most prediction models explain yield loss as a function of weed plant density. Other models predict yield loss using relative leaf area of weeds, weed biomass, or percentage of weed cover. Which of these variables predict yield loss most accurately is dependent on a variety of factors such as predominant weed types, water availability, temperature, type of crop, and time of sampling. This study is being conducted to test and compare the effectiveness of weed plant density and percentage of weed cover in predicting spring oilseed (*Brassica carinata*) and spring wheat (*Triticum aestivum*) yield losses at different sampling times (early-season, mid-season, and at harvest) in the inland Pacific Northwest. Weed density and percentage of weed cover were significant predictors of yield loss ($R^2 \leq 0.88$, $P<0.05$, see Fig. 2). Weed sampling at mid-season produced the most accurate yield loss predictions. These results indicated that the critical time to control weeds in spring oilseed might be later than that for spring wheat.

Figure 1. View of one of the plots of the experiment.

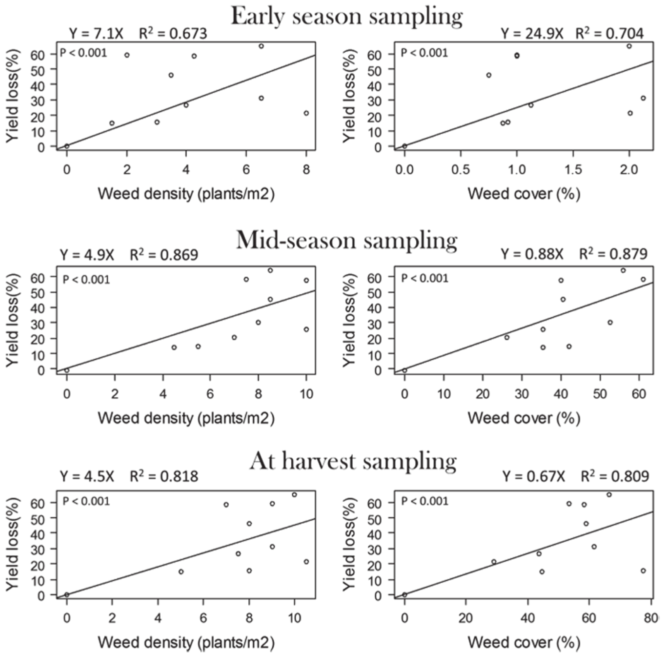


Figure 2. Relationship between weed abundance and yield loss in the different sampling times.

Variation in Root-Associated Microbial Communities of Different Wheat Varieties

AARON MAHONEY[1], CHUNTAO YIN[1], PAT OKUBARA[2], TIM PAULITZ[2], AND SCOT HULBERT[1]
[1]DEPT. OF PLANT PATHOLOGY, WSU; [2]USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT

Soil microbial communities are altered by the presence of plant roots and different root-associated microbes prefer roots of different plants species. Some of these root-associated (rhizosphere) microbes provide benefits to plants by promoting growth or suppressing other disease-causing microbes. Alterations in the communities of microbial species by different plant roots account for many of the benefits of crop rotations. There is evidence in some crops, like corn, that different varieties can even favor different rhizosphere microbes, raising the possibility that varieties could be bred to have more favorable communities of microbes on their roots or even causing soils to be suppressive to certain diseases. We therefore conducted experiments to determine if different winter wheat cultivars favor different rhizosphere bacteria.

Nine different wheat cultivars were grown on replicated plots at both the Cook Farm and the Plant Pathology Farms in Pullman. Soil closely associated with the plant roots was collected and the bacterial communities were examined by DNA sequencing of ~ 20,000 bacteria per plot. While the frequencies of most bacterial species were similar between the different wheat varieties, 25 of the species favored specific wheat varieties. We do not yet know much about most of these bacterial species, but some seem to have beneficial effects. For example, we identified a species of *Chryseobacterium* that is inhibitory to *Rhizoctonia* in lab assays and persists on roots of the variety Lewjain, but not Madsen.

We also have preliminary evidence from greenhouse experiments that some wheat lines can make soils become suppressive to Rhizoctonia root rot after two cycles of growth in the same infested soil, while other varieties do not. Current efforts are focused on determining how wheat lines affect rhizosphere bacterial and fungal communities, what types of genes control these effects, and which of the affected bacterial species help suppress various root diseases.

Stripe Rust Control and Research in 2015

X.M. CHEN, K.C. EVANS, A.M. WAN, M.N. WANG, Y.M. LIU, C.J. XIA, M. HEATH, AND J.I. COFFEY
USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT AND DEPT. OF PLANT PATHOLOGY, WSU

In 2015, stripe rust was accurately forecasted using prediction models 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. Wheat stripe rust started early and developed to significant levels on susceptible varieties in the Pacific Northwest. Yield loss due to stripe rust was determined to be 26% on susceptible wheat varieties in our experiment fields near Pullman, WA. The early application of fungicides in the commercial winter wheat fields in the central and southeastern Washington controlled stripe rust. The dry and hot summer stopped stripe rust development on spring wheat. Barley stripe rust was very low. Wheat leaf rust and barley leaf rust occurred in western Washington, but were absent in eastern Washington. Stem rust of wheat and barley was not observed in Washington. In contrast to the relatively low stripe rust in the western U.S., wheat stripe rust was widespread and caused severe yield losses in the Great Plains and eastern states, with national yield loss estimated as over 165 million bushels or 8% of production, the highest in record. From 370 stripe rust samples collected from 21 states, we identified 32 races of the wheat stripe rust pathogen, 3 races of the barley stripe rust pathogen, and determined their distributions and frequencies in the country, each state, and each epidemiological region. Five of the wheat stripe rust pathogen races were new. We developed more than 100 single-nucleotide polymorphism markers for the stripe rust pathogen and used the markers to characterize the stripe rust pathogen populations in the different epidemiological regions in the U.S. and identified markers associated to virulence genes. We evaluated 29,860 wheat and 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 releasing three wheat varieties (WA 8180, WA 8193, and 4J071366C) and one barley variety (09WA265.5), and registered three wheat varieties and two barley varieties. In 2015, we published six papers on molecular mapping of 32 quantitative trait loci or genes for resistance to stripe rust. We completed studies of mapping stripe rust resistance genes in four populations of wheat crosses, and made progress in phenotyping and advancing generations for ten crosses. We made new crosses with 40 winter wheat varieties that have shown excellent resistance to stripe rust to identify and mapping new resistance genes. We developed 26 wheat lines carrying individual or combinations of stripe rust resistance genes that were recently identified in our program. We tested 19 fungicide treatments in fields for control of stripe rust; and 24 winter and 16 spring wheat varieties for their yield loss and fungicide response. The results and resources from our research have been used to develop stripe rust resistant varieties, registering new fungicides, and guiding the control of stripe rust.

Integrated Management of Insect Pests in Cereal Crops

DAVID CROWDER[1], DIANA ROBERTS[2], DALE WHALEY[2], AND STEVE VAN VLEET[2]
[1]WSU ENTOMOLOGY; [2]WSU EXTENSION

Cereal crops are attacked each year by multiple insect including wireworms, multiple species of aphids (which transmit pathogens such as barley yellow dwarf virus and cause direct feeding injury), and Hessian fly. Occasional pests include grasshoppers, cereal leaf beetle, the wheat head armyworm complex, and wheat midge.

For many pests we lack the knowledge of their biology, phenology, and damage potential needed to make sound management recommendations. Moreover, because there is limited monitoring of many of these insect pests, outbreaks can occur with little warning. ***We are addressing these issues by developing an integrated approach to monitoring multiple insect pests in cereals and generating information on economic damage they cause.*** Our three objectives are: (1) monitor the range and severity of insect pest infestations throughout the dryland cereal production region, (2) use monitoring data to estimate economic thresholds, and (3) communicate results through the small grains website and presentations at grower events.

In 2015, with preliminary funding from WSU Extension we established a network of cereal fields (wheat and barley) for monitoring insect pests throughout the dryland production region. We are seeking funding to continue this network. We had two sampling "routes", one in southern Washington (Walla Walla, Columbia, Asotin, Garfield, and Whitman counties) and one in northern Washington (Whitman, Adams, Lincoln, Stevens, and Spokane counties). Each route contains 10 fields dispersed throughout the region, for a total of 20 fields sampled weekly.

In each field we conduct weekly monitoring for a suite of insect pests: (1) aphids; (2) Hessian fly; (3) wheat midge; (4) wheat head armyworm (WHA); (5) cereal leaf beetle (CLB); and (6) grasshoppers. Wireworms are also monitored early in the season (when they are most active) in another project run by PI Crowder.

The data for each pest are published weekly to www.smallgrains.wsu.edu. We use geographical information systems (GIS) models to predict pest densities throughout the region. Inverse-distance weighting (IDW), is a procedure that interpolates pest densities based on observations from our 20 sampled fields. IDW predicts pest densities at un-sampled locations by taking the weighted average of densities from nearby fields, with closer fields weighted more heavily than distant fields.

An example of IDW with a hypothetical pest distribution is shown in Figure 1 (**note that the area covered in our sampling network is broader than shown**). Maps are colored to show three categories of infestation: (1) none – pests not present; (2) low risk – pests present at low rates, likely below economic thresholds (i.e., treatment not recommended but growers should sample their fields); and (3) high risk – pests likely occurring at densities requiring treatment.

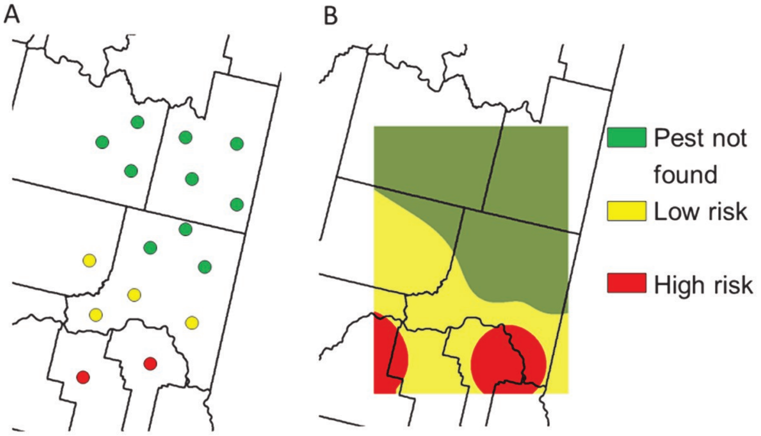


Figure 1. Example output of an insect monitoring network that shows how insect pest densities from sampling locations (A) are used to predict densities across a region (B).

Update on a New Aphid in the Pacific Northwest

THOMAS SETH DAVIS, EBRAHIM SADEGHI, BRAD STOKES, YING WU, AND SANFORD EIGENBRODE
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

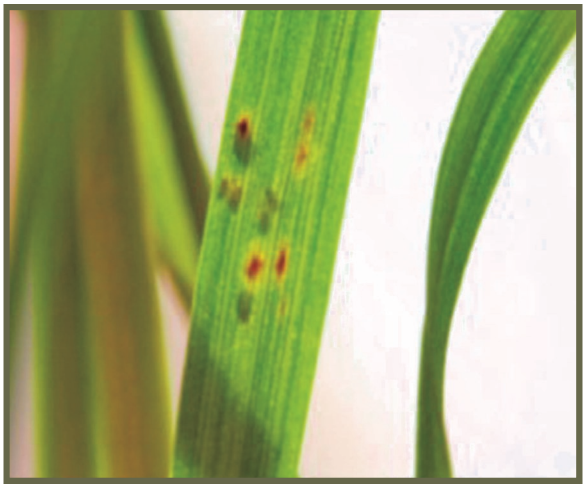


Figure 1. Example of feeding injury caused by MFC; on some hosts it can cause a red staining, as shown here. Photo by Brad Stokes.

Aphid sampling efforts around the Pacific Northwest (PNW) conducted as part of the Regional Approaches to Climate Change (REACCH) project, discovered a newly invasive aphid to North America in large numbers at dozens of sites in 2011. The aphid, *Metopolophium festucae cerealium* (MFC), is evidently native to Great Britain and little is known about its ecology and potential as a pest here in the PNW. Although MFCs average numbers per sweep net sample have declined in 2014 (compared to 2013), MFC is still abundant, constituting more than half of all aphids sampled in wheat fields. MFC can cause reddish staining around feeding sites on wheat leaves, a type of injury not caused by most other aphids in our region (Fig. 1). As part of REACCH, we have established a laboratory colony to allow us to conduct experiments to learn more about its biology. In a multiple-choice experiment, MFC aphids prefer to settle on wheat and avoid corn, but they will also settle on barley, oat, and several grasses native to the PNW (Fig. 2). When confined on these plants, MFC reproduction is high on wheat and barley, intermediate on oat and blue wild rye, and poor on Idaho fescue, rough fescue and blue bunch wheatgrass.

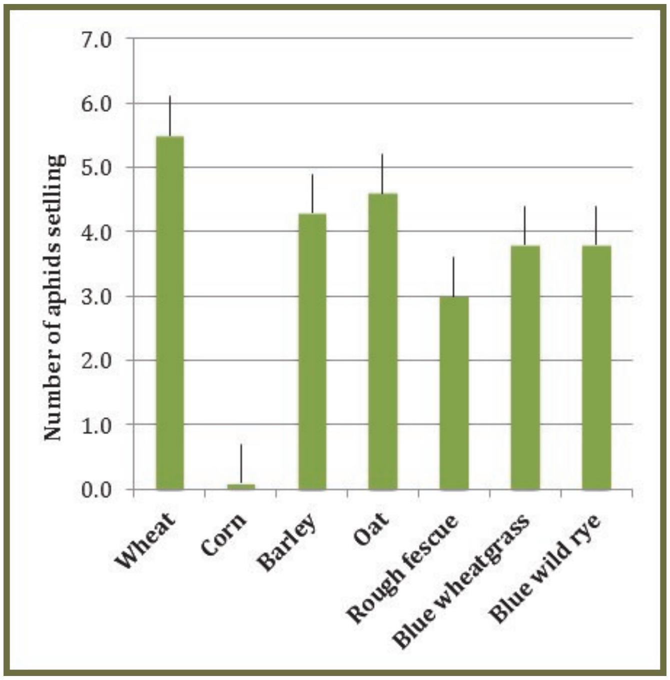


Figure 2. Response of MFC to cultivated and native grasses of the PNW. Number of aphids settling on each species when presented with all seven host plants in a choice test.

It has not been established whether MFC causes more direct injury per aphid than other aphids in our region, but preliminary observations, such as the leaf discoloration, suggest that it does. In one greenhouse trial, MFC caused as much injury to plant growth as the Russian wheat aphid. On the other hand, based on our published study, MFC is not a vector of a prevalent Barley yellow dwarf virus isolate (BYDV-PAV). In single-aphid and multiple-aphid caged tests on 'Lambert' wheat MFC was unable to transmit BYDV-PAV. Whether the aphid can transmit the rarer BYDV isolates has yet to be determined. Still, based on the direct injury results so far, producers should be attentive to the presence of this aphid.

Predicting and Monitoring Weed Distributions in Dryland Wheat Using Landsat Data

JUDIT BARROSO[1], ARON BOETTCHER[1], AND DANIEL LONG[2]
[1]COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU; [2]COLUMBIA PLATEAU CONSERVATION RESEARCH CENTER, PENDLETON, OR

Weeds are a serious management issue in the U.S., causing an estimated $136 B in crop damage each year. An estimated $20 B is spent annually in attempted control. Remote monitoring of weeds can provide information about long term changes in weed distribution, helping inform management practices and estimates of regional crop yields. Despite this, we have thus far lacked the ability to detect, map, and monitor weeds at spatial scales relevant for decision-making. This inability is partly due to the prohibitively high cost of reference data over broad geographic ranges and environmental conditions.

This study examines the potential of hyperspectral on-combine sensing as a source of reference data for mapping weed species distributions in dryland wheat. We compare on-combine visual assessments of weediness with hyperspectral measurements made during the harvest of a 17 acre field of dryland spring wheat in the Columbia Basin (Fig. 1 and 2). The objective of this study was to use these two sources of reference data as the basis for developing a model predicting weed distributions in Landsat 8 imagery. In comparing these two methods of generating reference data to map green weed distributions, the highest correlation was found between NDVI at the time of harvest and medium and high density visual weed observations. A good linear relationship ($R^2 = 0.685$, $p < 0.001$) was found when comparing NDVI values from the satellite image with visual medium and high density weed observations. Hyperspectral measurements made in the grain stream did not perform as well as visual estimates for predicting weeds distributions in satellite images.

Figure 1. Ground reference measurements of weed density obtained from a combine harvester.

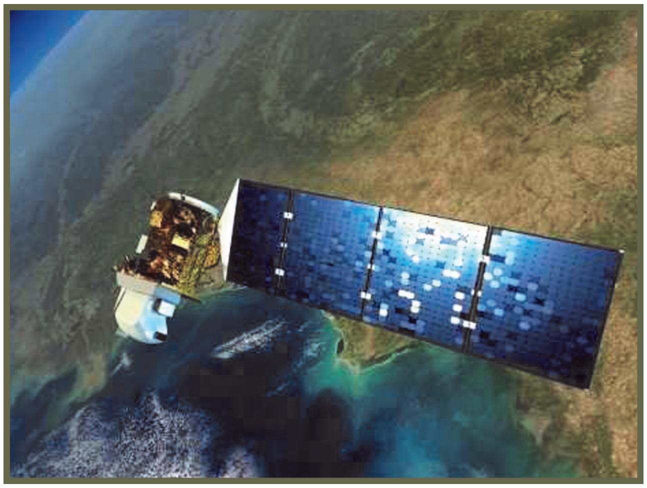


Figure 2. Landsat 8 providing multispectral image data at 30 m spatial resolution and 16 day repeat coverage.

Phenotyping for Root Rot Resistance

PAT OKUBARA[1,2], AARON MAHONEY[2], SCOT HULBERT[2], AND KAREN SANGUINET[2]
[1]USDA-ARS ROOT DISEASE AND BIOLOGICAL CONTROL; [2]DEPT. OF PLANT PATHOLOGY AND MOLECULAR PLANT SCIENCES PROGRAM, WSU

Current screens for *Rhizoctonia* resistant wheat incorporate both field trials and greenhouse assays, but *Rhizoctonia* levels in the field can be difficult to reproduce from year to year. We are exploring endogenous early seedling root growth phenotypes as predictors of *Rhizoctonia* resistance in Pacific Northwest wheat lines. Recent screens have produced five promising synthetic or synthetic-derived wheat lines showing enhanced growth in the presence of *R. solani* AG-8. These new lines provide much-needed genetic resources for comparing root growth in resistant and susceptible wheat. Total root length in the presence of the pathogen, quantified using digital images of roots and the pixel-counting WinRHIZO software (Regent Instruments, Quebec, Canada), is strongly correlated with disease resistance in the EMS mutant Scarlet -Rz1. This has been confirmed for resistant and susceptible recombinant inbred lines of crosses between cv. Louise (susceptible) and synthetic-derived SPCB 3104, or SYN 172 (resistant). However, other root growth variables that are obtainable within 14 days at low cost are also of interest. These include the timing and uniformity of root emergence from imbibed seed, the rate of early root growth, and seminal root branch angle. Seminal root angles, as well as lateral root branch angles, will be quantified from seedlings grown against the inner walls of transparent pots; using this method, *Rhizoctonia* or other pathogens can be added to the soil to determine effects on branch angle and lateral root development. Phenotypes of mature roots include lateral root number, branching pattern, root hair number and other architecture traits. Preliminary experiments indicated that wheat seedling roots grow well in the gellan gum-based clear medium GelZan (Phytotech Labs). When combined with 360° imaging (Ortery Technologies), seedling root architecture can be assessed in three dimensions and quantified using GiaRoots software. We are deploying the CI-600 i*n situ* root imaging system to examine mature root phenotypes both in the field and in greenhouse soil. Cooperators: Drs. Tim Paulitz and Deven See.

Raul Arroyo from the Sanguinet lab acquiring a 360 scan window of a minirhizotron tube using the CI-600 root scanner in a wheat plot at the Lind Dryland Research Station.

Part 3. Breeding, Genetic Improvement, and Variety Evaluation

Washington Extension Cereal Variety Testing Program

RYAN HIGGINBOTHAM[1], VADIM JITKOV[2], AND ANDREW HORTON[2]
[1]WSU EXTENSION; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

The WSU Extension Cereal Variety Testing Program provides growers, the agribusiness industry, university researchers, and other interested clientele with comprehensive, objective information on the adaptation and performance of wheat and barley cultivars across the various climatic regions of eastern Washington. The Cereal Variety Testing Program conducts comparisons using scientifically sound methodology, produces independent results, disseminates all data to clientele, and uses uniform testing procedures across common locations. The evaluation trials are conducted at many locations: 22 for soft white winter and 13 for hard winter wheat; 18 for soft white and hard spring wheat; and 12 for spring barley. Trial results are available in printed form in *Wheat Life* and the Cereal Variety Testing Annual Report. Comprehensive results for last year and many previous years can be found on the Variety Testing Website (http://variety.wsu.edu). Variety performance data is provided within days after harvest via the program website and an email list-serve. Oral presentations, field days, and industry and extension meetings are other means used for delivering research results. Growers and interested parties are welcome to visit the testing sites whenever they'd like. Plot maps are available on the program website and can also be found attached to the large Variety Testing signs at each trial location.

An additional method that growers may use to access data generated by the Variety Testing program is through the Variety Selection Tool, located on the small grains website (http://smallgrains.wsu.edu). The small grains website was launched in early 2014 by our small grains Extension team and aims to provide growers with a one-stop place to find current information about small grain production in the region. The Variety Selection Tool is based on two years of results of variety performance data from the variety trials along with other variety characteristics from multiple sources. Users are able to select a market class of grain, along with a precipitation zone, and an interactive table is populated with varieties and their performance within that precipitation zone. Information available includes yield, test weight, protein, plant height, disease ratings, maturity and more!

Progress of Soft White Winter Wheat Breeding at University of Idaho Campus

YUEGUANG WANG[1], PAUL MCDANIEL[1], AND JEAN-BRUNO BEAUFUMÉ[2]
[1]DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI; [2]LIMAGRAIN CEREAL SEEDS

The soft white winter wheat (SWWW) breeding program at the University of Idaho collaborates with Limagrain Cereal Seeds (LCS). Program objectives include: 1) Developing new SWWW cultivars with increased yield, improved agronomic traits, abiotic tolerance, disease resistance, and superior end-use quality. 2) Improving the level of disease resistance in the SWWW program's germplasm. 3) Developing and evaluating lines with herbicide resistance to be used as a tool to control grassy weeds in wheat using Clearfield technology (IMI trials). The methods used in the SWWW breeding program have included conventional wheat breeding methods, double haploid (DH) and molecular marker analysis. F_1 crosses were made in the greenhouse on the UI campus. More diverse parents were used to make crosses, including backcrosses and 3-way crosses in order to broaden the genetic base. Early generations, such as F_2, F_3, and F_4 were planted in Moscow, Genesee and Walla Walla. Advanced generations such as F_5 and F_6 were planted in Idaho Yield Trials at locations in Idaho and Washington. Excellent elites were selected for Variety Testing Trials and Western Regional Trials.

One SWWW variety, UI-WSU Huffman, was released in 2014. UI-WSU Huffman is a soft white winter release co-developed between the University of Idaho and Washington State University. Named after the late Bradley Huffman, this variety has shown an excellent adaptation to rain-fed areas of Idaho and Washington. Along with excellent quality and high test weight, this new release has good resistance to C-stripe, crown rot, soil-borne wheat mosaic virus and stripe rust.

Three 2-gene IMI Clearfield Plus varieties, UI Castle CL+ (09-DH10), UI Magic CL+ (09-DH11) and UI Palouse CL+ (3_5_10), have been prepared for release. Studies in northern Idaho demonstrated that UI Palouse and UI Magic have very similar performance, both approx. 8-10 bu below conventional check varieties. UI Castle is less competitive in this region. In southern Idaho under irrigation, UI Magic is the clear choice at 131.7 bu/ac, only 6-7 bu below conventional check varieties. Under dryland conditions in southern Idaho, limited data indicate UI Castle has the best yield at only 1-2 bu below the check varieties. In Oregon, UI Magic was the best overall performer. In Washington (LCS data), UI Magic showed the best performance, superior to ORCF102. Other Clearfield Plus varieties were very similar, slightly below the level of ORCF102. In summary, all three varieties have agronomic merit in various parts of the PNW region, but UI Magic is superior in most circumstances.

In 2015, five excellent elites (01-10704A, 02-29001A, 06-18102A, 06-03303B and 07-28017B) were selected for Western Regional Trials, state variety trials, and the UI-LCS trial network. A total of 36 elite lines selected for Idaho Yield Trials were grown in southern Idaho (Aberdeen), northern Idaho (8 locations) and Washington state (6 locations). A total of 72 F_6 breeding lines, 680 F_5 breeding lines, 56 F_5R breeding lines and 60 double haploid breeding lines were selected for yield trials at different locations in Idaho and Washington. A total of 7800 F_4 head rows, 120 F_3 bulk populations, 212 F_2 bulk populations and 794 F_1 crosses were planted in the field or greenhouse in Moscow for ongoing wheat-breeding projects.

Winter Wheat Breeding and Genetics

A. CARTER, G. SHELTON, K. BALOW, AND A. BURKE
DEPT. OF CROP AND SOIL SCIENCES, WSU

The Winter Wheat Breeding and Genetics Program at Washington State University remains committed to developing high yielding, disease resistant, and high end-use quality cultivars for release to maintain sustainability of production. We 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 2015, crusting events in the <12” rainfall zones of the state allowed good selection of lines with excellent emergence capabilities. Good snow cover also has allowed for snow mold tolerance to be screened this year, although we had limited ability to screen for cold tolerance under field conditions because of it. 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 and we are developing models to select breeding lines using the entire genome instead of one or two markers. We have completed a lot of research on identifying markers throughout the wheat genome with traits associated with disease resistance 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 finalizing our systems of high-throughput phenotyping to make it ready for selecting in the breeding program. A new USDA grant will allow us to fully implement this selection for identification of superior lines. 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 available for certified seed purchase. This line is a soft white wheat targeted to the high rainfall zones of the state and particularly eastern Whitman county. Puma maintains a very high yield potential overaged over multiple years in both the >20” rainfall zone and the 16-20” 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 on registered seed increase. This line is a soft white winter wheat, which appears to be broadly adapted to multiple rainfall regions of the state. In the 2014 and 2015 Variety Testing trials, Jasper (WA8169) was in the top significance group for yield potential in all rainfall zones. 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, although test weight did drop a little bit. 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 could replace this line, along with others, for production in the intermediate to high rainfall zones of the state.

Sequoia (WA8180) was released in 2015 and is currently under foundation seed increase. 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 lines has average protein content, good test weight, good stripe rust resistance, and very good end-use quality.

Two other lines, **Sprinter** (hard red winter) and **Earl** (hard white winter) are grown on limited acres under special license agreements. Contact Washington Genetics for more information on these lines.

Testing Winter Wheat Variety Mixtures (Blends) for Improved Yields and Disease Management

---

VALTCHO D. JELIAZKOV (ZHELJAZKOV)[1] AND CHRISTOPHER C. MUNDT[2]
[1]DEPT. OF CROP AND SOIL SCIENCE, OSU; [2]DEPT. OF BOTANY AND PLANT PATHOLOGY, OSU

Wheat variety blends (mixtures) have become increasingly popular among growers in eastern Oregon. Some seed suppliers reported that around 30% of seed sold in 2014/2015 was blends. Some of the blends were developed by seed suppliers, while others were put together by individual growers following their experiences and specific environmental conditions. Blends have been reported to outperform single varieties with respect to disease resistance and resiliency to unfavorable environmental conditions (Castro 2001; Mundt 2002). The hypothesis of this study was that 2-way blends of winter wheat varieties may outperform single varieties with respect to grain yield and disease resistance. Two field studies were set up in Fall 2015 at CBARC. The first field study includes 10 treatments (combinations) of the varieties Rosalyn, WB 1529, ArtDeco, and Trifecta II (Table 1). This study was set up at two locations; Pendleton, and Moro. The second study involves 10 treatments (combinations) of Clearfield varieties ORCF 101, ORCF 102, WB 1070CL, and Curiosity and is being conducted at Moro (Table 2). Plot sizes are 16 ft x 100 ft in Moro and 10 ft x 100 ft at Pendleton. The trials are both demonstration and research and will provide local growers with important practical information about the performance of some of the most promising winter wheat varieties in blends.

Table 1. Entries in winter wheat variety blend trial at Moro and Pendleton.

1. Rosalyn
2. WB 1529
3. ArtDeco
4. Rosalyn + WB 1529
5. ArtDeco + Rosalyn
6. WB 1529 + ArtDeco
7. Trifecta II
8. Trifecta II + Rosalyn
9. Trifecta II + WB 1529
10. Trifecta II + ArtDeco

Table 2. Entries in Clearfield winter wheat blend trial in Moro.

1. ORCF 101
2. ORCF 102
3. WB 1070CL
4. Curiosity
5. ORCF 101 + ORCF 102
6. ORCF 101 + WB1070CL
7. ORCF 102 + WB1070CL
8. ORCF 101 + Curiosity
9. ORCF 102 + Curiosity
10. WB 1070 CL + Curiosity

References:

Castro, A. 2001. Cultivar Mixtures. The Plant Health Instructor. DOI: 10.1094/PHI-A-2001-1230-01. Revised 2007.

Mundt, C.C. 2002. Use of multiline cultivars and cultivar mixtures for disease management. Annual Review of Phytopathology 40: 381-410.

Functional Cloning of the Barley High-Grain Lysine Content *Lys3* Gene

SACHIN RUSTGI[1,2], DITER VON WETTSTEIN[1,2], JANET MATANGUIHAN[1], YUE SUN[1], XIUFANG OU[1], NUAN WEN[1], RICHA GEMINI[1], KEVIN M. MURPHY[1], AND PATRICK REISENAUER[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]MOLECULAR PLANT SCIENCES, WSU

All cultivated barley worldwide is deficient in an essential amino acid lysine. Improving grain lysine content in barley will add value to the crop by alleviating the need for lysine fortification in feed, which is expected to cut down on the cost, and project barley as the preferred feed grain over other available choices. In this connection the Danish breeders produced a number of high-lysine barley mutants during 1960-70s. But despite of several attempts, were unsuccessful in dissecting the yield penalty associated with the only agronomically relevant (having 44% more lysine than wild type) high-lysine barley mutant Risø 1508 (*lys3a*). The possible reasons behind the unsuccessful attempts were either the size of the primary mutation (encompassing more than one gene), its tight association with other undesirable background mutations or its pleiotropic negative effect on grain carbohydrate and b-glucan (dietary fiber) content in addition to its primary effect on the grain lysine content. However, the later possibility was dismissed by the development of barley varieties Lysimax, Lysiba, and Piggy with some improvements in grain plumpness, starch content and yield. Due to limited availability of genomic resources at the time, the gene responsible for the high grain lysine content in Risø 1508 could not be cloned and characterized, and its wider application in barley breeding remained obstructed. Moreover, miss-localization of the *Lys3* locus on barley chromosome 5H compounded the problem, which recently got resolved by us jointly with our German collaborators.

The resurging interest in this mutant is not only due to its high nutritive value, which is suggested to be close to the milk protein, but also due to its low immunotoxicity for the celiac patients. It has been demonstrated that the observed increase in lysine content of Risø 1508 is a consequence of 66% decrease in the amount of immunogenic prolamins (hordeins) and a compensatory increase in the amount of other balanced grain storage proteins and free amino acids. In particular, B- and C-hordeins that comprise >90% of hordeins are exceptionally lysine poor and known sources of celiac causing epitopes, are diminished in this mutant. Inferentially, Risø 1508 that is low in hordeins and high in lysine content is good for brewing reduced-gluten beer, development of celiac-safe foods products and high-lysine feed for monogastric animals. In view of the multifaceted benefits of using Risø 1508 in barley breeding, the major objective of the present research is to fine-map and clone gene responsible for the high grain lysine content in this mutant line. Cloning of the *Lys3* gene from Risø 1508 will also establish the possibility that the observed defect in starch accumulation in the mutant grains is separable from the beneficial effect on the lysine content.

For fine mapping of the *Lys3* gene a near-isogenic line (BW496) in Bowman background is crossed with Bowman and Golden Promise. The DNA markers flanking the region of interest will be evaluated in 2000 F_2s to identify recombinants. The identified recombinants will be genotypes with 27 additional DNA markers known to map within the region. This exercise will allow identification of more recombinants in the target region, which will bring us closer to the gene of interest. The process will be continued until a limited number of candidate genes will be identified whose function can be confirmed by gene silencing. Total grain nitrogen content of the F_4 grains derived from selected F_3 plant will be measured using the standard Kjeldahl procedure, and the grain lysine content will be determined by examining dye-binding capacity of proteins.

Looking at Falling Numbers and Sprouting Scores to Determine Preharvest Sprouting Susceptibility and Tolerance in PNW Winter Wheat

SHANTEL A. MARTINEZ[1,3], REHANA S. PARVEEN[3], KIMBERLY A. GARLAND CAMPBELL[2,3], ARRON H. CARTER[1,3], AND CAMILLE M. STEBER[1,2,3]
[1]MOLECULAR PLANT SCIENCES, WSU; [2]USDA-ARS; [3]DEPT. OF CROP AND SOIL SCIENCES, WSU

Preharvest sprouting (PHS), the germination of grain on the mother plant under cool and wet conditions, is a reoccurring problem for wheat farmers worldwide. PHS susceptibility can lead to degradation of starch granules, which results in low Falling Numbers (FN). PHS tolerance is also associated with higher grain dormancy, the inability to germinate even under favorable conditions. The spike wetting test mists intact spikes after the grain is physically mature and measures genotypic germination potential, if a rain event were to occur. In 2015, a mild rain event occurred in Pullman, lower FN of harvested grain after the cool and wet conditions (Fig. 1A). However, the heat in Central Ferry did not reduce overall FN of the same exact genotypes (Fig. 1B). In addition, spikes were harvested at physiological maturity (before any rain events) and tested for sprouting scores after 5 days of misting (Fig. 1C, D). The two different environments show different distributions of sprouting scores over the same genotypes, suggesting that environments have a big effect on grain dormancy. Lastly, named varieties have a wide variation of FN in Pullman 2015 (Fig. E). Future work on this project will include association mapping of these two PHS traits which will hopefully identify loci contributing to PHS tolerance and susceptibility in the WSU Winter Wheat and USDA-ARS Club Wheat breeding programs.

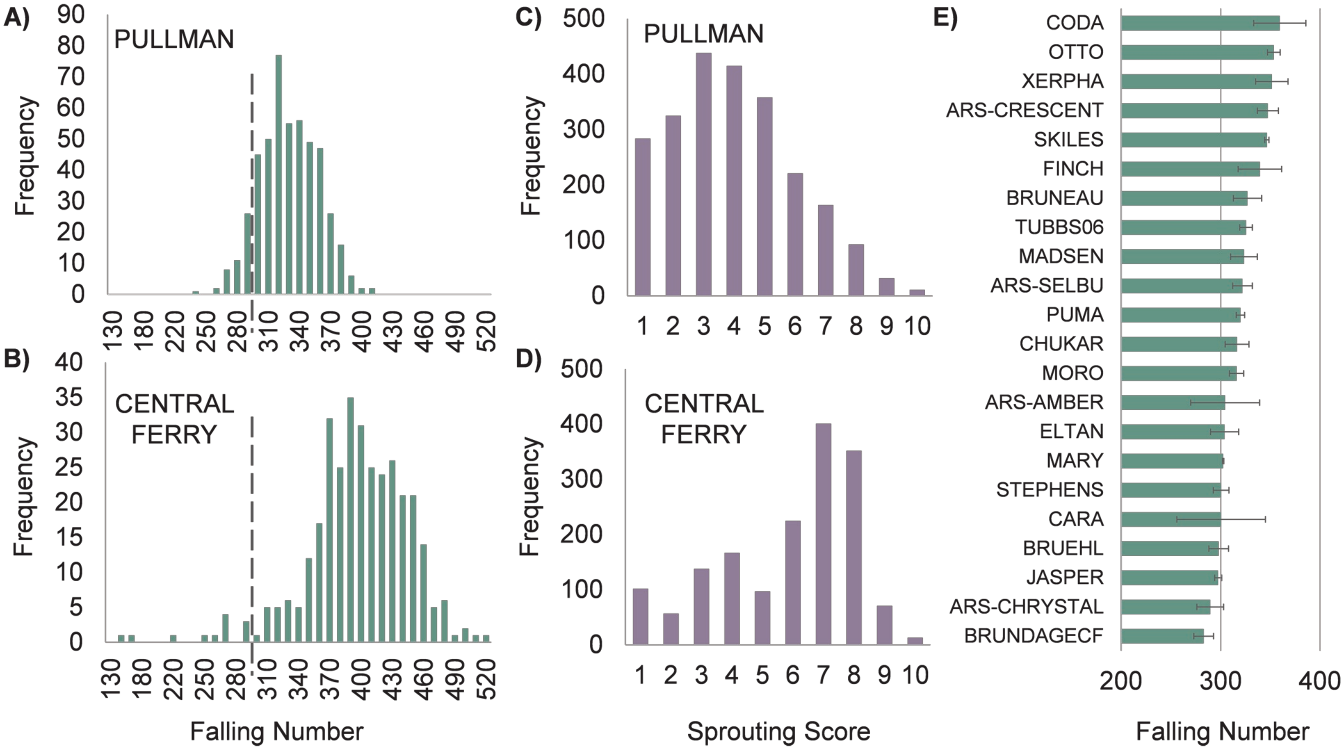


Figure 1. PHS traits conducted on genotypes from WSU's Winter Wheat and USDA-ARS Club Wheat breeding programs. Histograms of the Falling Number (FN) test are reported for 480 winter wheat lines selected from the 2 breeding programs in 2015; harvested in Pullman (A) and Central Ferry (B). The dash bar references 300 seconds. Histograms of the spike wetting tests are also shown from harvest locations: Pullman (C) and Central Ferry (D). E) The 2015 Pullman FN of select PNW wheat varieties. Raw means from 2 technical reps and standard deviations are reported.

Varietal Response of Soft White Winter Wheat to Nitrogen Fertilizer and Seeding Rate

COLE SENEFSKY, DAVID WHITE, AND KURTIS SCHROEDER
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

New cultivars and sources of germplasm for soft white winter wheat are continually being introduced to growers in the Pacific Northwest region, offering improved yields, superior disease resistance packages and better quality compared to older varieties. While current seeding and nitrogen fertilizer recommendations are useful guides, some of these new varieties may respond differently to seeding rate and nitrogen fertilizer. This study focuses on ten newly released cultivars and advanced germplasms that may soon be released: UI-WSU Huffman, UI Magic CL+, Brundage 96, IDN01-10704A, IDN02-29001A, SY-Ovation, LCS Biancor, LCS Artdeco, LCS Drive, and LWW10-1073. Cultivars were grown using four nitrogen rates (1.5, 2.0, 2.5 and 3.0 lb N/bu expected yield) and three seeding rates (0.6, 0.8 and 1 million/A) at locations near Genesee and Reubens in northern Idaho. Overall yields were 110 and 76 bu/A for Genesee and Reubens, respectively. With increasing nitrogen rate, there was a corresponding increase in yield with a range of 96 to 120 bu/A for Genesee and 63 to 84 bu/A for Reubens (Fig. 1). While most varieties did not respond favorably to the highest rate of nitrogen in Reubens, UI Magic CL+, SY-Ovation and LCS Biancor gained additional yield. In Genesee, the majority of varieties had the highest yields corresponding to the highest nitrogen rate, with only IDN01-10704A, UI/WSU Huffman and Brundage 96 not responding to the extra nitrogen.

While higher yields may be observed with increasing nitrogen rates, this may be offset by higher protein and lower test weights. Protein percentage dramatically increased as the nitrogen rate increased. Grain protein at Genesee ranged from 9.5% to 12%. At Reubens, grain protein was lower, ranging from 7.8% to about 12%. Test weights for both locations decreased as the nitrogen rates increased. Seeding rate had very little impact on yield or quality at either location.

Trials are currently being repeated to verify the variety responses. Information gained from this study will aid in the potential development of variety-specific recommendations, which could lead to additional gains in yield and/or savings in inputs and increase the profitability of growing these varieties.

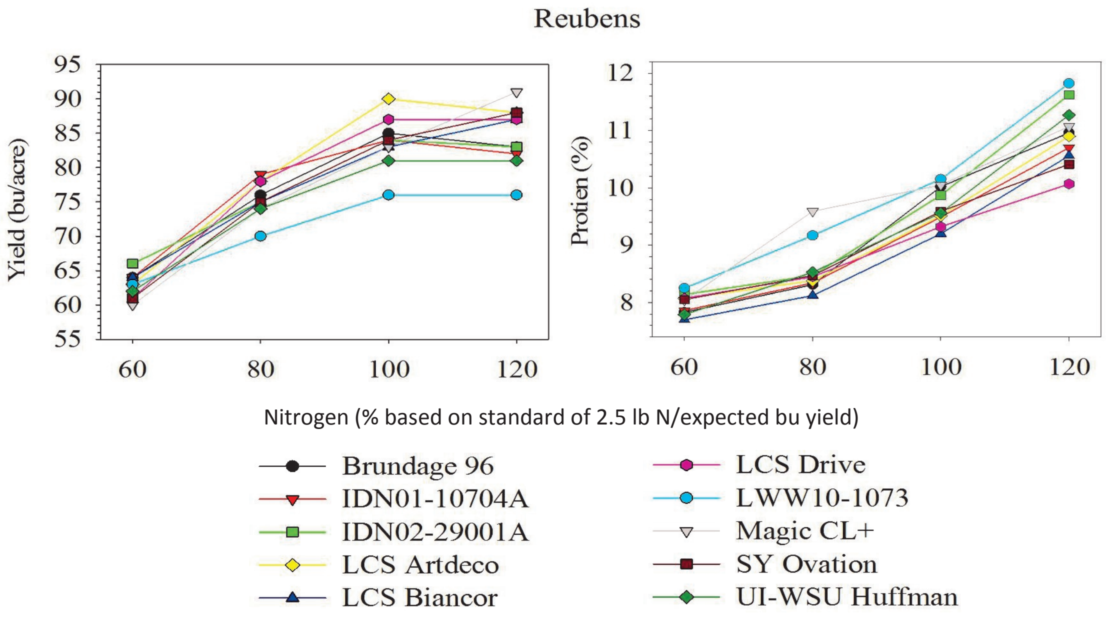


Figure 1. Yield and protein for wheat growers in Reubens, ID at four nitrogen rates.

The USDA-ARS Western Wheat Quality Laboratory

Craig F. Morris, Director; and Doug Engle

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://www.wsu.edu/~wwql/php/index.php provides great access to our research. Our research publications are readily available on our web site.

Our current research projects include soft durum wheat, grain hardness, arabinoxylans, puroindolines, polyphenol oxidase (PPO), waxy wheat, and quinoa. Our recent publications include an article on soft kernel durum wheat published in Cereal Foods World. Research on use of a student's t statistic as a phenotype of relative consumption preference of wheat grain was published in the Journal of Cereal Science. A study modeling end-quality in United States soft wheat germplasm was published in Cereal Chemistry. Research on the internal structure of carbonized wheat grains and the relationship to kernel texture and ploidy was published in Vegetation History & Archaeobotany. A study on arabinoxylan content and characterization throughout the bread-baking process was published in the International Journal of Food Science and Technology. Three book chapters on wheat grain uses and quality attributes were published in the Encyclopedia of Food Grains. Other research includes extrusion characteristics, thermal and rheological properties of waxy soft white wheat flour; tracking arabinoxylans through the preparation of pancakes; the effect of soft kernel texture on the milling properties of soft durum wheat; and quinoa seed quality research. Currently the lab is working on grant-funded research aimed at removing the culinary constraints of soft kernel durum wheat, a genetically rich cereal species. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Bobtail, ARS Selbu, Curiosity CL+, Mela CL+, Otto, Puma, and Sprinter.

In situ Imaging of Root Architecture to Improve Drought Tolerance in Spring Wheat

Bikash Ghimire, Raul Arroyo, and Karen A. Sanguinet
Dept. of Crop and Soil Sciences, WSU

Drought is a predominant abiotic constraint to successful wheat production in Washington state. According to United State Drought Monitor, 98.61 % of the total area of Washington was under *'severe drought'* in mid-July of 2015 which worsened to 67.96 % of *'extreme drought'* in September and October of 2015 (http://droughtmonitor.unl.edu/). Thus, farmers engaged in dryland farming systems are in dire need of drought tolerant wheat varieties with better grain yield. Past breeding approaches have focused on the improvement and selection of above ground traits, while the importance of below ground root systems was largely neglected. Nevertheless, root system architecture (RSA) is one of the most important contributors to drought tolerance including grain yield. Optimum root traits for increased grain yield have not been widely investigated. Owing to that fact, the study of RSA of economically important crops has been a keen area of interest for crop physiologists and plant breeders in recent years. We have initiated a project on *in situ* imaging techniques to assay RSA of spring wheat. We began in the spring of 2015 at Lind Dryland Research Station which obtains an average annual precipitation of 9.53 inches. Hollis X Drysdale recombinant inbred lines (RILs) that were either high or low yielding in previous field trials were studied along with the parental lines to correlate root traits (root length, root diameter, surface area, volume and branching angle) with grain yield in dryland conditions. Drysdale is a hard white wheat bred in Australia for low to medium rainfall zones and has a well-developed root system, high water use efficiency and drought tolerance. Hollis is a hard red spring wheat developed for semi-arid to intermediate rainfall regions in Washington state. Briefly, three foot-deep holes at an angle of 60^0 were drilled with a hand-held auger just after seedling emergence. The high-resolution *CI-600 in situ root imager* (CID Bio-Science) was used to take serial images of roots in a non-destructive way over the growing season. *RootSnap* software is being used to map the root images and generate quantitative data on RSA. Grain yield of the individual plots will help to assess the correlation with root traits. Our expectation is to identify specific root traits from Drysdale that contribute to increased grain yield in dryland conditions. The experiment is being replicated this year using six-foot long acrylic tubes to track the growth of entire root system as the three-foot tubes used in 2015 were insufficient in length to track rooting depth. The current experiment will test five high and five low yielding RILs in the Hollis X Drysdale background. We are testing two additional spring wheat lines widely cultivated in the PNW: Alpowa and Louise in addition to two drought tolerant lines: AUS28451 and Dharwar Dry. The same tools and techniques for root imaging at specific crop growth stages and quantifying the root traits will be followed as described above. Additionally, the volumetric soil moisture content (%) will also be measured using HH2 soil moisture meter along with PR2/6 profile probes (Delta-T). This study will provide a deeper understanding of temporal root growth behavior under drought conditions and will provide a basis for selecting wheat parental and breeding lines with important root traits for crop variety improvement. The ultimate outcome of this research project is to identify specific root traits for the development of sustainable and drought-tolerant wheat varieties that can benefit Washington wheat growers working in dryland farming systems.

Part 4. Agronomy and Soils

Soil Acidity in Eastern Oregon Wheat Fields

STEPHEN MACHADO, KARL RHINHART, AND RAKESH AWALE
COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU

Soil acidification, or decrease in soil pH, is increasingly becoming a concern due to the continuous application of ammonium based N-fertilizers within dryland cropping systems in inland Pacific Northwest (PNW) region. Continuous use of N-fertilizers, particularly ammonium-based, lowers soil pH because of the production of acidity (H+ ion) during nitrification process (oxidation of NH_4^+ to NO_3^-). Most native prairie soils in the PNW had neutral to near neutral pH (6.5 to 7.2) before the onset of cultivation. Three to four decades of N-fertilizer addition caused surface foot soil pH to decline to less than 5.2, a critical limit for wheat production. An ongoing long-term tillage-fertility study under a winter wheat - summer fallow cropping system established in 1940 near Pendleton, Oregon, revealed that soil pH has decreased from 5.6 to 4.6 and from 5.7 to 4.9 in the 0-4 and 4-8 inch soil depth profiles, respectively (Fig. 1). Similar low soil pH levels were also observed in other wheat fields around Pendleton and Moro.

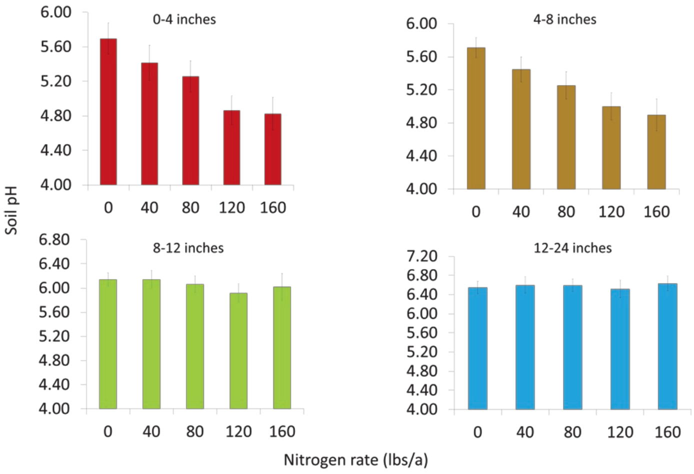


Figure 1.

Soil acidity (low pH) influences most chemical and biological processes in soils, and consequently influences agronomic yields. Availability of many essential plant nutrients (N, P, K) is optimum for wheat when pH is between 6.0-6.5 and decreases as soil pH drops. In addition, soil pH levels below 5.5 increase the solubility of Al and Mn in soils, leading to toxicity and interference with root growth and crop development. Consequently, low soil pH can lead to low fertilizer-use-efficiency (FUE) and water-use-efficiency (WUE), increased incidence of winter kill and disease, and consequently low crop yields and farm profitability. For example, (FUE) is reduced by about 50% when pH drops to 5.0, indicating that about half the fertilizer applied is unavailable.

Cereal and grass crops are more tolerant of low soil pH levels than legume crops. However, significant yield reduction in wheat and barley are possible when soil pH values drop below 5.2. Lime ($CaCO_3$) amendments to soil have potential to increase soil pH and improve crop growth and agronomic yields, but liming effects have not been extensively studied within the inland PNW. Lime research is expected to increase in the future.

Tools for Exploring Past, Current, and Future Climate at Scales Relevant to Agricultural Decision Making

KATHERINE HEGEWISCH AND JOHN ABATZOGLOU
DEPT. OF GEOGRAPHY, UI

Dryland farmers rely on a balance of precipitation and evapotranspiration to water their crops. Seasonal climate forecasts and future climate projections can be used to anticipate changing conditions and to proactively plan for the future. A set of web tools for visualizing historical climate data, seasonal climate forecasts, and future climate projections is now available through the Regional Approaches to Agriculture under Climate Change (REACCH) project at http://www.climate.nkn.uidaho.edu/REACCH. Streamlined tools allow users to examine historical and future climate and weather data for any location in the contiguous USA. Relatively high-resolution (~2.5 miles) gridded climate datasets offer an advantage over in-situ data from weather stations and can be used to monitor annual and seasonal variations in weather relative to previous years.

WSU Wilke Research and Extension Farm Long-Term Rotation Study

AARON ESSER AND DEREK APPEL
WSU EXTENSION

Washington State University maintains and operates the WSU Wilke Research and Extension Farm on the eastern edge of Davenport, WA. The predominant cropping system practiced by farmers in this region is a 3-year crop rotation, which includes summer fallow, winter wheat, and spring cereals. Farmers are interested in intensifying rotations to reduce fallow years and increasing crop diversity to improve long-term agronomic and economic stability.

The farm is in a direct seed cropping system utilizing no-till fallow, winter wheat, and spring cereals. Broadleaf crops remain a viable option and are substituted for spring and winter cereals when weed pressures and market prices create opportunities for profitable production.

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 is 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 reduce 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 rotations at $195 and $174/ac. Economic returns for the continuous crop rotation have been significantly less at only $138/ac. More information and complete reports can be found at http://wilkefarm.wsu.edu/.

Diversified crop rotation at the WSU Wilke Research and Extension Farm.

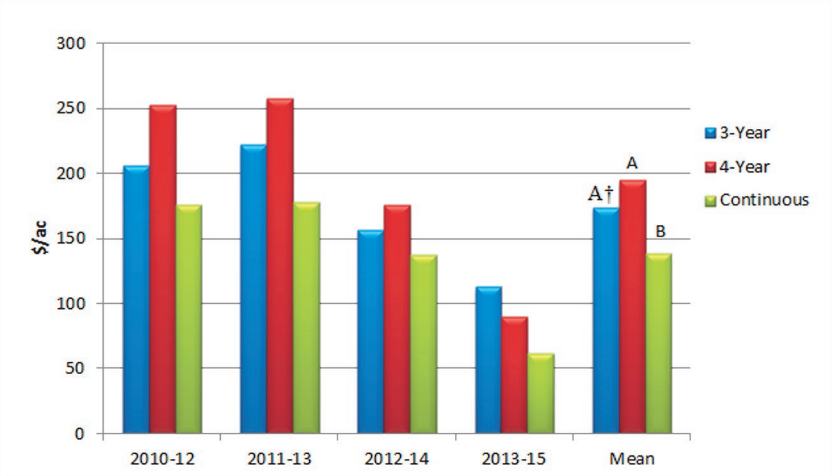


Figure 1. Three year average economic return over input costs of a 3-year, 4-year, and continuous cropping system at the WSU Wilke Research and Extension Farm. Costs do not include fixed costs associated with the farm. †Means within column assigned different case letters are significantly different (P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

Evaluation of High Lime Rates in Large Scale Strip Trials

Doug Finkelnburg[1] and Kurtis Schroeder[2]
[1]University of Idaho Extension; [2]Dept. of Plant, Soil, and Entomological Sciences, UI

Agricultural soils have been acidifying for decades in north-central Idaho due to the use of certain fertilizers, particularly ammonium based fertilizer. Many area soils now have acidity levels literature that indicates could limit nutrient availability and/or exhibit metal (Al) toxicity. Agricultural lime is widely used to neutralize soil acidity elsewhere in the USA, but local sources are not developed and available liming products are expensive. Current knowledge of rates of application relative to economic return on investment are lacking. This study compares a locally sourced limestone-derived agricultural lime at three rates (1, 2, & 4 tons/A) applied to 60 x 300 ft. strips in a direct seed small grains/grain-legume rotation. The 4 ton rate is approximately equivalent to the Adams-Evans lime requirement test that recommended 9,507 lb of calcium carbonate be applied to the top 6 inches to achieve a soil pH of 6.5. Limestone was sourced from the Mission Creek quarry owned and operated by the Nez Perce Tribe and refined at Kaschmitter Enterprises, Grangeville, ID. Lime was applied in the fall of 2014 and lightly incorporated the next season. Soil tests in the fall of 2015 showed a significant decrease in acidity in the top six inches with the highest rate of lime (Table 1). KCl-extractable aluminum trended downward with increasing rates of application (Table 2). These large replicated plots will be monitored for agronomic responses to the applications as well as additional changes in soil chemistry over time.

Figure 1. Line was applied using a two-paddle distributer mounted on a "floater" truck.

***Table 1.** Soil pH change by depth for liming treatments.*

	Soil pH by Depth (Inches)*		
Rate/Acre	0-3″	3″-6″	6″-12″
No lime	5.3^{a}	5.2^{a}	6.1^{a}
1 ton	5.4^{a}	5.1^{a}	6.2^{a}
2 ton	5.5^{ab}	5.3^{ab}	6.2^{a}
4 ton	5.7^{b}	5.5^{b}	6.2^{a}

*Means within a column followed by the same letter are not significantly different using LSD (P = 0.05).

***Table 2.** Impact of lime application on KCl-extractable aluminum.*

	KCl-Extractable Aluminum (ppm) by Depth (Inches)*		
Rate/Acre	0-3″	3″-6″	6″-12″
No lime	1.8^{a}	4.5^{a}	0.3^{a}
1 ton	1.0^{a}	4.5^{a}	0.3^{a}
2 ton	0.8^{a}	3.8^{a}	0.3^{a}
4 ton	0.5^{a}	0.8^{a}	0.0^{a}

*Means within a column followed by the same letter are not significantly different using LSD (P = 0.05).

Comparative Climate Change Risk Perceptions for Inland Pacific Northwest Producers

J.D. Wulfhorst, Jenny Gray, Ildiko Roth, and Liza N. McNamee
Dept. of Agricultural Economics and Rural Sociology, UI

Management of global risk to food security will rely on farmer behavior and capacity for adaptation within climate change dynamics. For decades, research in rural sociology has analyzed farmers' willingness to adopt changes in production practices, mostly in relation to the need for increased conservation. Within this long inquiry, analysis of farmers' perceived risk remains under-developed and without context or empirical data related to climate change effects. Greater focus is needed on perceived risk of changing environmental conditions from climate variability such as long term drought, less reliable precipitation, changing cost of inputs and possible climate change policies (Fig. 1). To analyze changing environmental conditions, agroecological class designations are used to delineate geographic, agronomic, and social community variability for a more in-depth analysis about risk perceptions (Fig. 2). Data for this analysis were generated from a 2012 survey of 900 wheat producers in the inland Pacific Northwest dryland production region. The producer population survey investigated producer perspectives on farm operations and climate change impacts. The effort relates behavior and perception of risk to attitudes and beliefs regarding climate change.

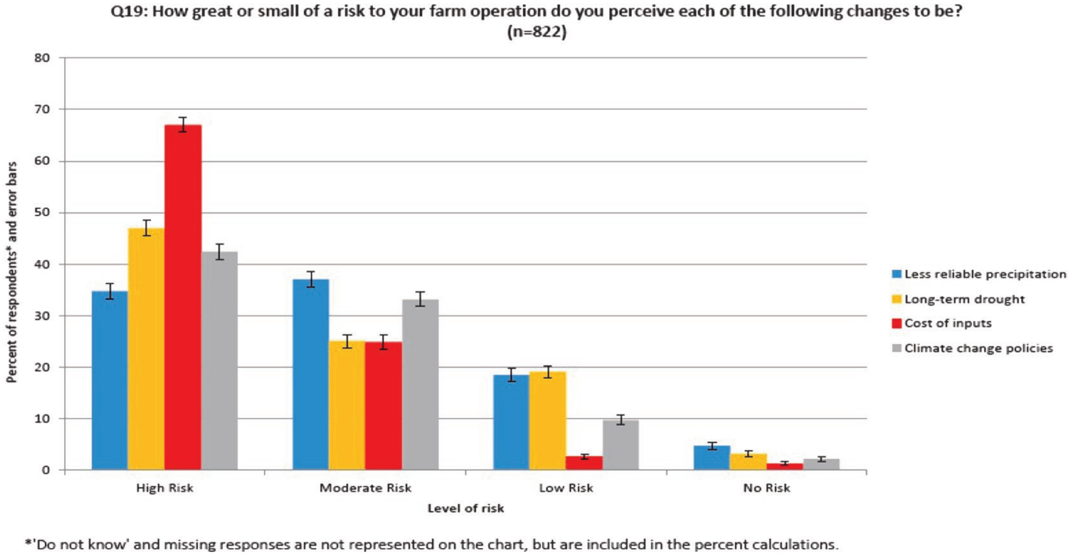


Figure 1. Distribution of producer responses to a series of measures on perceived risk in relation to climate change effects in the Inland Northwest agricultural production region.

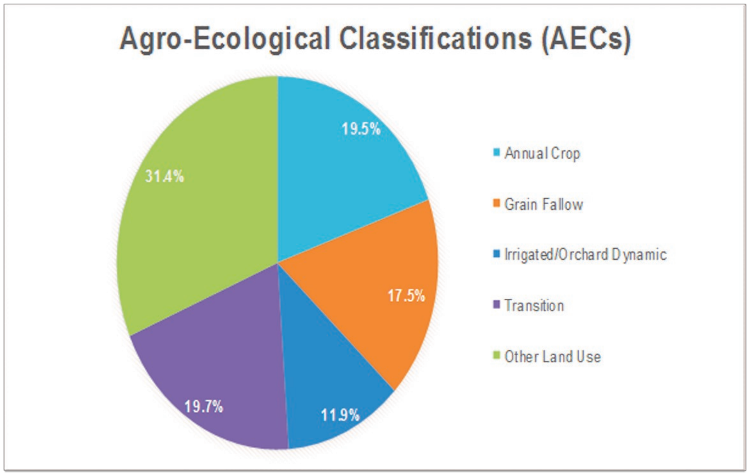


Figure 1. Agroecological classifications of Inland Northwest agricultural producers responding to a survey about farm operations and climate change effects.

Management Zone Delineation Based on NUE Performance: A Decision Support and Evaluation System for Precision Nitrogen Applications

STEPHEN TAYLOR[1], DAVE BROWN[1], DAVID HUGGINS[2], AND WAYNE THOMPSON[3]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS; [3]WSU EXTENSION

Precision nitrogen (N) management has been proposed as a strategy to improve fertilizer use efficiencies. Current N recommendations for soft white winter wheat in the inland Pacific Northwest are based on uniform, whole-field applications. However, uniform N applications result in highly variable site-specific yield response and N use efficiencies (NUE) (Huggins 2010). Low NUE represent a financial loss to the grower, while environmental N losses contribute to air and water quality degradation.

The overall goal of this study is further the development of science-based decision support, monitoring, and evaluation systems for farmers who want to implement precision N management. The data presented here are preliminary analyses of the spatial variability in wheat yield response to N. These data will be combined with spatial NUE data into management zones that both evaluate variable rate applications and aid in N fertilizer application decisions.

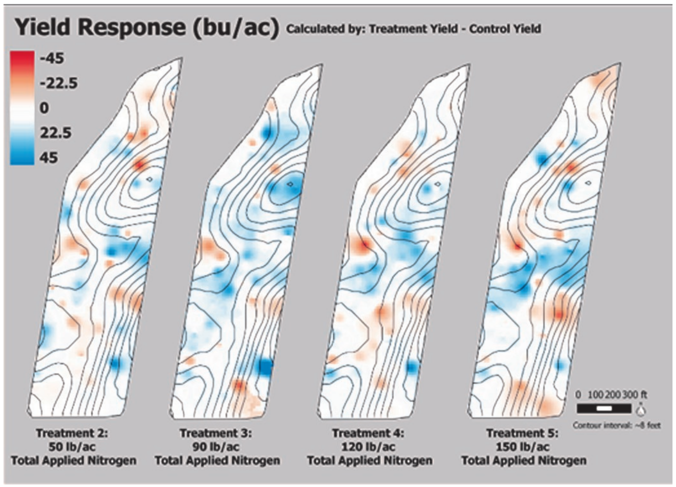


Figure 1. Yield differences by treatment, IDW interpolation.

Preliminary Results

($\text{Yield}_{\text{treatment}} - \text{Yield}_{\text{control}}$) maps show areas of the field with both negative and positive yield responses to applied N compared to the control (Figure 1)

Yield response to N across the field varied from positive to negative (Figure 1)

Yield across all N treatments ranged from 52.0-145.4 bu/ac. Average yields ranged from 88.3 bu/ac for control (17 lb N/ac) to 97.8 bu/ac for treatment 3 (90 lb N/ac) (Table 1)

N balance index ($N_{\text{Grain}} / N_{\text{fertilizer}}$) decreased with increasing N fertilizer (not shown)

Table 1. *Average grain yield and protein data for each nitrogen treatment.*

Applied N (lb N/ac)	Avg Yield (bu/ac)	Range: Min/Max	Standard Deviation	Avg Protein (%)	Range: Min/Max	Standard Deviation
17	88.3	52.0/130.7	14.54	8.37	6.6/12.9	1.14
50	92.6	55.3/133.3	14.12	8.88	7.2/12.0	1.09
90	97.8	65.7/129.4	14.14	9.84	7.4/14.2	1.32
120	94.1	61.5/145.4	14.32	10.46	8.2/13.4	1.23
150	93.9	61.6/140.4	17.51	11.25	8.4/16.2	1.48

Nutrient Uptake and Plant Available Nutrient Dynamics of Three Long Term Experiments Over the Period of 20 Years (1995-2015)

SANTOSH SHIWAKOTI[1], VALTCHO JELIAZKOV[1], HERO GOLLANY[2], AND MARKUS KLEBER[1]
[1]DEPT. OF CROP AND SOIL SCIENCE, OSU; [2]USDA-ARS COLUMBIA PLATEAU CONSERVATION RESEARCH CENTER

The effect of management practices on soil available nutrients often takes decades to manifest under dryland in semiarid environments of the Pacific Northwest (PNW). The effect of management practices on plant available nutrients in this region of PNW has not been tested yet, except for nitrogen (N) and carbon (C). The Pendleton long-term experiments (LTEs) provide a great resource for studying nutrient dynamics in the semiarid environments of the PNW. Besides the evaluation of C and N, evaluation of nutrients like phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), manganese (Mn), copper (Cu), zinc (Zn), boron (B), and iron (Fe) is also important in determining the sustainability of wheat production. According to previous research in the winter wheat-summer fallow (WW-SF) cropping system, intensive tillage along with burning or removal of crop residue has decreased soil organic carbon (SOC) and N whereas manure and pea vine incorporation have reduced the decline of SOC and N. Soil nutrients continue to decline in WW-SF cropping system with time if proper management is not practiced. We hypothesized that additions of manure, pea vine and proper fertilization will improve levels of N, P, K, Ca, C, S, Mg, Mn, Cu, Zn, B, and Fe while intensive tillage and burning/removal of crop residue will deplete these nutrients in the WW-SF cropping system. The three LTEs at Pendleton selected for this study are:

1. Crop Residue (CR) Experiment: Treatments are: spring burn (SB); no burn (NB) with 0, 40, and 80 lb. N per acre; fall burn (FB) with 0 lb. N per acre; manure (M); and pea vine (Pv).
2. Wheat/Pea rotation (WP) Experiment: Treatments are tillage intensities (fall chisel, fall plow, spring plow, and no-till) in wheat/pea rotation.
3. Tillage Fertility (TF) Experiment: Treatments are three primary tillage systems (moldboard plow, offset disk, and sub-surface sweep) and six N levels (0 to 160 lb. N per acre in 40 lb. N per acre increments).

Soil and grain samples from archived samples (1985, 2005, and 2015 samples) will be tested for N, P, K, Ca, C, S, Mg, Mn, Cu, Zn, B, and Fe. This study will reveal how crop and soil management affects plant available soil nutrients in four soil depths (0-4, 4-8, 8-12, and 12-24 inches) and uptake of nutrients by wheat in the three LTEs mentioned above. The results from this analysis are expected to elucidate the sustainability of the treatments commonly being practiced in the dryland winter wheat cropping system of PNW.

Wind Erosion Potential Following Application of Biosolids

BRENTON SHARRATT[1], WILLIAM SCHILLINGER[2], ANDREW BARY[2], AND CRAIG COGGER[2]
[1]USDA-ARS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

The application of biosolids to agricultural land has the potential to improve crop production. In addition, organic material contained in biosolids may enhance biological activity, retention of soil water, and soil aggregation These benefits could possibly reduce the threat of wind erosion in arid and semiarid regions. Therefore, we assessed the impact of biosolids on wind erosion of agricultural land at Lind, Washington. Synthetic fertilizer and biosolids were applied to a loess silt loam at the time of primary conventional (disk) or conservation (undercutter) tillage in the spring (April) during the fallow phase of a winter wheat – summer fallow rotation. Wind erosion potential was assessed after the first rodweeding (mid-June) and sowing winter wheat (early September) in 2015 using a portable wind tunnel. The working section of the tunnel is 17.1 feet long, 3.3 feet wide and 4 feet high (Fig. 1). Sediment flux inside the tunnel was measured with an isokinetic sampler and at a free-stream wind velocity of 40 mph for two consecutive sample periods having respectively little and copious saltation activity. Windblown soil loss from the footprint of the tunnel was greater for conventional (3970 lbs/ac) than conservation (2529 lbs/ac) tillage averaged across dates and sample periods. Differences in soil loss were not found between fertilizer and biosolid treatments. Preliminary results suggest that biosolids may not affect the wind erosion potential of loessial agricultural soils. Chemical and microbial analyses are being performed on the windblown sediment collected inside the tunnel. We will collect a second and final year of data after rodweeding and sowing wheat in 2016.

Figure 1. Portable wind tunnel used to assess the wind erosion potential of soils amended with biosolids at Lind, Washington.

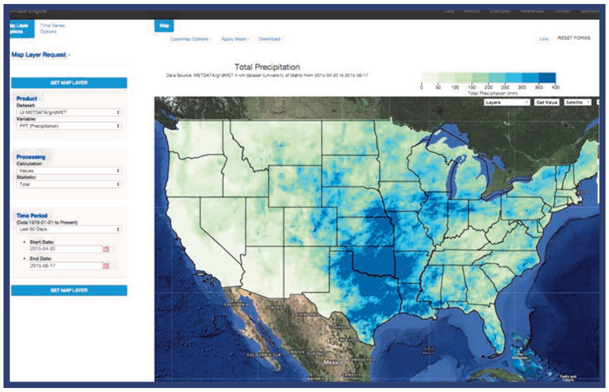
Climate Engine: Monitoring Weather, Climate, and Land Cover for Agriculture

KATHERINE HEGEWISCH[1], JOHN ABATZOGLOU[1], DONOVAN VANSANT[1], BRITTA DAUDERT[2], CHARLES MORTON[2], AND JUSTIN HUNTINGON[2]
[1]DEPT. OF GEOGRAPHY, UI; [2]DESERT RESEARCH INSTITUTE, UNIVERSITY OF NEVADA

The advent of high-resolution and near real-time climate and remote sensing datasets provides novel opportunities for real-time environmental monitoring to support agricultural decision-making. The data can provide an advantage over in-situ observations from weather stations, which may be of limited value to users because of spatial and temporal gaps. Climate Engine (http://www.ClimateEngine.org) uses big data archives of geospatial climate and remote sensing data to allow users to interactively view and analyze data specific to their land. The site utilizes Google Earth Engine's cloud computing resources.

Climate Engine's mapping interface (Fig. 1), allows the user to zoom into a farm location and view maps of the landscape greenness at spatial resolutions of approximately 100 ft using the Normalized Difference Vegetation Index (NDVI). The interface allows easy comparison of the current NDVI to past growing seasons by displaying maps that indicate the locations where there are changes in the land cover.

Climate Engine's time series tool (Fig. 2) allows the user to delineate the boundaries of a farm and analyze weather and climate data specific to their location. For example, users can examine how seasonal averages of temperature or total precipitation have changed for a location over the last 30 years or see how the greenness of the landscape has changed during the current growing season compared to a previous year. The Climate Engine tool places the information from real-time weather and remote sensing datasets into the hands of anyone with an internet connection.



Total Precipitation
Data Source: METDATA/gridMET 4-km dataset (University of Idaho) from 2015-04-20 to 2015-06-17

Product
Dataset: UI METDATA/gridMET
Variable: PPT (Precipitation)

Processing
Calculation: Values
Statistic: Total

Time Period
(Data 1979-01-01 to Present)
Last 60 Days

Figure 1. Shown here are precipitation totals from April 20th to June 17th 2015 for the contiguous USA at a 2 mile (100 ft) resolution. Users can zoom into any region in the USA to see how precipitation varies at this resolution.

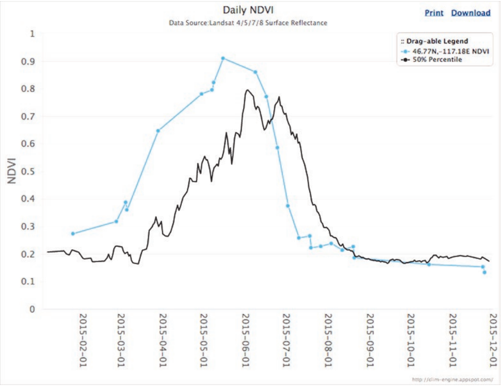


Figure 2. Shown here is the NDVI greenness for a wheat field north of Pullman during 2015 (blue) compared to the average greenness observed at this site from 1984-2014. The nearly one-month advancement in peak greenness timing reflects the unusually early maturation of wheat across the region in 2015.

Cover Cropping for the Intermediate Precipitation Zone of Dryland Eastern Washington

D.E. ROBERTS[1], F.J. FLEMING[2], C. GROSS[2], T. RUSH[2], E. WARNER[2], C. LANEY[2], B. DOBBINS[2], D. DOBBINS[2], R. VOLD[2], A. ESSER[1],
D.P. APPEL[1], AND J. CLAPPERTON[3]
[1]WSU EXTENSION; [2]DRYLAND GRAIN FARMER; [3]RHIZOTERRA INC

Cover cropping with multiple species is a trending innovation for improving soil health in the Midwest and Eastern US. Cover crop cocktails (CCC) are a mix of broadleaf and grass species, including cool and warm season types. Legumes fix atmospheric nitrogen and tap-rooted crops penetrate compacted soil layers, improving water retention.

In eastern Washington, research with single-species cover crops has not proven them both agronomically and economically beneficial. With funding from USDA SARE (Sustainable Agriculture Research and Education), farmers from the intermediate rainfall area are working with WSU Extension on CCCs. Farmer cooperators planted 5-acre demonstration plots of the CCC in question. We had large, replicated plots on the Wilke Farm at Davenport.

While not widely conclusive, results to date show that CCCs in dryland eastern Washington are often high risk because they use too much soil water, especially when planted in place of the fallow cycle.

The farmers want to develop beneficial systems for our winter precipitation region that complement cash crop production. We are exploring Companion Crops that are grown for a short period along with the cash crop, for example low rates of faba bean, tillage radish, and buckwheat seeded with standard rates of winter wheat (Fig. 1). The companion crops provide benefit to the soil in the fall, and freeze out over winter. (Currently there is a moratorium on growing buckwheat so we will find alternatives).

Figure 1. Winter wheat growing with companion species faba bean, buckwheat, and tillage radish.

We are seeking funds to continue and broaden this research effort.

Crop Response and Economics of Liming in Northern Idaho

KURTIS SCHROEDER[1], KATHLEEN PAINTER[2], DOUG FINKELNBURG[2], AND DAVID HUGGINS[3]
[1]DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI; [2]UNIVERSITY OF IDAHO EXTENSION; [3]USDA-ARS

Soil pH in northern Idaho is continuing a progressive decline originally documented in the 1980s. In a current survey taken across seven northern Idaho counties, 34% of 116 fields had a pH below 5.0 and measurable quantities of potassium chloride (KCl) extractable aluminum. This indicates that these fields could be at risk of aluminum toxicity and might respond to lime application. In the fall of 2013, field sites in Winchester, ID and Potlatch, ID as well as a location north of Pullman, WA were limed with either ground limestone, sugar beet lime from Moses Lake or NuCal fluid lime at rates of 500, 1000 or 2000 lb/A, followed by incorporation. At each location, winter wheat and peas were seeded to determine whether there were differential responses to types of lime or rates of application. In addition to yield monitoring, soil chemical tests were done at each site to monitor soil pH, calcium concentrations, changes in KCl-extractable aluminum, and base saturation. Although immediate significant increases in yield have not been observed in either winter wheat or spring pea, in both 2014 and 2015 there were increases in yield in plots that were limed in 2013. In 2015, the average yield of winter wheat increased by 2 to 17 bu/A in limed plots in Potlatch, compared to no-lime control plots, and by 1 to 10 bu/A in the limed plots in Pullman. There was no response to lime application in Winchester with the quantities tested. Corresponding to the improvement in yield, there has been an increase in the soil pH and a significant decrease in KCl-extractable aluminum. Increases in yield typically corresponded to the rate of material added to each plot, but differences in yield corresponding to the types of lime used were very small.

A major impediment to widespread adoption of liming practices in northern Idaho has been the absence of affordable and relatively close liming sources. Depending on the type and rate of lime used, the cost of the liming treatments described above ranged from a low of $29/A with the 500 lb/A rate of sugar beet lime to a high of $388 per acre with the 2000 lb/A rate of NuCal fluid lime (2015 prices). Costs include the material, transportation, and application in the

Moscow/Pullman area. Given the increases in yield observed in 2015 at Pullman and Potlatch, many of the applications would be profitable. Since lime application is likely to result in a multi-year benefit, this needs to be taken into account when considering the economics of the application. If there is no improvement in yield, obviously there will not be a return on the investment, but even a small to modest increase in yield can provide a profitable return. Other potential benefits of liming should also be considered, such as improvements in soil health as well as improved nutrient cycling and availability.

Climate Change May Shift USDA Hardiness Zones

Lauren Parker and John Abatzoglou
Dept. of Geography, UI

Climate change does not just mean changes in average temperatures, but also changes in extremes. The USDA uses a multi-decadal average of cold extremes – the coldest night of the year – to define plant hardiness zones. These zones are can be used by commercial growers and backyard gardeners alike to determine what varieties of crops, flowers, or ornamentals will fare well in their climates or survive over the winter. Output from 20 global climate models shows that these cold extremes will be higher in the coming decades, warming by more than 10°F in some portions of the interior Northwest, more than double how much average winter lows are projected to warm. As a result of these warming extremes, the USDA hardiness zones will shift northward (Fig. 1), changing the zone of many key agricultural regions across the Northwest.

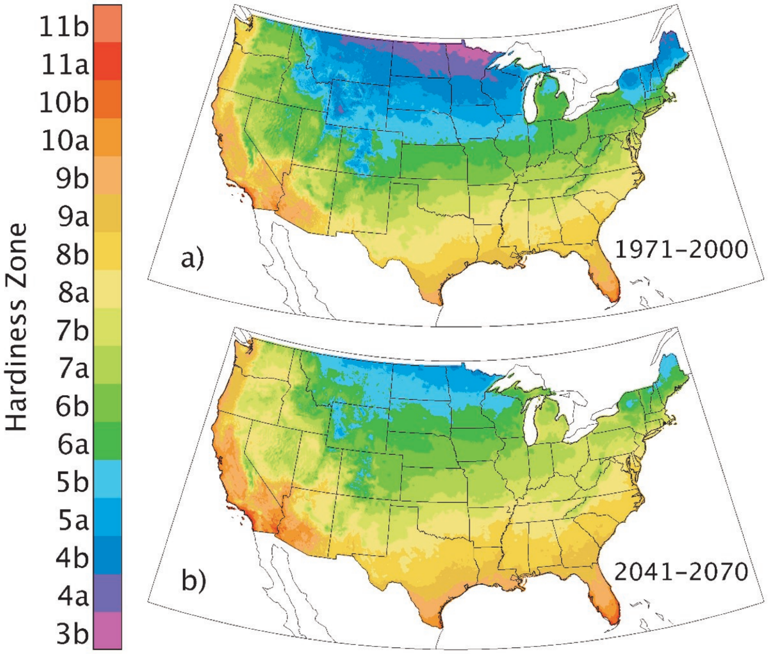


Figure 1.

Warming winter temperatures and shifts in hardiness zones may provide both opportunities and challenges for growers moving into the mid-21st century. Warmer winter temperatures may allow for the cultivation of less cold-hardy varietals, potentially opening up economic opportunities in some markets. However, these same warmer temperatures will also influence pest and weed management as winter loses its chill and consequent mortality rates for pests and weeds decline.

Fate of Biosolids Carbon and Nitrogen to Grain and Soil Fractions in Wheat-Fallow Over 20 Years

Lauren Port, Craig G. Cogger, Andy Bary, and William L. Pan
Dept. of Crop and Soil Sciences, WSU

Global sustainability will increasingly be dependent on our ability to recycle photosynthetically fixed-carbon and concentrated plant nutrients in organic wastes back into food production. Anaerobically digested and dewatered biosolids are an effective source of recycled nutrients.

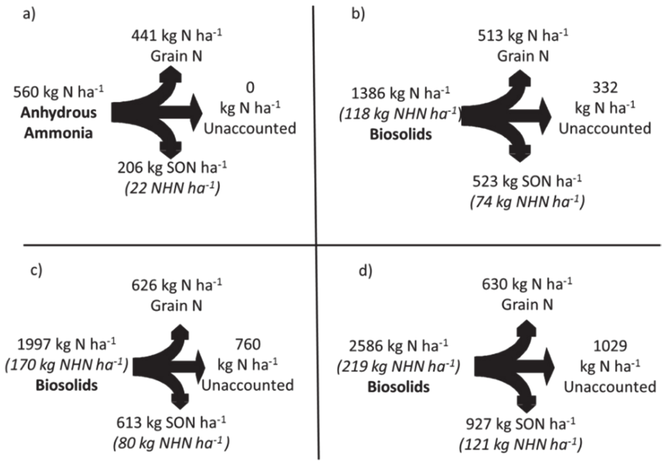


Figure 1: Fate of applied total N and non-hydrolyzable N (NHN) to grain, top 10 cm soil organic N and soil NHN from a) anhydrous ammonia and b, c, d) three biosolids rates applied at regular 4 year intervals over 20 years into grain N, soil organic N and NHN.

Biosolids have been applied to a semi-arid winter wheat-fallow system for 20 years (Cogger et al., 2010). Three rates of biosolids were applied and incorporated into the soil following wheat harvest every four years and compared to a no fertilizer check and a commercial anhydrous ammonia treatment. Increases in total soil organic carbon (SOC) and nitrogen (SON) were correlated to cumulative rates of the total and acid-resistant fraction of biosolids application, with 77% of added biosolids C retained in the soil. Soil carbon and nitrogen fraction analysis revealed that 28% of the applied C has been stored in the acid resistant fraction and 46% in the light fraction. Total soil N was also correlated with cumulative biosolids N added, with 35% of added biosolids N retained in the soil of which 4% was stored in the acid resistant fraction. Light fraction C and N levels were maintained by anhydrous ammonia, while they decreased by 50% and 33% respectively, in the zero N check, likely due to lower straw production. Anhydrous ammonia affected little if any increase in non-hydrolyzable soil C over the control, despite increasing wheat yields by 27% averaged over the 20 year experiment. In addition, only AA slightly increased non-hydrolyzable N, whereas increasing biosolids rates increased non -hydrolyzable soil N proportionate with the estimated quantities of NHN contained in the applied biosolids. This raises the prospect that anaerobically digested biosolids contains ample acid-resitant organic matter in the applied amendment that can account for increases in stable soil C and N pools in semi-arid cropping systems. The high efficiency of SOC storage with biosolids suggests land application represents significantly greater reductions of GHG than previously modeled (Brown et al., 2010). All rates of biosolids effectively fed the wheat crop and the soil, by increasing grain N production over the anhydrous ammoonia check, while building total and acid resistant soil N at high rates of retention. Stable N, C in the biosolids could account for the total buildup of soil NHN; quality may be important as quanitity to build SOM.

Brown et al., 2010. *Environ. Sci. Technol.* 2010, *44,* 9509–9515.

Cogger et al., 2014. *J. Environ. Qual.* 42:1872–1880.

Identification of Preferences for Hard White Wheat, Hard Red Wheat, and Non-Whole Grain Bread Products in Young Children and Their Parents

---

Lauren Keeney, Amir Gol Mohamadi, Ling-Ling Tsao, Suzanne Planck, and Samantha Ramsay
School of Family and Consumer Sciences, UI

Dietary Guidelines encourage greater whole grain consumption. Hard white wheat (HWW) has fewer tannins, making whole grain bread made from HWW less bitter than bread made from other grains. The primary purpose of this study was to identify children's preferences for bread from HWW, hard red wheat (HRW), and non-whole grain wheat, and to identify parent bread preferences and purchasing habits.

Parents and their child 3-5 years of age (n=26) were recruited from a child development laboratory. Parents completed a demographic questionnaire that included bread preferences and purchasing habits. Children participated in a hedonic taste preference activity. Descriptive statistics captured parental/child consumption patterns. A Wilcoxon Signed Ranks Test was used to determine child reported taste preference, a chi-square was used to examine consumption habits at home, and a paired-t test was used to determine difference in bread consumption.

Questionnaire results indicated typical consumption of bread at breakfast, lunch, and evening snacks by both parents and children. 69% percent of parents and 72% of children consumed whole grain bread. Whole grain bread was consumed significantly more than non-whole grain bread (76% 1/week or more compared to 41% 1/week or more). Baseline taste preference indicated 92% of children preferred bread made from HWW, while 73% preferred bread made from HRW, but no significant difference was identified in hedonic testing. However, children consumed significantly more HWW (3.7 grams) than HRW (3.3 grams).

Children may be more likely to prefer and consume 100% whole grain bread prepared with HWW grain compared to HRW grain.

Farmer to Farmer: Multi-Media Case Studies to Build Adaptive Capacity Among Cereal-Based Farmers in the Pacific Northwest

Georgine Yorgey[1], Chad Kruger[1], Sylvia Kantor[1], Kristy Borrelli[2], Kathleen Painter[3], Hilary Donlon[4], Leigh Bernacchi[4], and Dennis Roe[5]
[1]Center for Sustaining Agriculture and Natural Resources, WSU; [2]Dept. of Plant, Soil, and Entomological Sciences, UI; [3]University of Idaho Extension; [4]Dept. of Agricultural Economics and Rural Sociology, UI; [5]Dept. of Crop and Soil Sciences, WSU

Across our region, farmers are adopting innovative practices that increase resiliency in the face of ever-changing market pressures and continuing climate uncertainty. To support farmer to farmer learning, we have developed a set of ten multimedia producer case studies for cereal-based cropping systems in the Pacific Northwest as part of the Regional Approaches to Climate Change in Pacific Northwest Agriculture (REACCH-PNA) project. Innovative strategies for the dryland region included precision nitrogen application, enhancing crop diversity, flex cropping, grazed cover cropping and use of the stripper header and undercutter sweep (Fig. 1).

Figure 1.

In-depth interviews with each producer were used to produce a video segment and a written document. Participants explain their processes for successful adaptation of these various risk-reducing practices, their perspectives on benefits and challenges, and their thoughts on risk and climate change. Case studies can be accessed at www.casestudies.reacchpna.org. Five videos and two written case studies have been posted; others will be added as they become available.

Bioclimatic-Driven Future Shifts in Dryland Agroecological Classes

Harsimran Kaur[1], Rick Rupp[1], John Reganold[1], David Huggins[2], John Abatzoglou[3], and Claudio Stockle[4]
[1]Dept. of Crop and Soil Sciences, WSU; [2]USDA-ARS; [3]Dept. of Geography, UI; [4]Dept. of Biological Systems Engineering, WSU

Climate change may result in substantial geospatial shifts in dryland cropping systems or agroecological classes (AECs). Study region constitutes three major dryland AECs: (1) annual cropping (limited annual fallow) (AC); (2) annual crop-fallow transition (e.g. 3-yr rotations with fallow every 3rd year) (AC-T); (3) grain-fallow (e.g. 2-yr rotation) (GF); developed from USDA-NASS produced annual cropland data layer. The main objectives of the study were to: (1) identify important bioclimatic variables which can discriminate among current dryland AECs; and (2) use identified bioclimatic variables with future climate scenarios to predict potential shifts in dryland AECs for the coming century under given production technology. To achieve these objectives, we successfully predicted current AECs based on land use/cover using bioclimatic variables. Current AECs (2007-2014) with further subdivisions into stable and dynamic AECs (Fig. 1) were used to identify bioclimatic variables that significantly affect actual land use. Holdrige evapotranspiration index, spring precipitation (March-May), and summer precipitation (June-September) were identified as key bioclimatic variables in the empirical analysis. Overall cross-validated classification accuracy was 69-88% and 48-59% for stable and dynamic AECs, respectively. Future climate data from 19 different Global Climate Models were used to project shifts in AECs for three different time periods (2030, 2050 and 2070) and two different climate change scenarios RCP (Representative Concentration Pathways) 4.5 and 8.5. Our empirical analyses show that the stable annual crop AEC, stable annual crop-fallow transition AEC and dynamic annual crop AEC would decrease with the changes converting into annual crop-fallow transition and dynamic grain fallow AEC (Table 1). The projected shifts would be predicted to significantly decrease cropping system diversification and intensification, reduce overall soil organic matter and increase soil vulnerability to erosion processes.

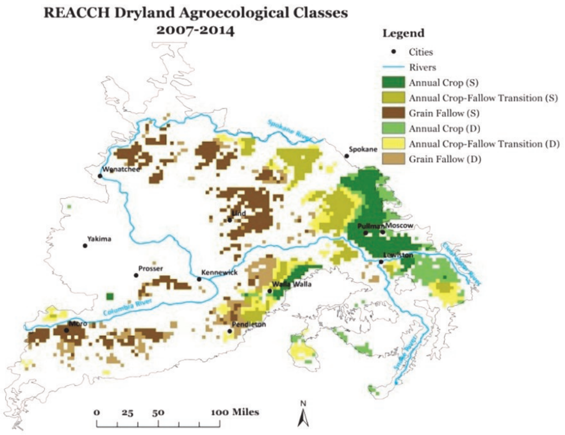


Figure 1. Agroecological Classes for 2007-2014.

Table 1: *Number of pixels (4 × 4 km) classified in each AEC for present and future scenarios and coefficient of variation across projected results*

	Stable AECs						Dynamic AECs					
Time Period	**AC**	**%CV**	**AC-T**	**%CV**	**GF**	**%CV**	**AC**	**%CV**	**AC-T**	**%CV**	**GF**	**%CV**
(1981-2010)	276	--	271	--	455	--	205	--	235	--	262	--
Future scenario (RCP -4.5)												
2030	264	22.2	200	30.6	426	30.0	150	40.5	343	57.3	320	43.5
2050	234	43.6	152	45.1	464	22.7	125	47.6	334	47.7	394	40.6
2070	243	40.2	123	55.6	476	57.3	122	57.2	348	50.7	391	50.1
Future scenario (RCP -8.5)												
2030	235	32.9	171	36.5	438	26.4	147	47.7	363	48.8	349	46.3
2050	241	41.9	129	54.2	437	41.0	102	57.0	343	50.7	452	42.8
2070	236	42.1	105	62.7	431	76.7	90	69.5	381	61.3	461	53.1

Effect of Glyphosate on Soil Bacterial Communities in Long-Term No-Till and CRP

DANIEL C. SCHLATTER[1], CHUNTAO YIN[2], SCOT HULBERT[2], IAN BURKE[3], AND TIMOTHY C. PAULITZ[1]
[1]USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT; [2]DEPT. OF PLANT PATHOLOGY, WSU; [3]DEPT. OF CROP AND SOIL SCIENCES, WSU

Soil microbial communities are critical to soil functions and are key contributors to plant productivity. Although it is the most widely used herbicide worldwide, there are few data on the specific effects of glyphosate on soil microbes. Glyphosate is reported to have toxic effects on some microbial taxa, while it is also hypothesized to be degraded for use as a C, N, or P sources by others. Thus, applications of glyphosate in no-till systems may shift the composition of soil communities with subsequent impacts on key soil functions. Moreover, since soil microbes can rapidly respond to perturbations, the effects of glyphosate on soil communities may be contingent on application history.

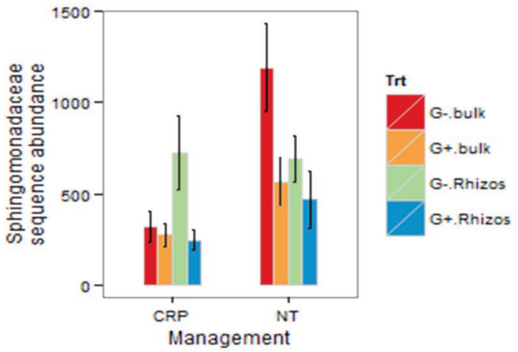


Figure 1. Relative abundance of Sphingomonadaceae among treatments.

Using a greenhouse study, we investigated the effects of glyphosate on bacterial communities in bulk-soil and wheat rhizospheres using soils with different histories of glyphosate use (no-till and CRP). After 3 cycles of wheat-glyphosate (1.5 lbs ai/A, or 42 oz of RT3) in the greenhouse, glyphosate application had little effect on soil bacterial community composition or diversity relative to farm site, management (no-till vs. CRP), or root proximity. However, a small number of bacterial taxa appeared to be less abundant in glyphosate-treated vs. nontreated soils. Specifically, bacterial species belonging to the families Sphingomonadaceae (Fig. 1) and Sphingobacteriaceae tended to be less abundant in bulk and rhizosphere soil after glyphosate applications, though the role of these taxa in plant health is unclear. Sphingomonadaceae is best known for degrading xenobiotics (eg. herbicides) and plant compounds, whereas bacteria within Sphingobacteriaceae are sometimes described as plant growth-promoting. Overall, our results suggest that glyphosate has little impact on soil bacterial communities as a whole, perhaps due to low concentrations in soil, rapid binding to soil particles, or efficient degradation by soil microbes, but may have targeted impacts on the abundances of specific taxa.

Impacts of Biosolids and Tillage on Microbes in Soil and Dust

DAN SCHLATTER[1], TIM PAULITZ[1], BILL SCHILLINGER[2], ANDY BARY[3], AND BRENTON SHARRAT[4]
[1]USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU; [3]WSU PUYALLUP; [4]USDA-ARS NORTHWEST SUSTAINABLE AGROECOSYSTEMS RESEARCH UNIT

Biosolids are nutrient rich organic material from treated sewage sludge that are applied to fields to provide nutrients, increase soil organic matter, and prevent erosion. Although biosolids are safe to use, concerns remain that pathogenic microbes found in class B biosolids may persist in soils and be dispersed with dust during high-wind events. Tillage may also impact the survival and dispersal of pathogens. While burying biosolids with conventional tillage (disking) exposes introduced microbes to competition by indigenous soil communities, conservation tillage (undercutter) leaves residues on the surface where harsh environmental conditions (eg. heat, UV, drying) are often lethal to microbial species.

To assess the potential for pathogen indicators to persist in soils and be aerosolized in dust under different tillage regimes, we used high-throughput DNA sequencing to characterize microbial communities in soil, dust, and intact biosolid aggregates (Fig 1.) collected one month after field application of biosolids or conventional fertilizer at Lind, WA. We examined samples for the presence and relative abundance of human-associated microbes and explored the impacts of biosolids and tillage on microbial communities more broadly. Fecal indicators (eg *E. coli*) were extremely rare and were only detected in a single biosolid aggregate. However, a small number of other human-associated taxa were much more common in biosolids aggregates and soil/dust where biosolids were applied. Specifically, *Clostridium* species were detected at higher abundances in biosolid treatments. Though clostridia are common gut inhabitants and are rarely pathogenic, their greater abundance in dust samples from biosolid treatments suggest that human-associated bacteria from biosolids may be aerially transported. In contrast, tillage had no significant effect on populations of human-associated microbes in soil or dust.

Figure 1. Biosolid aggregates extracted from soils.

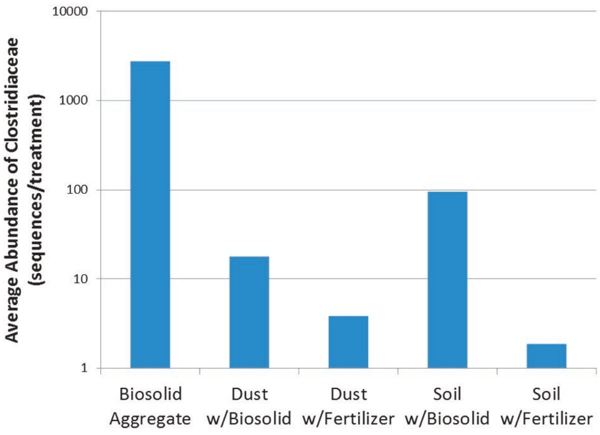


Figure 2. Impact of treatments on abundances of Clostridiaceae.

Biosolid treatments impacted indigenous soil and dust communities, increasing abundances of many fast-growing fungi (*Fusarium, Mortierella*, and *Neurospora*) and spore-forming bacteria (*Streptomyces*, *Bacillus*). These are naturally found in soil and are unlikely to be human pathogens or inhabitants of the human gut. Similarly, tillage also had broad effects on the composition of microbial communities in soil and dust. Specifically, disking increased the abundances of decomposers in soil (*Chaetomium*, Actinomycetes), whereas undercut conservation tillage increased the abundances of yeasts in dust. Thus, the impacts of tillage on soil and dust microbial communities are likely related to whether plant residues are buried, favoring soil decomposers, or left on the surface, favoring populations of heavily sporulating fungi (molds).

Seasonal Variations in Exotic Earthworm Populations in Palouse Wheat Fields

CHELSEA WALSH, JODI JOHNSON-MAYNARD, AND IAN LESLIE
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Exotic earthworms are found throughout the Palouse, the high yielding, dryland wheat-producing region of eastern Washington and northern Idaho. Through their manipulation of soil physical and chemical properties, earthworms have the potential to increase nutrient mineralization and benefit crop production. However, this effect is dependent on numerous factors, including earthworm density. Earthworms have only recently begun to receive more serious attention on the Palouse and only rough estimates of earthworm density and seasonal activity exist.

In our study, six Palouse wheat fields were monitored over the course of 14 months in 2014 and 2015 to describe seasonal variations in earthworm density and activity. Earthworm community density, age structure and diversity, soil moisture and soil temperature were also monitored. Only exotic species were collected. The endogeic species *Aporrectodea trapezoides* was the predominant species collected at all sites (87% of all adults identified). *Allolobophora chlorotica, Lumbricus terrestris* and *Aporrectodea tuberculata* were also collected at lower frequencies (1.8-6.4% of adults). In 2015, earthworms were active for 121 days with average densities of 14 to 75 m^2 during this period. Population transition to aestivation began in mid-June of both years and appeared to be driven by an interaction between soil moisture and soil temperature. A short active period and average densities at most sites of less than 100 individuals per m^2 suggest the impact of *A. trapezoides* may be limited in conventional crop fields of this region. However, in organic or other limited input systems earthworms have greater potential to make a measurable contribution to nutrient mineralization.

Cover Crops Demonstration Project in North-Central Idaho

DOUG FINKELNBURG, KENNETH HART, AND JAMES CHURCH
UNIVERSITY OF IDAHO EXTENSION

Table 1. *Spring Cover Crop Mixes.*

Nitrogen Mix (lbs/A): Forage Pea (16.0), Lentil (4.5), Common Vetch (4.5), Rapeseed (1.0), Flax (5.5)

Grazing Mix (lbs/A): Forage Pea (8.9), Common Vetch (2.5), Rapeseed (0.6), Crimson Clover (0.9), Everleaf Oats (8.3), Spring Barley (8.3), Appine Forage Turnips (0.6), Groundhog Forage Radish (0.8), Pearl Millet (1.1)

Soil Enhancement Mix (lbs/A): Forage Pea (5.3), Rapeseed (0.3), Crimson Clover (0.5), Everleaf Oat (8.3), Spring Barley (5.0), Pearl Millet (1.1), Soybean (1.8), Winter Pea (4.2), Hairy Vetch (0.8), Spring Triticale (5.0), Purple Top Turnip (0.3), Nitro Radish (0.5), Pacific Gold Mustard (0.5), Sunflower (1.3), Buckwheat (2.3)

Dryland small grains and oilseeds farmers in the Pacific Northwest are interested in sustainable and profitable methods of improving soil quality. In this collaborative on-farm demonstration project, cover crop mixes and cattle grazing were integrated into a small grains and oilseeds rotation (Table 1). Cover crop mixes had mixed effects on winter wheat yield. As forage, they were found to be acceptable to good. This has led to expanded acres of cover crop mixes planted for grazing.

In 2013, 24 head of cattle grazed 15.9 acres of cover crop forage in small paddocks. The yearling heifers gained 2 pounds per day. Forage quality analysis showed in late July each mix was acceptable for yearling heifers and comparable or better than other non-irrigated summer pasture grazing options. However, by mid-August the forage was too mature. Grazing should begin earlier in the season, preferably prior to July 1st.

In 2014, the cover crop grazing demonstration expanded to 46 cow-calf pairs on 46 acres. The stocking rate was 1.75 animal units per acre. The estimated forage production was 5000 pounds per acre. In 2015, a cooperator seeded 150 acres to the six-way cover crop mix in early May. In mid-June, 75 head of spayed heifers and 52 head of cow and their calves were turned in to graze 50 acres of the field divided into approximately 2 acre paddocks. The heifers gained 1.75 pounds per day. The cooperator contracted with another cattleman to sell forage based on the heifer's rate of gain, an uncommon arrangement in dryland annually cropped systems.

Cover crop grazing in north-central Idaho dryland cereal-based production systems is proving to be a viable practice. Crop yields either benefited or were unchanged depending on the mix of species they followed, indicating the importance of species selection in this system (Table 2). This study did not determine why a winter wheat yield advantage was seen following grazed cover crops. Further research should be conducted to determine if the crop response was anomalous or a result of the presence of grazing animals.

Table 2. *Yield results of winter wheat after spring-seeded cover crops, 2014. Plot were at least 600' long, planted with a 45' FlexiCoil direct seed drill and replicated three times.*

Cover Crop Effects*	Yield (bu/A)
Nitrogen Mix	72 a
Soil Enhancement Mix	68 ab
Fallow	62 b
Grazing Mix	61 b
Grazing Effects	
Grazed	75
Non-Grazed	56
CV, 10.3%	

* Significant at the 0.05 probability level.

No-Tillage Systems Can Replace Traditional Summer Fallow in North-Central Oregon

Stephen Machado, Larry Pritchett, and Erling Jacobsen
Columbia Basin Agricultural Research Center, OSU

Many wheat growers in the low precipitation regions of north-central Oregon still prefer to use the traditional winter wheat–summer fallow rotation with some form of tillage. However, research has shown that this cropping system will deplete soil organic matter, exacerbate soil erosion and may not be biologically sustainable if tillage is excessive and insufficient residues are produced. To assist growers' transition from the traditional winter wheat-summer fallow system to no-till systems, we identified both annual and no-till (direct seed) systems that can replace the traditional wheat-fallow system without sacrificing grain yield, using a long-term experiment that started in the 2003-04 crop year. The 11-yr average winter wheat grain yields in the winter wheat-chemical fallow (66 bu/a) and winter wheat-spring barley-chemical fallow (57 bu/a) rotations were not very different from wheat grain yields from the traditional wheat-fallow rotation (59 bu/a) in this period (Table 1). The amount of wheat produced per acre per inch of soil water was 238, 248, and 268 pounds for the traditional winter wheat-summer fallow, winter wheat-chemical fallow, and winter wheat-spring barley-chemical fallow rotations, respectively. Annual cropping of winter wheat, spring wheat and barley, although risky, can be practiced in this region (Table 1). When grain yields were annualized, spring barley produced higher grain yields than winter wheat in rotations involving fallow. Furthermore, residue cover and soil organic matter were highest under annual cropping systems and lowest following peas in the winter wheat-winter pea rotation and following summer fallow in the traditional winter wheat–summer fallow rotation. Given the conservation attributes of no-till systems brought about by increased surface residues, we recommend the adoption of no-till winter wheat-chemical fallow or the more intensified winter wheat-spring barley-chemical fallow rotation, which allows the production of two crops in three years in place of the traditional winter wheat-summer fallow system. Furthermore, weeds were easier to control in the 3-yr rotation compared to other rotations. Annual cropping of winter wheat, spring wheat and spring barley under no-till is also recommended if deemed profitable. Annual cropping increased soil surface residues and soil organic matter, which are essential factors for enhancing grain yields and agricultural sustainability and for developing climate resilient cropping systems.

Table 1. *Wheat and barley grain yields under annual and fallow traditional no-till practices (2004-15). Earlier data not included.*

Rotation	Grain yield (bu/ac)						
	2010-11	2011-12	2012-13	2013-14	2014-15	2011-15	Annualized
Annual cropping							
Continuous winter wheat	57.9	34.7	33.4	26.6	26.3	35.6	35.6
Continuous spring wheat	33.4	37.2	32.3	21.8	13.6	27.7	27.7
Continuous spring barley	55.1	48.4	42.4	38.2	31.3	43.1	43.1
Two-year rotations							
Conventional fallow-Winter wheat	84.8	60.8	56.2	47.2	44.7	58.7	29.4
Chemfallow-Winter wheat	85.9	72.8	62.0	59.6	52.4	66.5	33.3
Winter wheat-winter pea	61.8	48.5	33.0	16.0	41.2	40.1	20.1
Three-year rotations							
Chemfallow-winter wheat-spring barley	72.3	70.2	62.6	59.8	48.8	57.1	33.2
Winter wheat-spring barley-chemfallow	54.2	37.4	40.0	32.0	20.6	42.5	
Precipitation (inches)	12.0	9.8	8.7	9.1	8.6	9.9	

Calcium Carbonate Application on Low pH Soil

A.D. ESSER[1] AND C. SCHMIDT[2]
[1]WSU EXTENSION; [2]FARMER COOPERATOR

Farmers across eastern Washington have experienced decreased soil pH and increased aluminum toxicity. This is mostly created by the application of acid based fertilizers such as anhydrous ammonia. Farmers in this region who have incorporated no-till conservation farming systems into their operation also experience soil pH stratification between 2-5 inches into the soil profile where fertilizer is predominately applied. An on-farm trial (OFT) was established near Rosalia, WA examining the feasibility of NuCal calcium carbonate application over time. The OFT is in a no-till field that soil pH averaged 4.9 in the top 0-6 inches, and it ranged from 4.7 to 5.4. Three treatments were established in the spring of 2015 prior to seeding spring wheat (*Triticum aestivum* L.); a no application check, 31.5 gal/ac NuCal (378 lbs. calcium carbonate costing $86.65/ac with application), and 58.5 gal/ac NuCal (702 lbs. calcium carbonate costing $150.64/ac with application). The OFT is a RCBD with 3 replications and long-term data will be collected including chickpea (*Cicer arietinum*) in 2016 and winter wheat in 2017. Overall no significant differences were detected in spring wheat yield (46 bu/ac), test weight (58.0 lb/bu), and grain protein (13.3%). Differences were detected in economic return over calcium carbonate costs. The check was the greatest at $311/ac., the 31.5 gal/ac treatment was $221/ac, and the 58.5 gal/ac treatment was only $124/ac. In conclusion this study is just getting started and additional soil pH understanding and mitigation work needs to be completed across the region.

Figure 1 and 2. Large OFT were established looking at calcium carbonate application over time. On the left shows the three treatments and on the right shows the overall topography of the long-term study.

Leopard Spots: Circles of Healthy Wheat During Drought

ANN KENNEDY[1], BILL SCHILLINGER[2], RON JIRAVA[3], JEREMY HANSEN[1], AND RENEE SCHULTHEIS[2]
[1]USDA-ARS NORTHWEST SUSTAINABLE AGROECOSYSTEMS RESEARCH UNIT; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND;
[3]COLLABORATING GROWER, RITZVILLE

Abiotic stresses, particularly drought, reduce grain yield of wheat in many semiarid regions of the world. In a long-term cropping systems experiment near Ritzville, WA, we observed circles of green, vibrant spring wheat in the midst of wheat stunted by severe water stress in late May and June in 2001, and again in 2005, 2008 and 2009. These were drought years where crop-year (Sept. 1-Aug. 31) precipitation was only 8.62, 7.99, 6.06, and 10.00 inches, respectively. In these years, recrop (i.e., no fallow year) spring wheat and spring barley showed severe stunting due to water stress. However, several circular areas or “leopard spots” of non-stressed wheat and barley were present throughout the plot area (Fig. 1).

What could be the cause of these leopard spots in recrop spring cereals during drought years? Soil and roots were sampled from transects that extended from the center of circles up to 30 feet outside each circle. Soil samples varied little in pH, electrical conductivity, penetrometer readings, enzyme activities, carbon, and nitrogen. In addition, soil microbial communities, characterized by fatty acid methyl ester analyses (FAME) and phospholipid fatty acid analyses (PLFA), showed limited differences overall. During kernel-fill in late June, healthy wheat within circles contained 2.88 inches more soil water to a depth of six feet than stressed wheat outside of circles. Arbuscular mycorrhizae (AM) counts in roots and AM biomarkers from FAME and PLFA analyses were greater at the edge or inside the circle than outside.

Figure 1. Leopard spot in continuous annual no-till spring wheat in long-term cropping systems experiment near Ritzville, WA. Note other leopard spots in the background including field in the far background where Ron Jirava, the collaborating grower, also produced continuous annual spring wheat. Photo was taken on 28 June 2005.

Arbuscular mycorrhizae interactions were present in the circles and enabled the greater accumulation of limited water, thus keeping the wheat in the circles healthy and green longer than the wheat in the surrounding field. Drought appears to have enhanced AM relationships with wheat. This research illustrates the contribution that AM can have on wheat growth especially under water stress conditions. These results suggest that AM fungal inoculation of seed prior to planting is a potential tool to enhance wheat growth and yield.

Assessing Carbon and Water Dynamics in Multiple Wheat-Based Cropping Systems in the Inland Pacific Northwest Using the Eddy Covariance Method

JINSHU CHI[1], SARAH WALDO[1], SHELLEY PRESSLEY[1], PATRICK O'KEEFFE[1], BRIAN LAMB[1], WILLIAM PAN[2], CLAUDIO STÖCKLE[3], DAVID HUGGINS[4], AND ERIN BROOKS[5]
[1]DEPT. OF CIVIL AND ENVIRONMENTAL ENGINEERING, WSU; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU; [3]DEPT. OF BIOLOGICAL SYSTEMS ENGINEERING, WSU; [4]USDA-ARS; [5]DEPT. OF BIOLOGICAL AND AGRICULTURAL ENGINEERING, UI

Carbon and water fluxes at five agricultural sites (11 site-years) covering a large precipitation gradient and a variety of management practices and crop species were measured in the inland Pacific Northwest using the eddy covariance method. Three winter wheat fields were net CO_2 sinks, with annual net ecosystem exchange of CO_2 (NEE) ranging from -450 ± 32 to -525 ± 28 g C/m^2. Spring crop fields can be a net CO_2 source, CO_2 sink, or close to CO_2 neutral. Partitioning of NEE and evapotranspiration (ET) showed that the low-rainfall winter wheat field had lower total ecosystem respiration (Reco), gross primary productivity (GPP), evaporation (E), and transpiration (T) compared to the high-rainfall area. No-till practice resulted in lower Reco and E compared to conventional tillage, indicating no-till as a farming strategy to help mitigate CO_2 emissions from agriculture. No-till practice also caused slightly lower GPP for winter wheat, so long-term measurements are still needed to assess the no-till benefits of reducing carbon and water loss, maintaining crop production, and sequestering more carbon into soils. Irrigation applied in the dry area maintained good crop production, but resulted in large amounts of carbon and water losses into the atmosphere. Seeding dates, tillage fallow, weeds, and water stress also affected agricultural carbon and water budgets in these cropping systems via different physical and biological processes. In summary, agricultural ecosystems can be net CO_2 and carbon sinks, and the sink strength heavily depends on crop species, management practices, and climatic conditions.

Part 5. Farm Economics

Results of a 5-Year Survey of Dryland Wheat Producers: Yields and Production Costs by Cropping Intensity, 2011-2015

Kathleen Painter[1], Hilary Donlon Davis[2], Dennis Roe[3], and David Huggins[4]
[1]University of Idaho Extension; [2]Dept. of Agricultural Economics and Rural Sociology, UI; [3]Dept. of Crop and Soil Sciences, WSU; [4]USDA-ARS

Forty-five dryland wheat producers located across the dryland grain producing region of eastern Washington, northern Idaho, and southeastern Oregon provided yield and cost data for wheat production from 2011 through 2015. These survey participants were chosen based on their status as frequent university collaborators, early adopters of technology, leadership in the agricultural community, and location across the region.

Production data were grouped by agroecological class (AEC), a classification system based on cropping intensity; in other words, the percent of land that is fallow (Table 1). Average annual precipitation falls from 21 inches per year in AEC1 to 16 inches annually in AEC2 to 12 inches per year in AEC3. Average wheat yields decline along with average precipitation. Winter wheat yields in AEC1, the highest precipitation zone, averaged 87 bu/acre for 2011-2015, while those in AEC2 were 13% lower at 76 bu/acre. In AEC3, winter wheat yields averaged just 55% of those in AEC1, with 48 bu/acre reported for 2011-2015. The differences in spring wheat yields by AEC were even more dramatic for this time period, which experienced both wetter than average years in 2011 and 2012, and drier than average years in 2014 and 2015. Spring wheat yields in AEC1 averaged 59 bu/acre, while average spring wheat yields for AEC2 were 17% lower at 49 bu/acre. In AEC3, spring wheat yields averaged just 40% of those in AEC1 at 23 bu/acre. Some producers in AEC3 produce spring wheat annually rather than using a two-year winter wheat, summer fallow rotation. Average yields across the three agroecological classes by year are presented in Figure 2.

Table 1. *Average annual precipitation, typical rotation, and average winter wheat yields by agroecological class, 2011-2015.*

Agroecological Class (AEC)		Average Annual Precipitation (inches)	Typical Region	Average Winter Wheat Yield (bu/ac)	Average Spring Wheat Yield (bu/ac)
AEC1	Annual	21	Winter wheat, spring grain, legume	87	59
AEC2	Transition	16	Winter wheat, spring grain, fallow	76	49
AEC 3	Grain-Fallow	12	Winter wheat, fallow	48	23

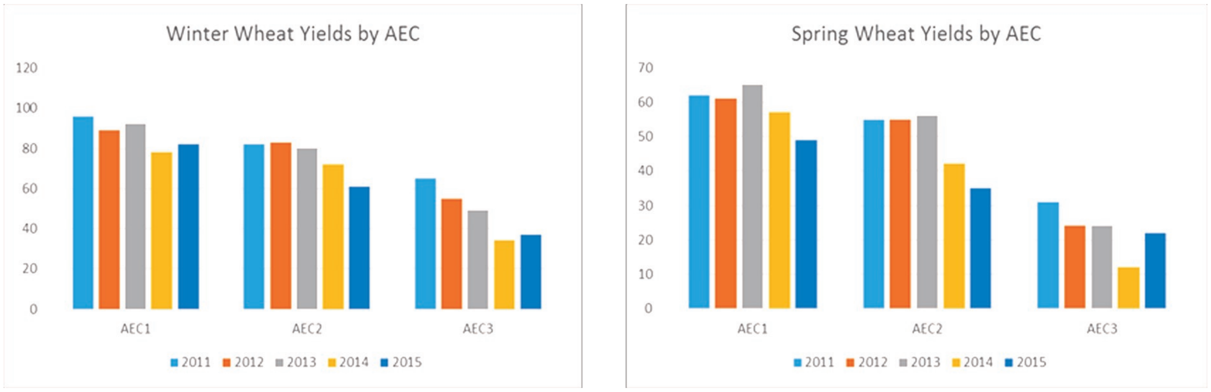


Figure 2. Dryland winter and spring wheat yields from 45 longitudinal survey participants by agroecological class, 2011-2015.

Decision Support Tools to Aid Wheat and Barley Farmers with Planting, Harvesting, and Spraying for Pests/Weeds

Katherine Hegewisch[1], John Abatzoglou[1], Brad Stokes[2], Sanford Eigenbrode[2], and Edward Bechinski[2]
[1]Dept. of Geography, UI; [2]Dept. of Plant, Soil, and Entomological Sciences, UI

Wheat and barley production zones in the Pacific Northwest encompass 4 million acres and are worth approximately $2 billion annually, but are subject to yield reductions caused by insect pests and weeds. Science and technology can help growers minimize damage from pests and weeds by using phonological models and climate datasets. A set of decision support tools is now available through the Regional Approaches to Agriculture under Climate Change (REACCH) project and can be accessed through http://www.climate.nkn.uidaho.edu/REACCH. There are three kinds of tools available: aphid tracking tools, decision support calculators based on economic models, and decision support tools based on growing degree day models.

The first set of tools provides information on aphid populations and aphid viruses on the Palouse. Every spring/summer since 2006, wheat aphids have been collected weekly from traps, counted, and tested for certain viruses. The 'Aphid Tracker' tool uses the resulting data to visualize aphid counts and the locations of aphid viruses over different seasons on the Palouse.

The second set of tools includes calculators to inform farmers on the costs and benefits of certain pest treatments, given current pest observations and economic conditions. The user fills out a form describing the situation and is presented with a suggested plan of action. Calculators are available for seed treatment and for determining when to spray for wheat aphids or for Russian wheat aphids in barley.

The third set of tools aids growers with decisions on when to plant or spray. They are based on phenological models for several pests and weeds as well as real-time weather monitoring and 7-month weather forecasts. Based on these growing degree day models, specific tools have been constructed to forecast harvest dates, alter spring wheat planting dates to avoid wheat midge damage, and suggest spraying dates to combat downy brome.

Decision Support Tools for Assessing Climate Smart Agriculture

John Antle, Susan Capalbo, Clark Seavert, and Laurie Houston
Dept. of Applied Economics, OSU

Climate variability will have differing impacts on agricultural sectors in the Pacific Northwest (PNW) and worldwide. Whether they appear in the form of increased intra-seasonal variability, severe heat waves, long-term drought, or warmer winters, growers need to be cognizant of the risks and opportunities that future weather patterns may bring to yields and profitability, as well as the possible environmental outcomes of changes in management regimes. The regional impacts of these risks will also be important to policy makers when designing adaptation and mitigation policies. Information at the local and regional level will be a key input to landscape modeling efforts aimed at analyzing such policies.

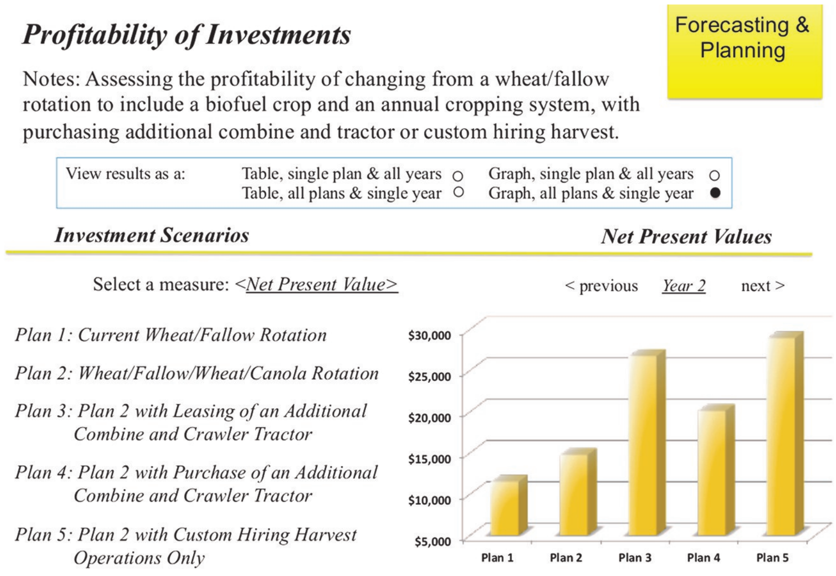
Three key elements are required to improve the capability to make better management and policy decisions: (1) timely and accurate data on climate variability and its impact on yield and cost projections; (2) scientific understanding of the agroecological system at the farm scale; and (3) incorporation of those two elements into knowledge products that meet the needs of growers and policy decision makers. The increasing utilization of precision farming and mobile technologies, together with improvements in data management software, offer expanding opportunities for an integrated data platform that links farm-level management decisions and resulting behavioral changes to site-specific biophysical data and analytical tools. Through the use of data technologies, farm-level information can be integrated with publically available data at the landscape scale for supporting science-based policy and sustainable management of agriculture.

The developers of AgBiz Logic (http://www.agbizlogic.com/) and TOA-MD (Tradeoff Analysis Model for Multi-dimensional Impact Assessment, http://tradeoffs.oregonstate.edu/) are working together to develop a link between farm-level data collected with *AgBiz Logic* and landscape-scale data needed for TOA-MD in order to support regional policy analysis. A tool like *AgBiz Logic* would be an ideal source for high quality, timely, low cost data. Several considerations would need to be incorporated into facilitating a link between *AgBiz Logic* and the TOA-MD framework. First, a statistically representative group of farms would need to be identified that would agree to use *AgBiz Logic* and allow their data to be used in a landscape scale analysis. This would involve a sampling process similar to identifying a sample of farms for a farm-level economic survey. Second, software would need to be designed to transmit and assemble the individual farm data into a database that could subsequently be used to estimate TOA-MD parameters while maintaining confidentiality of individual producers. Note that in most cases data would need to be collected over multiple growing seasons to account for crop rotations and other dynamic aspects of the farming system. The data acquired through tools such as *AgBiz Logic* can be combined with future projections to implement regional integrated assessments.

AgBizProfit™

CLARK SEAVERT
DEPT. OF APPLIED ECONOMICS, OSU

AgBizProfit is a capital investment tool that evaluates an array of short-, medium-, and long-term investments. These investments may include planting long-term perennial timber, tree fruit, nut and vine crops; evaluating annual crops, cropping systems or livestock enterprises; implementing technologies; and adopting conservation practices.


Profitability of Investments

Forecasting & Planning

Notes: Assessing the profitability of changing from a wheat/fallow rotation to include a biofuel crop and an annual cropping system, with purchasing additional combine and tractor or custom hiring harvest.

View results as a:
Table, single plan & all years ○
Table, all plans & single year ○
Graph, single plan & all years ○
Graph, all plans & single year ●

Investment Scenarios *Net Present Values*

Select a measure: <*Net Present Value*>

< previous *Year 2* next >

Plan 1: Current Wheat/Fallow Rotation
Plan 2: Wheat/Fallow/Wheat/Canola Rotation
Plan 3: Plan 2 with Leasing of an Additional Combine and Crawler Tractor
Plan 4: Plan 2 with Purchase of an Additional Combine and Crawler Tractor
Plan 5: Plan 2 with Custom Hiring Harvest Operations Only

AgBizProfit uses the economic concepts of net present value, annual equivalence, and internal rate of return to analyze the potential profitability of a given investment. Projected annual net returns are discounted back to their present value to be compared with other plans within each scenario. Each plan can be discounted with its own discount rate, and beginning and ending investment values.

Learn more about *AgBizProfit* when you sign up for *AgBiz Logic* at http://www.agbizlogic.com.

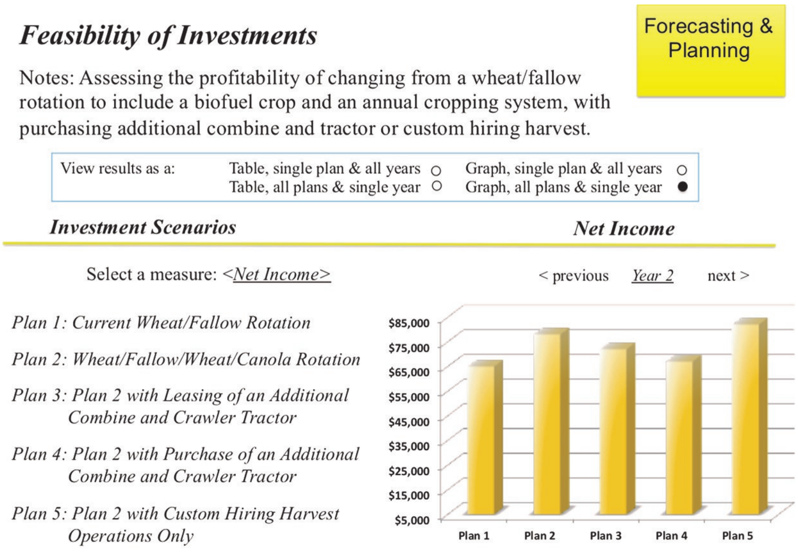
AgBizFinance™

CLARK SEAVERT
DEPT. OF APPLIED ECONOMICS, OSU

AgBizFinance is designed to help agricultural producers make investment decisions based on financial liquidity, solvency, profitability, and efficiency of the farm or ranch business. After an *AgBizFinance* analysis has been created, investments in technology, conservation practices, value-added processes, or changes to cropping systems or livestock enterprises can be added to or deleted from the current farm and ranch operation. Changes to a business' financial ratios and performance measures will also be calculated.

By inserting assets, liabilities, loan and capital lease information, *AgBizFinance* generates 19 financial ratios and performance measures based on annual returns and cash costs from each business enterprise.

Learn more about *AgBizFinance* when you sign up for *AgBiz Logic* at http://www.agbizlogic.com.



Feasibility of Investments

Forecasting & Planning

Notes: Assessing the profitability of changing from a wheat/fallow rotation to include a biofuel crop and an annual cropping system, with purchasing additional combine and tractor or custom hiring harvest.

View results as a: Table, single plan & all years ○ Table, all plans & single year ○ Graph, single plan & all years ○ Graph, all plans & single year ●

Investment Scenarios — *Net Income*

Select a measure: <Net Income>

< previous Year 2 next >

Plan 1: Current Wheat/Fallow Rotation

Plan 2: Wheat/Fallow/Wheat/Canola Rotation

Plan 3: Plan 2 with Leasing of an Additional Combine and Crawler Tractor

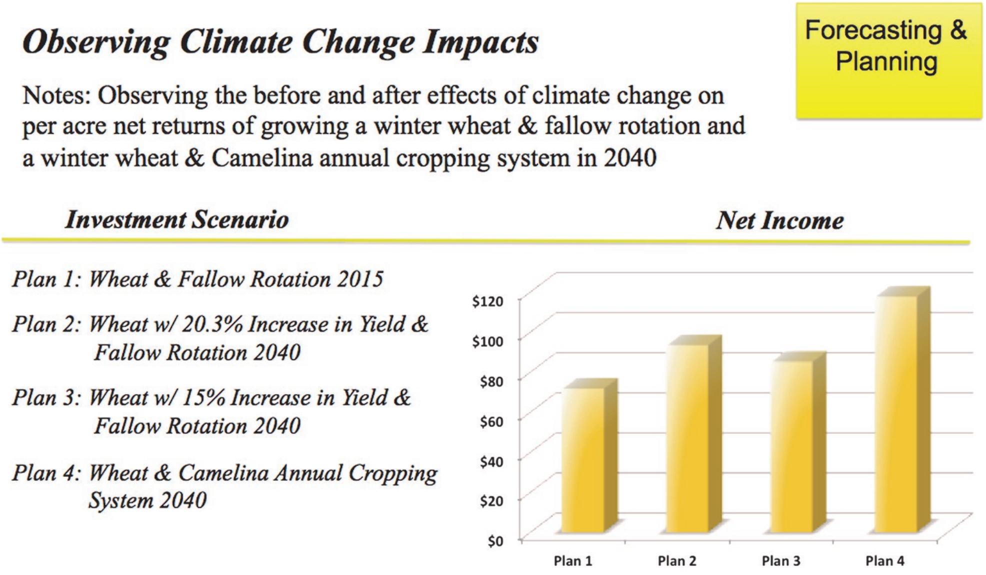
Plan 4: Plan 2 with Purchase of an Additional Combine and Crawler Tractor

Plan 5: Plan 2 with Custom Hiring Harvest Operations Only

AgBizClimate™

CLARK SEAVERT
DEPT. OF APPLIED ECONOMICS, OSU

AgBizClimate uses downscaled climate information relevant to an individual farm that the user can access to project yield and production input changes over time due to climate change. These yield changes are the impetus for producer-generated adjustments in input use, management and technology adoption that may lessen the negative impacts or take advantage of positive opportunities.



Observing Climate Change Impacts

Forecasting & Planning

Notes: Observing the before and after effects of climate change on per acre net returns of growing a winter wheat & fallow rotation and a winter wheat & Camelina annual cropping system in 2040

Investment Scenario — *Net Income*

Plan 1: Wheat & Fallow Rotation 2015

Plan 2: Wheat w/ 20.3% Increase in Yield & Fallow Rotation 2040

Plan 3: Wheat w/ 15% Increase in Yield & Fallow Rotation 2040

Plan 4: Wheat & Camelina Annual Cropping System 2040

Through the use of *AgBizClimate,* farmers can compare changes in their specific farm-level economic costs and returns associated with on-farm actions in response to climate change and/or policy and price changes. *AgBizClimate* summarizes the climate information that is available for the farmer's specific area, then demonstrates through powerful graphics how this downscaled information could impact the economic costs and returns the farmer is likely to face over the next 20-30 years.

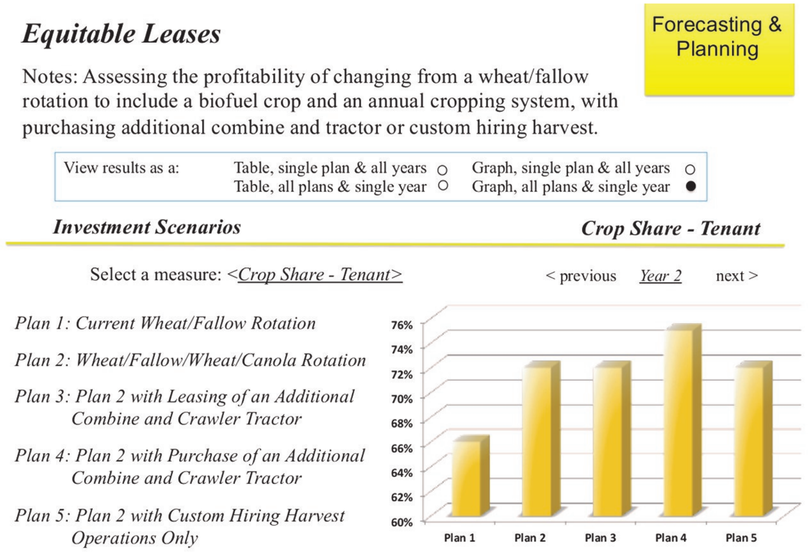
Learn more about *AgBizClimate* when you sign up for *AgBiz Logic* at http://www.agbizlogic.com.

AgBizLease™

Clark Seavert
Dept. of Applied Economics, OSU

AgBizLease is designed to help agricultural producers establish equitable short- and long-run crop leases. *AgBizLease* calculates two types of leases – crop share percentage and annual cash rent payment. The basis for which *AgBizLease* calculates these leases is the Net Present Value (NPV) of total costs paid by either the tenant or landowner. In each lease type, the more a tenant or landowner contributes to total costs over the length of the lease, the higher the percentage share of the crop return or annual cash rent payment. In a cash rent lease, the annual cash rent payment is calculated in two ways – the landowner's required cash rent payment and the tenant's ability to pay.

Learn more about *AgBizLease* when you sign up for *AgBiz Logic* at http://www.agbizlogic.com.



Equitable Leases

Forecasting & Planning

Notes: Assessing the profitability of changing from a wheat/fallow rotation to include a biofuel crop and an annual cropping system, with purchasing additional combine and tractor or custom hiring harvest.

View results as a: Table, single plan & all years ○ Graph, single plan & all years ○
Table, all plans & single year ○ Graph, all plans & single year ●

Investment Scenarios *Crop Share - Tenant*

Select a measure: <Crop Share - Tenant> < previous Year 2 next >

Plan 1: Current Wheat/Fallow Rotation
Plan 2: Wheat/Fallow/Wheat/Canola Rotation
Plan 3: Plan 2 with Leasing of an Additional Combine and Crawler Tractor
Plan 4: Plan 2 with Purchase of an Additional Combine and Crawler Tractor
Plan 5: Plan 2 with Custom Hiring Harvest Operations Only

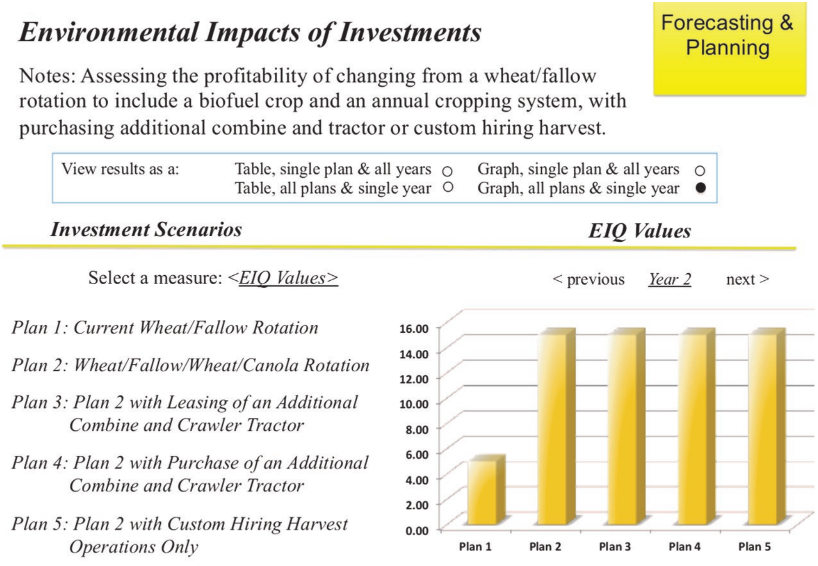
AgBizEnvironment™

Clark Seavert
Dept. of Applied Economics, OSU

AgBizEnvironment utilizes various components to measure and track environmental aspects of crop and livestock production. Aspects include pesticide, herbicide, fertilizer, and energy use, as well as tillage and land management practices. Combined with other *AgBiz Logic* tools, users can compare environmental, economic and financial tradeoffs.

An example of a component utilized by *AgBizEnvironment* is the Environmental Impact Quotient (EIQ) developed by Cornell University. The EIQ measures the effect of various pesticides and herbicides on consumers, workers, and ecosystems.

Learn more about EIQ and other *AgBizEnvironment* components when you sign up for *AgBiz Logic* at http://www.agbizlogic.com.



Environmental Impacts of Investments

Forecasting & Planning

Notes: Assessing the profitability of changing from a wheat/fallow rotation to include a biofuel crop and an annual cropping system, with purchasing additional combine and tractor or custom hiring harvest.

View results as a: Table, single plan & all years ○ Graph, single plan & all years ○
Table, all plans & single year ○ Graph, all plans & single year ●

Investment Scenarios *EIQ Values*

Select a measure: <EIQ Values> < previous Year 2 next >

Plan 1: Current Wheat/Fallow Rotation
Plan 2: Wheat/Fallow/Wheat/Canola Rotation
Plan 3: Plan 2 with Leasing of an Additional Combine and Crawler Tractor
Plan 4: Plan 2 with Purchase of an Additional Combine and Crawler Tractor
Plan 5: Plan 2 with Custom Hiring Harvest Operations Only

Photo by OSU EESC

1

2

3

Photo Credits

Front Cover #1 —Jillian Blume
#2 —Laurel Graves
#3 —Guy Swanson

Back Cover #1 —Dave Huggins
#2 —Nita Robinson
#3 —Leigh Bernacchi