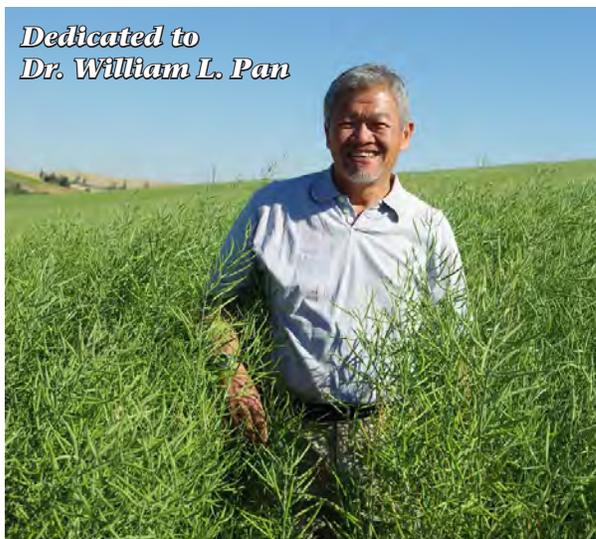


2013 Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS

*Dedicated to
Dr. William L. Pan*



WASHINGTON STATE UNIVERSITY
EXTENSION

Department of Crop and Soil Sciences
Technical Report 13-1

WSU Dryland Research Station Field Day—Lind, June 13, 2013
WSU Cook Farm Field Day—Pullman, June 27, 2013
WSU Spillman Farm Field Day—Pullman, July 11, 2013

LEAVE A **Land** LEGACY

legacyofland.wsu.edu



Ownership in agricultural, timber, or grazing land represents the hard work, sacrifices, courage, and stewardship of your family, oftentimes for generations. We know that your land is important to you—it has sustained you and become your heritage. But keeping a farm in the family is not easy and we appreciate the difficulty you face in making decisions about your land for the future.

Now is the time to consider **YOUR LEGACY.**

A well-planned charitable gift of our family property may provide significant tax benefits while addressing land-management and income issues. For over a century, WSU has been proud to partner with farmers, ranchers, orchardists, producers, agribusinesses, and consumers.

For more information about leaving a Land Legacy, contact:

Office of Alumni and Friends
College of Agricultural, Human, and Natural Resource Sciences
(509) 335-2243 • www.legacyofland.wsu.edu

WASHINGTON STATE
 UNIVERSITY

World Class. Face to Face.

Welcome to our 2013 Field Days!

As Chairman of the Department of Crop and Soil Sciences, I am proud to present the **2013 Dryland Field Day Abstracts: Highlights of Research Progress**. This publication is intended to introduce you to the numerous research projects conducted by WSU faculty and USDA-ARS research scientists working as part of, or in cooperation with, the Department of Crop and Soil Sciences. To learn more about the Department please visit us on the web at www.css.wsu.edu. There you'll find detailed information about faculty members and research programs in the Department.

We are engaged in many research activities of local, regional and national importance. Our 2013 department-sponsored field days are just one way for us to showcase the latest developments in our research programs. This publication is also an opportunity to thank the sponsors of this research, namely the wheat, barley, legume, and alternative crop growers of the State of Washington and the related agricultural industries that support them. Your generous contributions have allowed us to develop an extraordinarily strong research and extension base that produces competitive plant varieties to meet your specific needs and provides practical solutions to your agronomic challenges.

This edition of the Dryland Field Day Abstracts is dedicated to Dr. William Pan who has devoted his career to cutting edge research in the fertility of alternative crop rotations, crops for energy, waste utilization, nitrogen use efficiency, and nutrient cycling. He is also devoted to training and educating graduate and undergraduate students, and to serving Washington State and WSU, including leadership roles as CSS Chair from 2002-2008, current Cropping Systems Program Director and WSU Lead of the USDA-funded REACCH Program, and Project Director for the Washington State Biofuel Cropping Systems Initiative. Dr. Pan's efforts over the last decade have contributed immeasurably to the reputation of excellence that Crop and Soil Sciences enjoys today.

We also want to express our sincere appreciation to Ryan Davis, who worked tirelessly to keep the Spillman Farm and Cook Farm running smoothly. Although Ryan has moved on, the Farms still benefit from his leadership as Farm Manager.

Sincerely,



Dr. James B. Harsh, Professor and Chair
Department of Crop and Soil Sciences

2013 Dryland Field Day
Abstracts:
Highlights of
Research Progress

Technical Report 13-1
Editors: Cindy Warriner and
William Schillinger

Cover photos:

Top left: William Pan walking
one of John Hinnenkamp's
spring canola fields near Albion.
Photo by Karen Sowers

Top right: Dr. Arron Carter,
WSU winter wheat breeder,
taking one last look at advanced

breeding lines before harvest at
Spillman Farm.
Photo by Gary Shelton

Bottom: Wheat harvest at
Bauman Farms west of
Washtucna.
Photo by Karen Sowers

Dedication to Dr. William (Bill) L. Pan, Professor, Scientist, and Extension Specialist

Bill Pan has the land grant mission in his blood. His grandfather, Weng Ping Pan was the first Asian student at the University of Minnesota in 1914, and then a mining engineer in northern Minnesota, fueling the steel based industrial U.S. with rich iron ore. Bill's parents and two siblings also attended UM. Bill chose to attend University of Wisconsin with a B.S. focus on biochemistry, plant and soil sciences and he developed a passion for agricultural and environmental sciences during his travels around the hummocky glacial terrain surrounding Madison and his interactions with local crop and dairy farmers dealing with state regulations on wetland management. Undergraduate research opportunities were rare in those days, so waiter, grill cook, and Teamsters warehouseman were his part-time occupations to pay the education bills.



Bill's Grandfather,
Wen Ping Pan

Pan then earned his M.S. in Agronomy at another land grant institution, University of Missouri in 1979, and his PhD studying the physiology of N use efficiency in corn at a third land grant institution, North Carolina State University in 1983, the year Coach Jim Valvano and the Wolfpack made their miracle run to win the NCAA basketball championship. Today Valvano's words "Don't give up, don't ever give up" are still inspirational to cancer patients and their families. Throughout Bill's training at NCSU, Dr. William Jackson was recommended to Pan because "he would be a great advisor on more than just academics". Dr. Jackson, a classic pipe smoking, bearded professor with rye wit and sage wisdom, taught Bill to think broadly, critically question status quo theories, and most importantly, treat those around you with great respect, understanding and support. Along with these life lessons learned, Pan focused his research on the crop-root interface throughout his graduate training, and he was fortunate to land an interview with Washington State University.



Bill, graduate field research,
shelling corn. Photo by Dr.
James Camberato

William L. Pan was hired in 1984 to help bridge the gap between the crops and the soils programs of the "Agronomy Department" at WSU. Four land grant institutions across the U.S. Why all land grants? State and federally supported, affordable education institutions focused on agriculture and engineering programs underpinning the U.S. economy and productivity. Higher education of the people, for the people integrates missions of research, education and outreach to agriculture, engineering and public stakeholders.

In 2010, Pan was awarded the WSU College of Agricultural, Human and Natural Resource Sciences Award for Individual Integrated Excellence in Research, Teaching and Extension for career dedication to the tripartite mission of the land grant institution.

Throughout his 29 year career (and counting) at WSU, Bill has worked to improve the sustainability of agronomic cropping systems across Washington and the Pacific Northwest. He leads an active Nutrient Cycling and Rhizosphere Ecology program, while employing or advising over 150 undergraduate students in his laboratory, major advisor for 30 graduate students, 45 other graduate student advisory member. Many of Pan's former students have returned or stayed in Washington to become outstanding leaders in the state's private and public agriculture and ecology sectors. Ron Bolton has served as essential staff support of NCRE and research collaborator with Pan since the beginning. Ron's digital imaging, data management, and general computer and audio/visual technology knowledge have contributed to numerous successes of NCRE and CSS faculty, staff, and students.

Pan's research has improved nutrient use efficiencies, reduced fertilizer requirements, while increasing the value and diversity of agricultural products. He has developed nationally recognized expertise in the areas of variability of nitrogen use efficiency influenced by crop genetic diversity and cropping system management, root development and



Bill showing soil monoliths to graduate
students. Photo by Bob Hubner

(Continued from page 2)

imaging, and site-specific nutrient management. His research has promoted the adoption of winter cover crops in the irrigated Columbia Basin for reducing PM-10 emissions and reducing nitrate leaching to groundwater. New directions include the search for cropping system diversification towards more sustainable crop rotations to meet societal demands for food, fiber, feed, fuel, and specialty chemicals.

Currently, Pan directs the statewide, oilseed based Washington Biofuels Cropping Systems Project supported by the WA State Department of Agriculture, Governor's Office and Department of Commerce, and WSU Energy Program, supporting more than 70 WSU and USDA-ARS researchers, extension faculty and staff, and graduate students. Diversification of monoculture wheat based systems with oilseeds is the goal for addressing local biofuel, food and feed demand while positively addressing climate change and overall system sustainability. Pan also co-directs USDA funded STEEP and REACCH, with focus on tri-state cropping systems research for adapting to and mitigating climate change over the next 25 years.

Pan served as Chair of Crop and Soil Sciences (CSS) from 2002-2008, at a time when there was much serious discussion about the two programs splitting into separate departments. It was time for Pan to achieve the goal of those that hired him: bridge the department. It was time to demonstrate the synergies between the programs from organic agriculture to environmental soil remediation to crop breeding and genetics. The department stayed together, and is now a prospering flagship department of WSU CAHNRS. During his Chair term, CSS moved many research labs into state of art Vogel Plant Biosciences, moved, expanded and updated the turf research facility at Pullman, identified the current location for the new Organic Farm, and integrated Ag Education, Ag Technology, cereal chemistry faculty into CSS, and solidified CSS managed WSU research farms and community relations. Statewide experiment station based graduate training gained momentum. Key new faculty hires during Pan's term established a strong foundation for Crop and Soil Sciences to move into the next generation.



Bill as Chair of Crop and Sciences. Photo by Bob Hubner



Bill kneeling in a field of camelina. Photo by Karen Sowers

Currently, Pan is back on the CSS faculty with a research-academic-extension-administrative appointment that allows him to pursue the land grant mission. He directs an outstanding group of staff, students, and research associates comprising the Nutrient Cycling Rhizosphere Ecology Team that will become the next generation of innovative agricultural scientists and educators.

Table of Contents

TECHNICAL REPORT 13-1 (ALSO AVAILABLE ONLINE AT [HTTP://CSS.WSU.EDU/PROCEEDINGS](http://css.wsu.edu/proceedings))

Cooperative Personnel and Area of Activity.....	7
Acknowledgement of Research Support, 2012-13	9

Farm Overviews

Cook Agronomy Farm	12
Dryland Research Station	12
Palouse Conservation Field Station	13
Spillman Agronomy Farm	14
Wilke Research and Extension Farm.....	15

Variety History

Wheat Variety History at WSU	16
Barley Variety History at WSU.....	18
Dry Pea, Lentil and Chickpea Varieties History at WSU	18

Part 1. Breeding, Genetic Improvement, and Variety Evaluation

Development of Two-gene Clearfield Wheat Varieties through Forward Breeding Approach (Kumar et al.)	21
Spring Barley Improvement for Herbicide Tolerance, Malting and Food Quality Traits (Matanguihan et al.)	21
The Western Wheat Quality Laboratory (Morris et al.)	22
Breeding Barley Cultivars Adapted to the Pacific Northwest United States for Imidazolinone Resistance (Rustgi et al.)	22
Release of 'Lyon' and 'Muir': Two New Feed Barley Varieties from WSU (Murphy et al.)	23
Variety Selection for Management of Aluminum Toxicity (Schroeder et al.)	24
Winter Wheat Breeding and Genetics (Carter et al.)	24
Washington Extension Variety Trials 2013 – Bringing Variety Performance Information to Growers (Guy et al.)	25
Screening for Winter-Hardiness in a Cultivated Chickpea/Wild Relative RIL Population (Piaskowski et al.)	26
Dry Pea, Lentil, and Chickpea Variety Evaluation on the Palouse: Innovation of Energy Efficient, High Value Food Crops (Guy et al.)	27
Modification of Coleoptile Length in Wheat via Manipulation of the AHL Gene Family (Neff et al.)	27
Variation for Wheat Seedling Emergence from Deep Planting Depths and its Relationship with Coleoptile Length (Mohan et al.)	28
Evaluating Winter Wheat Seedling Emergence from Deep Planting Depths (Mohan et al.).....	28
Genetic Variation in Preharvest Sprouting Tolerance (Martinez et al.).....	29
Multipronged Approach to Develop Nutritionally Improved, Celiac Safe, Wheat Cultivars (Rustgi et al.).....	30
Discovering Drought Resistance Mechanisms in Wheat (Shrestha et al.)	31
Pre-Breeding for Root Rot Resistance Using Root Morphology Traits (Okubara et al.)	31
Genetic Mapping of Quantitative Trait Loci Associated with Important End-Use Quality Parameters in Soft White Winter Wheat (Jernigan et al.)	32
Cool Season Food Legume Breeding and Pathology (Chen et al.).....	32
A Promising New Pulse Crop for Washington State: Winter-hardy Faba Bean (<i>Vicia faba</i> L.) (Landry et al.)	33

Part 2. Pathology and Entomology

Suppression of Downy Brome (Cheatgrass) in Wheat Using a Soil Bacterium (Kennedy et al.)	34
Control of Rusts of Wheat and Barley in 2012 (Chen et al.).....	34
Ecology and Biology of Wireworms in Washington Dryland Wheat Cropping Systems (Milosavljevic et al.)	35
Controlling Wireworms with Thiamethoxam Insecticides in Wheat (Esser et al.)	35
Parasitic Weed Dodder Found on Chickpea in Washington (Chen et al.)	36
Stemphylium Blight – a New Disease of Lentil in the Palouse (Chen and Vandermark).....	37
Managing Risks of Virus Infections in Pulse Crops in the Palouse Region (Eigenbrode et al.)	37
Rhizobacterial Community Structure and Function in a Dryland Agroecosystem (Mavrodi et al.).....	38
Eyespot, Cephalosporium Stripe, Snow Mold, and Soilborne Wheat Mosaic Diseases of Winter Wheat (Murray et al.)	38
Natural Suppression of Rhizoctonia Bare Patch in a Long-Term No-Till Cropping Systems Experiment (Schillinger et al.).....	40

Part 3. Agronomy, Economics, and Sustainability

Row Spacing Experiments for Deep-Furrow Planting of Winter Wheat (Schillinger et al.)	41
Integrated Weed Management in Dryland Wheat and Barley (Lyon and Rood).....	42
Cover Cropping for the Intermediate Precipitation Zone of Dryland Eastern Washington (Roberts et al.).....	42
Soil Conservation Survey Results for 584 Pacific Northwest Farmers in 2010 (Kane et al.)	43
Evaluation of Deep-Furrow Drill Prototypes for Conservation Wheat-Fallow Farming (Schillinger et al.)	44
No-Till and Conventional Tillage Fallow Winter Wheat Production Comparison in the Dryland Cropping Region of Eastern Washington (Esser and Jones)	45
Straw Management and Crop Rotation Alternatives to Burning Wheat Stubble: Assessing Economic and Environmental Trade-offs (Birkhauser et al.)	45
Development of a VisNIR Penetrometer for <i>in situ</i> Soil Characterization and Site Specific Management (Poggio et al.).....	46
Carbohydrate and Ion Concentration Variation in Wheat Sap During Three Cold Temperature Treatments (Skinner and Bellinger)	47
Benefits and Challenges of Multidisciplinary Research Involving Agricultural Economists and Agricultural Scientists (Mooney et al.)	47
Kentucky Bluegrass Evaluation for Turf and Seed Production without Field Burning (Johnston et al.)	48

Part 4. Bioenergy Cropping Systems Research

The “Oilseed Based” Washington State Biofuels Cropping Systems (WBCS) Project (Pan)	50
Oilseed Extension and Outreach Activities and Outcomes (Sowers et al.)	50
Winter Canola Production in the Low- to Intermediate-Rainfall Zones of the Pacific Northwest (Roe et al.)	51
Spring Canola Production at the WSU Wilke Research and Extension Farm (Esser)	52
Winter Canola Rotation Benefit Experiment in the Intermediate Precipitation Zone (Schillinger et al.)	52

Economic Returns to Canola Rotations in Eastern Washington (McCracken and Connolly)	53
Double-Cropping Dual Purpose Irrigated Biennial Canola with Green Pea (Desta et al.)	54
Management of Fresh Wheat Residue for Irrigated Winter Canola Production (Schillinger et al.)	55
Nitrogen Use By Pacific Northwest Dryland Canola (Brassica napus) (Maaz et al.)	55
Assessing Crop Rotational Nitrogen Use Efficiency Using an N Balance Approach (Maaz et al.)	56
Residue Decomposition of Canola Cultivars (Stubbs et al.)	57
Oilseed Root Characteristics: Implications for Water and Nutrient Management (Pan et al.)	57
A Comparison of Oilseed and Grass Crop Residue Silicon and Fiber Composition and Impacts on Soil Quality (Beard et al.)	58
Emerging Diseases of Canola and Camelina in the Pacific Northwest (Paulitz et al.)	59
Analysis of Fatty Acid Content in Oilseeds (Baxter-Potter et al.)	60
Rotational Influence of Brassica Biofuel and Other Crops on Winter Wheat (Guy and Lauver)	60
Safflower Oilseed Production under Deficit Irrigation and Variable N Fertilization (Collins et al.)	61
Wind Erosion Potential from Oilseed Cropping Systems (Sharratt and Schillinger)	62
Safflower Cropping Systems Experiment in the Low-Precipitation Zone (Schillinger et al.)	63
Long-term Camelina Cropping Systems Experiment at Lind (Schillinger et al.)	64
Camelina: What Will it Take to Make this Crop Attractive to Pacific Northwest Growers? (Schillinger)	65
Development of Herbicide Tolerant Camelina Varieties (Hulbert and Burke)	66
Increasing Seed Size and Seedling Emergence in the Brassicas Arabidopsis and Camelina (Neff et al.)	67
International Commitment (Pan)	68

Cooperative Personnel and Area of Activity

Elson S. Floyd	President, Washington State University
Daniel J. Bernardo	Vice President for Agriculture and Extension—Dean of CAHNRS
James B. Harsh	Chair, Department of Crop and Soil Sciences
James W. Moyer	Associate Dean and Director, Agricultural Research Center
Kimberlee K. Kidwell	Executive Associate Dean for Academic Programs—CAHNRS
Richard T. Koenig	Associate Dean of CAHNRS / Director of WSU Extension

Cereal Breeding, Genetics and Physiology

WHEAT BREEDING & GENETICS

R.E. Allan (Collaborator), USDA	335-1976	allanre@wsu.edu
K.G. Campbell, USDA	335-0582	kgcamp@wsu.edu
A.H. Carter	335-6198	ahcarter@wsu.edu
K.S. Gill	335-4666	ksgill@wsu.edu
S.S. Jones	360-416-5210	jones@wsu.edu
C.F. Morris, USDA	335-4062	morris@wsu.edu
M.M. Neff	335-7705	mmneff@wsu.edu
M.O. Pumphrey	335-0509	m.pumphrey@wsu.edu
D.R. See, USDA	335-3632	deven.see@wsu.edu
C. Steber, USDA	335-2887	camille.steber@ars.usda.gov
<i>K. Balow, A. Burke, V.L. DeMacon, R. Higginbotham, S. Johnson, J. Kuehner, W. Nyongesa, P. Reisenauer, S. Rynearson, G.B. Shelton</i>		

BARLEY BREEDING & GENETICS

K. Murphy	335-9692	kmurphy2@wsu.edu
D. von Wettstein	335-3635	diter@wsu.edu
<i>C. Boyd, U. Gill, G. Kannangara, R. Kinney, J. Matanguihan, J. Nirmala, P. Reisenauer, M. Wood</i>		

Crop Diseases

CEREAL CEPHALOSPORIUM STRIPE, FOOT ROT, SNOW MOLDS, WHEAT STREAK MOSAIC

T.D. Murray	335-7515	tim.murray@wsu.edu
-------------	----------	--------------------

ROOT DISEASES

P. Okubara, USDA	335-7824	pokubara@wsu.edu
T. Paulitz, USDA	335-7077	paulitz@wsu.edu
D. Weller, USDA	335-6210	wellerd@wsu.edu
<i>A. Prescott, K. Schroeder</i>		

RUSTS, SMUTS; FOLIAR, VIRUS AND BACTERIAL DISEASES

L. Carris	335-3733	carris@wsu.edu
K. Evans, USDA	335-8715	kent_evans@wsu.edu
H. Pappu	335-3752	hrp@wsu.edu
T. Peever	335-3754	tpeever@wsu.edu
B. Schroeder	335-5805	bschroeder@wsu.edu
W. Chen, USDA	335-9178	w-chen@wsu.edu
X.M. Chen, USDA	335-8086	xianming@mail.wsu.edu
R.F. Line, USDA	335-3755	rline@wsu.edu
<i>K.C. Evans, Y.M. Liu, A.M. Wan, M.N. Wang</i>		

Wheat Quality, Variety Evaluation

WHEAT QUALITY

B.S. Beecher, USDA	335-4062	bbeecher@wsu.edu
C.F. Morris, USDA	335-4062	morris@wsu.edu
<i>M.L. Baldridge, A.D. Bettge, P.K. Boyer, D.A. Engle, E.P. Fuerst, T. Harris, G.L. Jacobson, W.J. Kelley, M.J. Lenssen, J. Luna, B. Paszczyńska, H. Ramseyer, S. Sykes, S. Vogl, E. Wegner</i>		

WSU EXTENSION VARIETY TESTING

S.O. Guy	335-5831	sguy@wsu.edu
<i>A. Horton, M. Lauver, V. Jitkov</i>		

Breeding and Culture of Legumes

DRY PEAS, LENTILS, CHICKPEAS

W. Chen, USDA	335-9178	w-chen@wsu.edu
R. McGee, USDA	335-9521	rebecca.mcgee@ars.usda.gov
F.J. Muehlbauer (Collaborator), USDA	335-7647	muehlbau@wsu.edu
G. Vandemark, USDA	335-7728	george.vandemark@ars.usda.gov

A. Bricklemyer, T. Chen, S.L. McGrew, J. Pfaff

DRY BEANS

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

Weed Management

I.C. Burke	335-2858	icburke@wsu.edu
D. Lyon	335-2961	drew.lyon@wsu.edu
E.P. Fuerst	335-7850	pfuerst@wsu.edu
R. Boydston, USDA	509-786-9267	rick.boydston@ars.usda.gov
F.L. Young, USDA	335-4196	youngfl@wsu.edu

L. McGrew, L. Molsee, J. Nelson, R. Rood

Agronomy, Conservation Systems, Soil Fertility and Biofuels

D. Brown	335-1859	david_brown@wsu.edu
A. Esser	509-659-3210	aarons@wsu.edu
S. Fransen	509-786-9266	fransen@wsu.edu
S. Hulbert	335-3722	scot_hulbert@wsu.edu
D. Huggins, USDA	335-3379	dhuggins@wsu.edu
R.T. Koenig	335-2726	richk@wsu.edu
W.L. Pan	335-3611	wlpan@wsu.edu
D. Roberts	509-477-2167	robertsd@wsu.edu
R.D. Roe	335-3491	rdroe@wsu.edu
W.F. Schillinger	509-235-1933	william.schillinger@wsu.edu
B. Sharratt, USDA	335-2724	brenton.sharratt@ars.usda.gov
J. Smith, USDA	335-7648	jlsmith@wsu.edu
M. Stannard, USDA	335-6892	stannard@wsu.edu

B. Barry, D. Bikfasy, R. Bolton, S. Higgins, J. Jacobsen, J. Morse, J. Rumph, R. Rupp, S. Schofstoll, R. Sloot, D. Ueberuaga

Soil Microbiology

L. Carpenter-Boggs	335-1533	lcboggs@wsu.edu
A.C. Kennedy, USDA	335-1554	akennedy@wsu.edu

J.C. Hansen, S. Higgins, T.L. Stubbs

Turfgrass Seed Production

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

C.T. Golob

Agricultural Economics

K. Painter	208-885-6041	kpainter@uidaho.edu
D.L. Young	335-1400	dlyoung@wsu.edu

WSCIA Foundation Seed Service

J. Robinson 335-4365 jerry@washingtontcrop.com
 M. Saam 335-4365 mark@washingtontcrop.com
G. Becker, D. Hilken, D. Kraus, K. Olstadt

Field Stations

WSU SPILLMAN FARM AND WSU COOK FARM
 D. Ueberuaga, Farm Manager 335-8345 duberuaga@wsu.edu
 WSU PLANT PATHOLOGY FARM
 D. Ueberuaga, Farm Manager 335-8345 duberuaga@wsu.edu
 WSU / USDA-ARS PALOUSE CONSERVATION FIELD STATION
 B. Sharratt, Unit Research Leader 335-2724 brenton.sharratt@ars.usda.gov
 WILKE FARM
 A. Esser, Adams Co. Director 509-659-3210 aarons@wsu.edu
 LIND DRYLAND RESEARCH STATION
 B.E. Sauer, Farm Manager 509-677-3671 sauerbe@wsu.edu
 IAREC-PROSSER, OTHELLO
 P. Jacoby, Director 509-786-9268 jacoby@wsu.edu

Acknowledgement of Research Support, 2012-2013

Although the field crops research programs in Washington receive substantial funding from both state and federal appropriations, the progress we have made would not be possible without additional contributions. We are most grateful for the contributions and cooperation by the cereal and legume growers, through the commodity assessment programs, as well as contributions from the agricultural industry, which facilitates our overall agricultural research progress. In addition, a special acknowledgment goes to the numerous individual farmer cooperators who generously contribute their land, labor, equipment, and time. These cooperators and contributors include:

COOPERATORS

Aeschliman, John—Colfax	Dingman, Russ—Hartline
Anderberg, Al—Fairfield	DM Ranch—Othello
Appel, Steve—Dusty	Dobbins, Bryan/David—Four Lakes
Ashburn, Douglas—Genesee/Uniontown	Druffel, Norm/Sons—Pullman
Ausman, Brit—Asotin	Druffel, Ross/Phil—Colton
Bailey, Don—Snohomish	Durheim, Wes—Spokane
Bandy, Bob—Creston	Echelbarger, Jason—Reardan
Bartelheimer, Dan/Peter—Snohomish	Ely, Brad—Dayton
Bauermeister, Dale/Dan—Connell	Evans, Jim—Genesee
Beckley, Gregg—Benge	Felgenhauer, Karl—Fairfield
Beechinor, Jason/Tom—Walla Walla	Ferrel, Greg/Gary—Walla Walla
Blachly, Beau—Pomeroy	Filan, Leon/Stace—Walla Walla
Blume, Kurt—Genesee	Fleener, Chris—Palouse
Boyd, Pat—Pullman	Fleming, Chad—Lacrosse
Braun, Dave—Ritzville	Fleming, Darrin—Lacrosse
Braunwart, Kurt—Othello	Fleming, Fred—Reardan
Bruce, Albert/Doug—Farmington	Gady, Larry/David—Rockford
Brunner, Rick—Almira	Gering, Gordon—Ritzville
Buchholtz, Paul—McGregor, Colfax	Green, Loney—Fairfield
Burress, Randy—Moses Lake	Gross, Charles/Hutterian Brethren—Deep Creek
Camp, Steve—LacCrosse	Harlow, David—Pullman
CBARC—Pendleton, OR	Haugerud, Nick—Colfax
Chvatal, Lowden, WA	Hauser, Gary—Pomeroy
Clausen, Mike—Rosalia	Heilig, Jerry—Moses Lake
Coffman, Seth—Wilbur	Heinemann, Bill—Ritzville
Cornwall, John—Mt. Hope	Hennings, Curtis/Erika—Ralston
Covington, Larry—Nespelem	Hennings, Ron—Ritzville
Davis, Ryan—Pullman	Herdrick, Tim—Wilbur
Deife, Dalles—Odessa	Herron, Chris—Connell
Degon, Dave—Fairfield	Hirst, Jim—Harrington
DeLong, Sara/Joe—St. John	Hodges, Tom—Oakesdale
Dewald, Rob—Ritzville	Hubner, Rodney—Garfield
	Hutchens, Bob/Clay—Dayton
	Idaho, Univ. Kambitsch Farms—Genesee, ID

Jacobsen, Adelbert/Neil—Waterville
 James, Randy—Dayton
 Jirava, Ron—Ritzville
 Johns, Bob—Athena, OR
 Johnson, Frank/Jeff—Asotin
 Johnson, Hal—Davenport
 Jones, Dwelley—Walla Walla
 Jones, Rick/Evan—Wilbur
 Juris, Ron—Bickleton
 Kehl, Russ—Moses Lake
 Klein, Jake—Ritzville
 Knodel, Jerry/Josh—Lind
 Koller, Randy/Roger—Pomeroy
 Kramer, Mark—Harrington
 Krause, Jerry—Creston
 Kuch, Ryan—Ritzville
 LaFave, John—Moses Lake
 Laney, Chris—Sprague
 Lange, Frank—Palouse
 Leahy, Ed—Walla Walla
 Lyle, Kevin—Connell
 Lyons, Rusty—Waitsburg
 Mader, Dan—Genesee
 Mader, Steve—Pullman
 Madison, Kent—Hermiston, OR
 Maier, Eric—Ritzville
 Marks, Scott—Connell
 Matsen, Steve—Bickleton
 McKay, Dan—Almira
 McKinleyk, Dan—Waitsburg
 McLean, John/Shirley—Coulee City
 Melcher, Rodney—Lind
 Miller, Mike—Ritzville
 Mills, Mac/Rod—St. John
 Monson, Jason—Lacrosse
 Moomaw, Cherie—Omak
 Moon, Jim—Prosser
 Moore, Jim—Kahlotus
 Morasch, Bob—Endicott
 Morscheck, Kyle—Genesee, ID
 Nelson, Bruce—Farmington
 Nelson, Howard—Wilbur
 Nichols, Mike—Horse Heaven Hills
 Nollmeyer, Jim—Reardan
 Oregon State University
 Pearson, Dave—Horse Heaven Hills
 Pennell, Roger—Garfield
 Penner, Jay—Dayton
 Pfaff, Richard—Farmington
 Pottratz, Dennis—Fairfield
 Rausch, Chris—Lexington, OR
 Richter, Mark—Endicott
 Roseberry, Dave—Prosser
 Ruegsegger Ranch, Inc—Ritzville
 Rush, Tracy—Harrington
 Sauer, Bruce—Lind
 Sawyer, John—Palouse
 Schafer, Derek—Ritzville
 Schibel, Jeff—Odessa
 Schmitt, Mike/Dan—Horse Heaven Hills
 Schmitz, Joe—Rosalia
 Schoesler, Mark—Ritzville

Schultheis, Art—Colton
 Sheffels, Jerry—Wilbur
 Sheffels, Mark—Wilbur
 Silflow, Brian—Kendrick, ID
 Smith, Glen—Waitsburg
 Smith, Steve—Horse Heaven Hills
 Smith, Tim—Ritzville
 Snyder, Jerry—Ralston
 Spangler, Dennis—Connell
 Starkel, Doug—Odessa
 Stubbs, Gerry/Mike—Dusty
 Suess, Randy—Colfax
 Swannack, Steve—Lamont
 Swinger, Jr., Dennis—Lind
 Tanneberg, Jason—Mansfield
 Tanneberg, Larry—Coulee City
 Thompson, Mark—Waterville
 Thorn, Eric—Dayton
 Tiegs, Brian—Fairfield
 Tokunaga, Steve—Moses Lake
 Townsend, Edd—Omak
 Troutman, Wade—Bridgeport
 University of Idaho
 USDA Central Ferry Farm
 Walli, Robert—Ritzville
 Walters, Craig—Palouse
 Warner, Ed—Harrington
 Wesselman, Roger—Mansfield
 Weishaar, Robin—Odessa
 White, Gil—Lamont
 Wilson, Eldon—Harrington
 Zenner, Russ—Genesee

CONTRIBUTORS

Adams County Wheat Growers
 Agricen Sciences
 Agri-Pro
 Agrium
 Ag Ventures NW, LLC
 Allstar, Inc
 Amen Endowment, Otto & Doris
 American Malting Barley Assn.
 Andersen Machine Inc.
 Arizona Plant Breeders
 Arysta LifeScience
 BASF
 Basin Pacific Insurance
 Bayer CropScience
 Benton Conservation District
 BNP Lentil
 Busch-Ag Resources
 C Farms Energy
 CalWest Seed
 Cedbeco Zaden BV
 Central Machinery Sales
 Central Washington Grain Growers
 CLD Pacific Grain
 Co-Ag, Inc.
 Columbia Bank
 Columbia Co. Grain Growers

Columbia Grain Int'l.
Connell Grain Growers
Connell Oil
Crites
Croplan Genetics/Winfield Solutions
Crop Production Services
Cross Slot
DOW Agrosience
DuPont
Earthkeep, Inc.
EMD Crop BioScience
Empire, Inc.
Evans Enterprises
Exactrix Global Systems
Fluid Fertilizer Foundation
FMC Corp.
Foundation for Agronomic Research
Franklin Conservation District
Genesee Union Warehouse
General Mills
Georgia Pacific
GMG
Grant Co. Crop Improvement Assn.
Great Plains Mfg.
Great Salt Lakes Mineral Corp.
Great Western Malting
Gustafson, Inc.
Harvest States
Horsch Maschinen GmbH
Idaho Barley Commission
International Plant Nutrition Institute
Jim's Pacific Garages
Johnson Union Warehouse
King County Biosolids
Land Institute
Laughlin Trading Co.
Limagrain Cereal Seeds
Lincoln/Adams Crop Improvement Assn.
McCubbins, Mike
McGregor Co.
McKay Seeds
Merrill Lewis
Micro-Ag, Inc.
Microsoft Corp.
Monsanto Co.
Moore, Jim & Ann
North Pine Ag Supply
Northwest Farm Credit Services
Northwest Grain Growers
Novozymes BioAg
Nu Chem
Pacific Coast Canola
Pendleton Grain Growers
Pioneer Seeds
Pomeroy Farm & Home Supply
Primeland
ProGene
Quincy Farm Chemicals, Inc.
Reardan Seed Co.
Ritzville Warehouse
Rubisco Seeds
Seedex
SeedTec
Simplot
Skone Irrigation
Small Planet Foods
Soiltest Farm Consultants
Spectrum Crop Development
Spokane Co. Assn. Wheat Growers
Spokane Co. Crop Improvement Assn.
Spokane Seed
St. John Grain Growers
St. John Hardware
Syngenta
Tomco Seed
Tri-Cities Visitor and Convention Bureau
Trigen Seeds, Inc.
Tri-State Seed Co.
TYCO
Union Elevator
U.S. Canola Association
USDPLC
Valent Biosciences
Valent USA Corp.
Von Wettstein, Diter
W.F. Wilhelm & Son, Inc.
Wagner Seeds
Walter Implement Co.
Washington Association Professional Crop Consultants
Washington Assn. Wheat Growers
Washington Canola & Rapeseed Commission
Washington Conservation Commission
WA State Department of Agriculture
WA State Department of Commerce
WA State Department of Ecology
Washington Wheat Foundation
Washington Grain Commission
Washington Trust Bank
Westbred, LLC
Western Ag Innovations
Western Farm Service
WetSol
Whitman Co. Growers
Wilbur-Ellis Co.
WSCIA
WSU Center for Sustaining Agriculture and Natural Resources

Cook Agronomy Farm

In 1998, a team of Washington State University and USDA-ARS scientists launched a long-term direct-seed cropping systems research program on 140 acres of the WSU-owned Cook (formerly referred to as 'Cunningham') Agronomy Farm located 7 miles NE of Pullman, WA. The goals are to:

Play a leadership role through research, education and demonstration in helping growers in the high-precipitation areas of the Inland Northwest make the transition agronomically and economically to continuous direct-seeding (no-till farming) of land that has been tilled since farming began near the end of the 19th century.

Provide databases and understanding of the variable soil characteristics, pest pressures, and historic crop yield and quality attributes over a typical Palouse landscape as the foundation for the adoption and perfection of precision-agriculture technology in this region.

These two goals are intended to facilitate the greatest technological changes for Northwest agriculture since the introduction of mechanization early in the 20th century. Growers and agribusinesses are recognizing both the need for and opportunities presented by these changes.

The past 9 years have been used to obtain site-specific data and develop physical maps of the 140-acre farm, with the greatest detail developed for a 92-acre watershed using 369 GPS-referenced sites on a nonaligned grid. Maps are available or being developed from various sampling efforts that characterize crop yield and economic returns, soil types, weed, seed banks, populations of soilborne pathogens, soil pH, carbon sequestration, soil water and nitrogen supplies, nitrogen use efficiency and precision N applications. This has been achieved while producing a crop of hard red spring wheat in 1999, spring barley in 2000, and initiating six direct-seed



cropping system rotations starting in the fall of 2001 that have continued through today. This past year, an adjacent 160 ac were added to the overall Cook Agronomy Farm bringing the total land area to 300 ac. This new acreage will provide much needed land for small plot research that can complement larger scale cropping system efforts.

The 92-acre portion of this farm is unquestionably the most intensively sampled and mapped field in the Inland Northwest. Some 20-25 scientists and engineers are now involved in various aspects of the work started or planned for this site. A 12-member advisory committee consisting of growers and representatives of agribusiness and government regulatory agencies provide advice on the long-term projects and the day-to-day farming operations, both of which must be cutting edge to compete scientifically and be accepted practically. This farm can become a showcase of new developments and new technologies while leading the way towards more profitable and environmentally friendly cropping systems based on direct seeding and precision farming.

Dryland Research Station

The Washington State University Dryland Research Station was created in 1915 to "promote the betterment of dryland farming" in the 8-to 12-inch rainfall area of eastern Washington. Adams County deeded 320 acres to WSU for this purpose. The Lind station receives an average of 9.6 inches of annual precipitation, the lowest of all state or federal dryland agricultural research facilities in the United States.

Research efforts at Lind throughout the years have largely centered on wheat. Wheat breeding, variety adaptation, weed and disease control, soil fertility, erosion control, and residue management are the main research priorities. Wanser and McCall were the first of several varieties of wheat developed at the Lind Dryland Research Station by plant

breeding. Twenty acres of land can be irrigated for research trials. Numerous journal articles have been published throughout the years from research conducted at the Lind Station and in farmers' fields throughout the low-rainfall region. The articles are available online at <http://www.lindstation.wsu.edu>.

The facilities at Lind include a small elevator which was constructed in 1937 for grain storage. An office and attached greenhouse were built in 1949 after the old office quarters burned down. In 1960, a 40' x 80' metal shop was constructed with WSU general building funds. An addition to the greenhouse was built with Washington Wheat Commission funding in 1964. In 1966, a deep well was drilled, testing over 430 gallons per minute, and an irrigation system installed. A modern laboratory and storage building was built in 1983 and later dedicated to Richard Deffenbaugh, former chair of the Washington Wheat Commission and longtime promoter of the Dryland Research Station. A machine storage building was completed in 1985.

Growers raised funds in 1996 to establish an endowment to support the WSU Dryland Research Station. The endowment is managed by a committee of growers and WSU faculty. Grower representatives from Adams, Franklin, Benton, Douglas, Lincoln, and Grant counties are appointed by their respective county wheat growers associations. Endowment funds support facility improvement, research projects, equipment purchase, and other identified needs. State Senator Mark Schoesler led a successful effort in 1997 to transfer ownership of 1000 acres of adjoining state-owned farmland to the WSU Dryland Research Station.

Since 1916, an annual field day has been held to show growers and other interested people the research on the Station. Visitors are welcome at any time, and your suggestions are appreciated.



Palouse Conservation Field Station

The Palouse Conservation Field Station (PCFS) originated in 1930 as one of 10 original erosion experiment stations established across the United States by Congressional funding to USDA. The research programs of the stations were designed to investigate the causes of erosion and to determine the most effective and practical methods of checking and controlling soil and water losses from agricultural lands. In 1935 the Soil Conservation Service (SCS) was established and the PCFS became a part of SCS research. When the Agricultural Research Service (ARS) was established in 1953, all SCS research, including the PCFS, was transferred to ARS. The Land Management and Water Conservation Research Unit (LMWCRU) that oversees the PCFS was officially formed in 1972 as an outcome of a major reorganization of ARS.



Historically, the LMWCRU has played a leading role in the development of science-based solutions to agricultural and environmental problems of the Pacific Northwest. Research on conservation tillage, soil quality, integrated pest management and soil erosion prediction and control have promoted the economic and environmental vitality of the region's agriculture by providing state-of-the-art technologies and management strategies. The research program of the scientists and staff has evolved over time as problems and issues change. Scientists and engineers from the ARS and Washington State University currently utilize the PCFS to conduct research projects ranging from soil erosion by wind and water to field-scale cropping and tillage practices on the steep slopes common on the Palouse. Both federal and state researchers, graduate students, and technicians conduct part or all of their research at the PCFS.

An ARS farm manager is assigned to the PCFS and is responsible for maintaining the station infrastructure, coordinating the complex planting and harvest schedule to meet the requirements of the various cropping systems research plots, and operating the machine shop, which fabricates much of the equipment used in the research projects. The PCFS infrastructure currently consists of several buildings including offices, soils laboratory, plant-drying facility, rain tower with tilting flume, greenhouse, machine shop, and equipment buildings, as well as the 202-acre research farm.

Today, the LMWCRU's research is actively engaged in issues of national as well as regional prominence. In collaboration with producers, land-grant universities, national laboratories, agribusiness, grower associations and commodity groups, state and federal agencies and other USDA-ARS Units across the nation, at PCFS and other locations, LMWCRU scientists conduct research on: 1) Integrated agricultural systems including cereal-based rotations, direct seed systems, biofuels, alternative crops, weed management strategies, and organic farming systems; 2) Management systems and decision models to prevent windblown dust and improve air quality and prevent water erosion; 3) Carbon sequestration, sustainable soil management, and mitigation of global climate change; and 4) Precision agricultural systems for effective and sustainable use of fertilizer and herbicides.

Spillman Agronomy Farm

The Spillman Agronomy Farm is located on 382 acres five miles southeast of Pullman, WA in the midst of the rich Palouse soils. In the fall of 1955, an initial 222 acres of land were acquired from Mr. and Mrs. Bill Mennet at the arbitrated price of \$420 per acre. The money for the original purchase came as the result of a fund drive which raised \$85,000 from industry and wheat growers. In addition, \$35,000 came from the Washington State University building fund, \$11,000 from the State Department of Agriculture, and another \$10,000 from the 1955-57 operating budget. A headquarters building, which is 140 feet long and 40 feet wide, was completed in 1956 followed in 1957 by a well that produced 340 gallons per minute. The dedication of the farm and new facilities took place at the Cereal Field Day July 10, 1957.

In 1961, the Agronomy Farm was named Spillman Farm after Dr. William Jasper Spillman (1863-1931), the distinguished geneticist and plant breeder at Washington State University that independently rediscovered Mendel's Law of Recombination in 1901.

Through the initiative of Dr. Orville Vogel, USDA Wheat Breeder at WSU, and the dedicated efforts of many local people, arrangements were made to acquire an additional 160 acres north of the headquarters building in the fall of 1961. This purchase was financed jointly by the Washington Wheat Commission and Washington State University. The newly acquired 160 acres was contiguous with the original 222 acres and became an integral part of the Spillman Agronomy Farm.

Facility updates to Spillman Agronomy Farm include: (1) a 100- by 40 foot machine storage addition built in 1981, (2) in 1968, the Washington Wheat Commission provided funds for a sheaf storage facility and at the same time (3) the



William J. Spillman, breeding plots at Pullman, 1900

Washington Dry Pea and Lentil Commission provided \$25,000 to build a similar facility for the pea and lentil materials. The facilities of the Spillman Agronomy Farm now range in value well over a half million dollars.

Development of Spillman Agronomy Farm was always focused with proper land use in mind. A conservation farm plan which includes roads, terraces, steep slope plantings, and roadside seedings has been in use since the farm was purchased. In addition, current breeders are utilizing the acreage to develop cropping systems that will include opportunities to include organic, perennial and biotechnological components in cereal and legume breeding programs.

On July 7, 2005, over 330 people attended a special 50th Anniversary Field Day at Spillman Agronomy Farm that included three faculty/staff that were present at the July 10, 1957 dedication: Dr. Robert Nilan (WSU Barley Breeder), Dr. Cal Konzak (WSU Wheat Breeder), Dr. Robert Allan (USDA/ARS Wheat Geneticist) and Carl Muir (Tech Supervisor, WSU Barley Breeding Program). Dr. Allan also presented the keynote luncheon address at the 50th Anniversary Field Day and reaffirmed the significance of Spillman Agronomy Farm in his opening remarks: "The importance of Spillman Farm will not diminish as time passes. Multimillion dollar structures on campus will not replace its (Spillman Agronomy Farm) vital role in crop development."

The Spillman Agronomy Farm continues to exemplify the vision of public and private cooperation that has become the 'home' for cereal and pulse crop research and development at Washington State University for over 50 years.

Wilke Research and Extension Farm

The Wilke Research and Extension Farm is located on the east edge of Davenport, WA. The 320-acre farm was bequeathed to WSU in the 1980's by Beulah Wilson Wilke for use as an agricultural research facility. Funding for the work at the Wilke Farm comes from research and extension grants and through the proceeds of the crops grown. The farm has been under a direct seed or no-till farming system since 1998 and the goals for research are centered on the need to develop cropping systems that enhance farm profitability and improve soil quality.

The Wilke Farm is located in the intermediate rainfall zone (12-17 inches of annual precipitation) of eastern Washington in what has historically been a conventional tillage, 3-year rotation of winter wheat, spring cereal (wheat or barley), followed by summer fallow. Historically wheat is the most profitable crop in the rotation and the wheat-summer fallow rotation has been the most profitable system.

The Wilke farm is split by State Highway 2. The north side has been in continuous winter or spring cereal production for approximately 19 years and being cropped without tillage for the past 14 years. Since 1998, the south side has been dedicated to the Wilke Research Project that is testing a direct seed, intensive cropping system. The south side of the Wilke Farm was divided into 21 separate plots that are 8 to 10 acres in size and farmed using full-scale equipment. In 2003 these plots were combined into 7 separate plots approximately 27 acres in size. Three plots remain in a 3-year crop rotation that includes winter wheat, no-till (chemical) fallow, and spring crop. Four plots remain in a 4-year crop rotation that includes winter wheat, no-till fallow, spring cereal and spring crop. Crops grown on the farm since the inception of the Wilke Project include barley, winter and spring wheat; canola, peas, safflower, sunflowers, yellow mustard, and proso millet. The farm provides research, demonstration, education, and extension activities to further the adoption of direct-seeding systems in the area. In addition to the large plots, the Wilke Farm is used increasingly for small plot research by WSU faculty, other University faculty, and private company researchers for small plot cropping systems research.

Due to its location and climate, the Wilke Farm complements other WSU dryland research stations in the Palouse area and at Lind and other locations in the region such as north central Oregon.



Wilke Farm field tour 2010

Wheat Variety History at WSU

VARIETY YEAR RELEASED MARKET CLASS BACKGROUND / NAMED AFTER

SPILLMAN

Hybrid 60	1905	HWW Club	Lost
Hybrid 63	1907	SWS Club	Turkey/ Little Club; still grown at Spillman Farm
Hybrid 108	1907	SRS Club	Jones Fife/Little Club; lost
Hybrid 123	1907	SWS Club	Jones Fife/Little Club; still grown at Spillman Farm
Hybrid 128	1907	SWW Club	Jones Winter Fife/Little Club; still grown at Spillman Farm
Hybrid 143	1907	SWS Club	White Track/Little Club; still grown at Spillman Farm

GAINES

Mayview	1915	SRS	Selected from field of Fortyfold near Mayview
Triplet	1918	SRW	Jones Fife/Little Club//Jones Fife/Turkey
Ridit	1923	HRW	Turkey/Florence; first cultivar in USA released with smut resistance
Albit	1926	SWW Club	Hybrid 128/White Odessa
Flomar	1933	HWS	Florence/Marquis
Hymar	1935	SWW Club	Hybrid 128/Martin

VOGEL

Orfed	1943	SWS	Oro/Federation
Marfed	1946	SWS	Martin/Federation
Brevor	1947	SWW	Brevon/ Oro
Orin	1949	SWW	Orfed/Elgin
Omar	1955	SWW Club	Oro and Elmar in pedigree
Burt	1956	HWW	Burton Bayles, principal field crop agronomist for ARS
Gaines	1961	SWW	EF Gaines (Vogel's professor) WSU Cerealist, 1913-1944
Nugaines	1965	SWW	Sister line of Gaines (new Gaines)

NELSON

McCall	1965	HRW	M.A. McCall, first superintendent of Lind Station
Wanser	1965	HRW	HM Wanser, early dryland agronomist

ALLAN

Paha	1970	SWW Club	Rail point (town) in Adams Co. between Lind and Ritzville
Coulee	1971	HWW	Town in Grant Co.
Tyee	1979	SWW Club	Rail point (town) in Clallam Co. between Beavor and Forks
Crew	1982	SWW Club	Multiline with 10 components (crew of 10)
Tres	1984	SWW Club	Spanish for three. Resistant to stripe rust, leaf rust & powdery mildew
Madsen	1988	SWW Club	Louis Madsen, Dean of College of Agriculture at WSU, 1965-1973
Hyak	1988	SWW Club	Rail point in Kittitas Co. east of Snoqualimie pass
Rely	1991	SWW Club	Multiline with reliable resistance to stripe rust
Rulo	1994	SWW Club	Rail point in Walla Walla Co.
Coda	2000	SWW Club	The finale (of a symphony). R.E. Allan's last cultivar

BRUEHL

Sprague	1972	SWW	Rod Sprague, WSU plant pathologist. First snowmold resistant variety for WA
John	1985	SWW	John Thompson and John Goldmark, both supporters of snow mold research

PETERSON

Luke	1970	SWW	Name of Nez Perce Indian that saved Rev. H.H. Spalding's life near Lapwai, ID
Norco	1974	SWW	Released as cultivar-recalled in 1975 due to susceptibility to new stripe rust race
Barbee	1976	Club	Earl Barbee, WSU agronomist
Raeder	1976	SWW	Plant pathologist JM Raeder, U. of ID professor of CJ Peterson
Daws	1976	SWW	Dawson Moodie, chair, Dept. of Agronomy, WSU
Lewjain	1982	SWW	Lew Jain, farmer friend of Peterson
Dusty	1985	SWW	Town in Whitman Co.
Eltan	1990	SWW	Elmo Tanneberg, Coulee City, WA wheat farmer/supporter
Kmor	1990	SWW	Ken Morrison, WSU Ext. State Agronomist
Rod	1992	SWW	Rod Betramson, chair, Dept of Agronomy, WSU
Hiller	1998	SWW Club	Farmer/cooperator in Garfield Co.

KONZAK

Wandell	1971	Spring Durum.....	WA + ND (North Dakota) + ELL (?)
Wared	1974	HRS	WA + red (HRS)
Urquie.....	1975	SWS.....	Urqhart, a farmer near Lind, WA
Walladay	1979	SWS.....	WA + Dayton (town in WA)
Wampum.....	1980	HRS	WA + wampum (Native American term for money, medium of exchange)
Waid	1980	Spring Durum.....	WA+ID, first WSU variety developed via induced mutation, also licensed in Europe
Waverly.....	1981	SWS.....	Town in WA
Edwall.....	1984	SWS.....	Town in WA
Penewawa	1985	SWS.....	Old town area in WA
Spillman.....	1987	HRS	WJ Spillman, first WSU wheat breeder
Wadual	1987	SWS.....	WA + dual; dual quality, pastry and bread, new concept for SW wheat
Wakanz.....	1987	SWS.....	WA + kan (KS -hessian fly testing) + nz (New Zealand - winter increase)
Calorwa	1994	SWS Club.....	CA (California) + OR (Oregon) + WA
Alpowa	1994	SWS.....	Town in WA
Wawawai	1994	SWS.....	Area or old town in WA

DONALDSON

Hatton	1979	HRW	Town in Adams Co.
Batum.....	1985	HRW	Rail point in Adams Co.
Andrews.....	1987	HRW	Old town in Douglas Co.
Buchanan.....	1990	HRW	Historical family name near Lind
Finley.....	2000	HRW	Town in Benton Co.

KIDWELL

Scarlet.....	1999	HRS	Red seed color
Zak	2000	SWS.....	Cal Konzak, WSU spring wheat breeder
Macon	2002	HWS	Vic Demacon, WSU spring wheat researcher
Tara 2002	2002	HRS	"Gone with the Wind" theme
Eden	2003	SWS Club.....	"Gone with the Wind" theme
Hollis.....	2003	HRS	Grandfather of Gary Shelton, WSU spring wheat researcher
Louise	2004	SWS.....	Nickname of the Breeder's niece
Otis.....	2004	HWS	Nickname of the Breeder's nephew
Farnum	2008	HRW	Major road in Horse Heaven Hills
Whit.....	2008	SWS.....	Suitable to Whitman County
Kelse	2008	HRS	Niece of Kidwell
JD	2009	SWS Club.....	In honor of Jim Moore and family (Kahlotus wheat producer)
Babe	2009	SWS.....	In honor of Dr. Kidwell's parents
Diva	2010	SWS.....	In honor of the creativity in every great scientist
Glee.....	2012	HRS	Virginia "Ginny" Gale Lee, remarkable person and graduate student at WSU
Dayn.....	2012	HWS	Dayna "Dayn" Willbanks, treasured friend and colleague

JONES

Edwin	1999	SWW Club.....	Edwin Donaldson, WSU Wheat Breeder
Bruehl.....	2001	SWW Club.....	George (Bill) Bruehl, WSU Plant Pathologist
Masami.....	2004	SWW Club.....	Masami (Dick) Nagamitsu, WSU wheat researcher
Bauermeister.....	2005	HRW	Dale and Dan Bauermeister, Connell, WA wheat farmers/cooperators
MDM.....	2005	HWW.....	Michael Dale Moore, Kahlotus area farmer/cooperator
Xerpha.....	2008	SWW	WSU botanist and wife of Edward Gaines

CAMPBELL

Finch.....	2002	SWW	WA bird
Chukar.....	2002	SWW Club.....	WA bird and names clubs beginning with a 'C'
Cara	2007	SWW Club.....	Short and starts with a 'C'
ARS Amber.....	2012	SWW	Named after color of ripe wheat
ARS Crescent	2012	SWW Club	ARS clubs beginning with a 'C'
ARS Chrystal	2012	SWW Club	ARS club beginning with a 'C'
ARS Selbu	2012	SWW	Named after Selbu Lutheran Church near LaCrosse, WA

CARTER

Otto	2011	SWW	Otto Amen, long-time Washington legislator and wheat farmer
Sprinter	2012	HRW	Dual agronomic characteristics of both Spring and Winter wheat
WA8134	2013	SWW	To be named

Barley Variety History at WSU

VARIETY	YEAR RELEASED	MARKET CLASS.....	BREEDER	BACKGROUND / NAMED AFTER
Olympia	1937	winter, 6-row, feed	Gaines.....	introduction from Germany collected in 1935
Rufflynn	1939	spring, 6-row, feed	Barbee	selection from Flynn (Club Mariout/Lion)
Belford.....	1943	spring, 6-row, hay	Barbee	selection from Beldi Giant/Horsford
Velvon 17	1947	spring, 6-row, feed	Gaines.....	selection from Velvon Composite 1 (Colorado 3063/Trebi)
Heines Hanna	1957	spring, 2-row, malting.....	Gaines.....	introduction from Germany collected in 1925 (selected from a Czech landrace)
Luther.....	1966	winter, 6-row, feed	Nilan.....	induce mutant of Alpine (first induced mutant variety released in North America)
Vanguard.....	1971	spring, 2-row, malting.....	Nilan.....	selection from Betzes/Haisa II/Piroline
Kamiak	1971	winter, 6-row, feed	Nilan.....	selection from Bore/Hudson
Steptoe.....	1973	spring, 6-row, feed	Nilan.....	selection from WA 3564 (sel. From CC V)/Unitan
Blazer.....	1974	spring, 6-row, malting.....	Nilan.....	selection from Trail/ WA1038 (induced mutant)
Boyer.....	1975	winter, 6-row, feed	Muir.....	selection from Luther/WA1255-60
Advance	1979	spring, 6-row, malting.....	Nilan.....	Foma/Triple Bearded Mariout/White Winter (WA6194-63)/3/Blazer
Andre	1983	spring, 2-row, malting.....	Nilan.....	selection from Klages/Zephyr
Showin	1985	winter, 6-row, feed	Ullrich	selection from 68-1448/2116-67
Cougbar	1985	spring, 6-row, feed	Ullrich	selection from Beacon/7136-62/6773-71
Hundred	1989	winter, 6-row, feed	Ullrich	selection from WA2196-68/WA2509-65
Crest.....	1992	spring, 2-row, malting.....	Ullrich	selection from Klages/2* WA8537-68
Bear.....	1997	spring, 2-row, hullless	Ullrich	selection from Scout/WA8893-78
Washford	1997	spring, 6-row, hay	Ullrich	selection from Columbia/Belford
Farmington.....	2001	spring, 2-row, feed	Ullrich	WA10698-76/Piroline SD Mutant/Valticky SD Mutant /3/ Maresi
Bob.....	2002	spring, 2-row, feed	Ullrich	selection from A308 (Lewis somaclonal line)/Baronesse
Radiant.....	2003	spring, 2-row, feed	Wettstein	selection from Baronesse/Harrington proant mutant 29-667
Muir	2013	spring, 2-row, feed	Murphy.....	selection from Baronesse/Spaulding (named after Carl Muir)
Lyon	2013	spring, 2-row, feed	Murphy.....	selection from Baronesse/Bob (named after Steve Lyon)

Dry Pea, Lentil and Chickpea Varieties History at WSU

The grain legume industry started in the early 1900s and progressed from using relatively old landraces to more advanced varieties produced by breeding programs. Initially, dry peas were produced from varieties that were commonly used for canning of fresh peas. Such varieties as 'Small Sieve Alaska', 'Alaska', 'First and Best' were commonly grown. These varieties gave way to 'Columbian', which is still the industry standard for color quality, and the so-called "stand-up varieties" such as 'Stirling'. Numerous varieties of the so-called stand-up peas have been developed and are in use for dry pea production. Lentil production began in the early 1920s on a small scale in the Farmington area and increased rapidly in the 1950s and 1960s. Varieties grown initially were described as "Persians" and "Chilean" types. The variety 'Brewer' released in 1984 quickly became the industry standard for the Chilean type. Other varieties such as 'Pardina', 'Redchief', 'Crimson', 'Pennell' and 'Merrit' are currently important lentil varieties. Chickpea production began in the Palouse in the early 1980s and quickly expanded to become an important crop for the region. However, the devastating effects of *Ascochyta* blight reduced production in the area to a minimum until resistant varieties such as 'Sanford' and 'Dwellely' were developed and released in 1994 and more recently 'Sierra' in 2003 and 'Dylan' in 2006. Spanish White types are a premium product and 'Troy' is the first *Ascochyta* blight resistant variety of this class to be developed.

The historical grain legume varieties show apparent changes made through breeding from the earlier types that were grown to the present day varieties. Varieties in the historical nursery include all three crops and are described as follows:

DRY PEAS

Spring Green Peas

Small Sieve Alaska – An old variety initially used for canning small green peas. It was used on a limited basis to produce dry peas with small seed size for specialty markets.

Garfield – Released in 1977 by USDA-ARS. The variety has long vines and larger seeds than other Alaska types.

Tracer – Released in 1977 by USDA-ARS. The variety was intended as a replacement for Small Sieve Alaska. It has a triple podding habit.

Columbian – Developed by the Campbell Soup Company for making split pea soup with good color. A green dry pea used by the industry because of excellent color qualities and good yields.

Alaska-81 – Released in 1984 by USDA-ARS, seeds are dark green, round and smooth with green cotyledons. Immune to pea seed borne mosaic virus and resistant to Fusarium wilt race 1.

Joel – A medium sized, green cotyledon dry pea released in 1997 by USDA-ARS. The variety has improved green pea color quality and has resistance to powdery mildew and Fusarium wilt race 1.

Lifter – A green cotyledon dry pea released in 2001 by USDA-ARS. The variety has multiple disease resistance, persistent green color of the seeds and yields are improved over Columbian and Joel. It has a dwarf plant habit with normal leaves.

Franklin – A green cotyledon dry pea released in 2001 by USDA-ARS. The variety is resistant to Fusarium wilt race 1, pea enation mosaic virus, and powdery mildew.

Stirling – A green cotyledon dry pea released in 2004 by USDA-ARS. It is a semi leafless stand up variety with resistance to Fusarium wilt race 1 and powdery mildew.

Medora – A green cotyledon dry pea released in 2006 by USDA-ARS. The variety was released for improved plant height and lodging resistance. It also has resistance to powdery mildew.

Spring Yellow Peas

First and Best – Was one of the first yellow pea varieties grown in the Palouse region.

Latah – Released in 1977 by USDA-ARS. The variety was a pure line selection from First and Best.

Umatilla - Released in 1986 by USDA-ARS, 'Umatilla' is about 15 cm shorter and is higher yielding when compared to Latah. Resistant to Fusarium wilt race 1 and tolerant to pea root rot.

Shawnee - A large seeded, yellow cotyledon dry pea released in 1997 by USDA-ARS. 'Shawnee' has large seed size, bright yellow seed color and resistance to powdery mildew.

Fallon - A large seeded, yellow cotyledon dry pea released in 1997. The variety is resistant to powdery mildew and with a semi-leafless upright growth habit.

Winter Peas

Common Austrian Winter Pea – The original Austrian Winter pea was grown extensively in the Palouse region for green manure plow down since the early 1900s. Improved types such as Melrose and more recently Granger have replaced the variety.

Melrose – An improved Austrian Winter pea released by the University of Idaho in 1978.

Granger - A semi leafless Austrian winter-type pea released in 1996 by USDA-ARS.

Specter – A white flowered winter pea released by USDA-ARS in 2004 as a feed pea. The variety is semi leafless and has yellow cotyledons. It is resistant to Fusarium wilt race 1 and 2.

Windham – A white flowered winter pea released by USDA-ARS in 2006 as a feed pea. The variety is semi leafless, has a dwarf plant habit, lodging resistance and has yellow cotyledons. It is resistant to Fusarium wilt race 1.

Lynx – A white flowered, semi-leafless, semi-dwarf winter pea released by USDA-ARS in 2012 for wildlife food plots.

LENTILS

Brewer Types

Chilean – A large seeded yellow cotyledon variety introduced into the region in 1920.

Brewer – A large seeded yellow cotyledon lentil with larger and more uniform seeds, released in 1984 by USDA-ARS.

Merrit – A large seeded yellow cotyledon variety released by USDA-ARS in 2003. The variety has seed coat mottling and is expected to replace Brewer.

Laird Types

Tekoa – A large seeded yellow cotyledon variety released by USDA-ARS in 1969. The variety had an absence of seed coat mottling.

Palouse – Released by USDA-ARS in 1981. The variety has large seed size and an absence of seed coat mottling.

Pennell – A large seeded yellow cotyledon variety released by USDA-ARS in 2003. The variety lacks seed coat mottling.

Mason – A large seeded, yellow cotyledon lentil released in 1997 by USDA-ARS. Mason has large seed size and no seed coat mottling.

Riveland – A large seeded yellow cotyledon lentil released in 2006 by USDA-ARS. Riveland has extremely large seed and lacks seed coat mottling.

Small-seeded Types

Pardina – A small, yellow cotyledon type cultivar with brown and speckled seed coats. It was introduced by the lentil industry from Spain and is now being produced extensively in the Palouse.

Richlea – Developed and released in Canada. The variety has medium sized seeds with yellow cotyledons and an absence of seed coat mottling. It is high yielding.

Eston – Developed and released in Canada. The variety has small seed size with yellow cotyledons.

Emerald – Released in 1986 by USDA-ARS, is a green seeded lentil cultivar with distinctive green cotyledons.

Essex – Released in 2010 by USDA-ARS, has a small seed size, with yellow interiors and green coats.

Morena – Released in 2010 by USDA-ARS, as replacement for Pardina, intended for export to Spain.

Turkish Red Types

Redchief – Released in 1980 by USDA-ARS, is a large-seeded red-cotyledon-type cultivar with seed coats that lack mottling.

Crimson – A small seeded, red cotyledon type lentil cultivar, released in 1990 by USDA-ARS. It originated as a pure line selection from 'Giza-9', a cultivar developed in Egypt and introduced into the U.S. by the ARS Grain Legume Program.

Morton – Morton is a small seeded red cotyledon winter hardy lentil that was developed specifically for use in direct seed or minimum-tillage cropping systems. The variety was released in 2002.

CHICKPEAS

Kabuli Type

Burpee 5024 – A large seeded Kabuli variety distributed by the Burpee Seed Company. We use the variety extensively in our Ascochyta blight screening nursery as a susceptible check.

Surutato 77 – A large seeded Kabuli variety developed and released in Mexico. The variety has very large seeds and was one of the first varieties of chickpea grown in the Palouse region. The variety is very susceptible to Ascochyta blight.

Tammany – Released by USDA-ARS in 1986. The variety is a large seeded Kabuli variety that is similar to Macarena from Mexico. The variety is very susceptible to Ascochyta blight.

UC-5 – A large seeded Kabuli variety developed and released in California. It was introduced into the Palouse in the late 1980s. The variety is very susceptible to Ascochyta blight.

UC-27 – A medium sized Kabuli variety developed and released in California. It was introduced into the Palouse in the late 1980s. The variety is very susceptible to Ascochyta blight.

Spanish White – Introduced from Spain into the Palouse in the mid 1980s as a large seeded Kabuli variety with white seeds. It is a specialty type in Spain. The variety is very susceptible to Ascochyta blight.

Blanco Lechoso – Similar to Spanish White. The variety has exceptionally large and white seeds. However, it is very susceptible to Ascochyta blight.

Sarah – Released by USDA-ARS in 1990. Sarah is a desi type and is susceptible to Ascochyta blight.

Dwelley – A large seeded Café type chickpea released in 1994 by USDA-ARS. Dwelley has good resistance to Ascochyta blight and is a sister line to Sanford.

Sanford – A large seeded Café type chickpea released in 1994. Sanford has a good resistance to Ascochyta blight and is a sister line to Dwelley.

Evans – A large seeded Café type chickpea released in 1997. Evans is earlier flowering and earlier to mature when compared with Sanford and Dwelley.

Sierra – A large seeded Café type chickpea released in 2003 by USDA-ARS. Sierra has improved resistance to Ascochyta blight when compared to Sanford and Dwelley.

Dylan – A large seeded Café type chickpea released in 2006 by USDA-ARS. Dylan has improved resistance to Ascochyta blight when compared to Sanford and Dwelley and a lighter seed coat color.

Troy – A large seeded Spanish White type chickpea released in 2007 by USDA-ARS. Troy has improved resistance to Ascochyta blight when compared to Sanford and Dwelley and is a replacement for the earlier Ascochyta blight susceptible Spanish White type varieties. Its extremely large seed size and bright white seed coat color are desirable quality traits and distinguish this variety from other releases.

Sawyer – A medium-seeded Café type chickpea released in 2008. Sawyer has improved resistance to Ascochyta blight compared to Sierra, Dylan and Troy. It has high yield potential across a wide geographical area from eastern Washington to North Dakota.

Desi Type

Myles – A desi type chickpea released in 1994. Myles has very good resistance to Ascochyta blight.

Part 1. Breeding, Genetic Improvement, and Variety Evaluation

Development of Two-gene Clearfield Wheat Varieties through Forward Breeding Approach

NEERAJ KUMAR, RYAN HIGGINBOTHAM, ARRON CARTER, DREW LYON AND KULVINDER S GILL; DEPT. OF CROP AND SOIL SCIENCES, WSU

Soft white winter wheat is the most important crop of the Washington State but the goatgrass and other annual weeds become major concerns in Pacific Northwest cropping systems and it may result significant yield loss. Imidazolinone class of herbicide can effectively control many grassy weeds affecting various classes of wheat but cannot be used because of presence of the susceptible acetolactate synthase (ALS) gene. For the effective control of these weeds, three mutants for ALS gene (*ahas1-1d*, *ahas1-1b* and *ahas1-1a*) have been identified in wheat and currently are being exploited to develop resistant varieties against herbicide 'Beyond'. Wheat varieties developed through Clearfield technology has become popular due to their ability to control troublesome weeds and benefits for crop rotation with legume crops. Using marker-assisted forward breeding approach, we have transferred two-gene Clearfield technology in the background of soft white winter cultivars Eltan and Madsen. The key feature of this approach is screening of a large number of backcross populations of BC₁ and BC₂ phenotypically to remove susceptible plants by spray with 'Beyond' and also exploits the information available about wheat genome. In BC₁ generation, we apply three step marker-assisted selection and fixed target gene using flanking markers then we fixed the background of carrier chromosomes of the gene. Additionally, we make selection for grain quality parameters using the seed harvested from single plant, where we apply single kernel characterization system (SKCS) to test grain quality and followed by solvent retention capacity (SRC) test to improve flour quality. In BC₂F₂ generation, we apply four steps marker-assisted background selection (MABS) approach and we recover plants carrying background similar to the recurrent parent except target gene along with additional features by selecting plants phenotypically for superior agronomic traits. Due to the complex nature of the quality traits, we repeat above steps again after BC₂ generation and apply SKCS as well as SRC test to select soft white winter class. Developed lines showed significantly better herbicide resistance than any single gene Clearfield varieties of PNW and their agronomic performance were equal or better than their recipients in multi-location yield trials as well as variety testing trials.



Eltan

Sprayed @ 12 oz/A of imazamox + MSO

WA8143

Spring Barley Improvement for Herbicide Tolerance, Malting and Food Quality Traits

JANET MATANGUIHAN¹, MAX WOOD¹, DEVEN SEE², IAN BURKE¹ AND KEVIN MURPHY¹

¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²USDA-ARS WESTERN REGIONAL SMALL GRAINS GENOTYPING LAB

The overall goal of the WSU Barley Breeding Program is to improve the agronomic, adaptation, and grain quality factors of two-row spring barley for feed, food and malting use for dryland cropping systems. At present, we are developing cultivars tolerant to imidazolinone (IMI) herbicides. In the greenhouse, we harvested 234 families of the 07M mutants (BC₁F₃) derived from 'Bob'. From these, 537 seeds were sown in the greenhouse and sprayed with Beyond® at the 4-5 leaf stage. The plants were visually evaluated 21 d after imazamox application. Of the 537 seeds planted, 340 germinated and from these, only 6 plants were susceptible to IMI, showing 98% resistance. However, 47 plants (14%) had to be discarded for growth abnormalities such as stunting, leaf striping, curling, and yellowing. Because of these growth abnormalities, a second backcross was done to remove undesirable mutations. There were 62 crosses using IMI-resistant mutants as male parents, and 'Bob' plants as female parents. Twenty-one reciprocal crosses were also made, for a total of 83 crosses. The progeny from these crosses will be tested in the field in Spring 2013, with 311 headrows and 78 bulk plots to be sprayed with Beyond® at a rate of 4 oz/acre.

Another project is to use molecular markers to augment field selection of malting barley breeding lines for agronomic and quality traits. The objective of the project is to identify, optimize and validate molecular markers that will allow for rapid, large-scale identification and scoring of traits important to malting barley production and quality improvement. Specifically, these traits include malt extract, diastatic power, grain nitrogen, alpha amylase activity, grain protein content, β-glucanase activity (kilned and green malt), β-glucan (barley), β-glucan (malt), soluble/total protein, and

polyphenol oxidase activity. We have identified 48 single nucleotide polymorphism (SNP) loci based on the linkage map of the Oregon Wolfe Barley Mapping Population, which has integrated hundreds of several kinds of molecular markers associated with malting quality. These SNP markers were used to genotype an initial set of 192 malting breeding lines. We plan to add more markers that will be identified from association mapping studies for malting traits. We will integrate several years of phenotypic data based on multi-location trials of a diverse set of cultivars and breeding lines with existing genotypic data from the Triticeae CAP (<http://www.triticeaecap.org/>).

The WSU Barley Breeding Program is also working towards the release of new food barley cultivars. β -glucans in barley have been shown to lower blood cholesterol and glycemic index in humans. Wholegrain barley also appears to be associated with increased satiety and weight loss. Due to the health benefits from barley, more consumers have been incorporating barley into their diet. Companies such as Kellogg's and Clif Bar have also shown interest in developing food products with barley as key ingredient, or replacement for other grains. We have screened 998 food barley lines for β -glucan content, and 94 lines have shown high β -glucan content (>6% w/w). Nine lines had β -glucan content higher than 7.5% w/w, and 3 had levels higher than 8% w/w/. These 94 lines show promise as food barleys and will be advanced for further field tests.

The Western Wheat Quality Laboratory

CRAIG F. MORRIS, DIRECTOR; BRIAN S. BEECHER 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 grain hardness, puroindolines, waxy wheat, soft durum wheat, polyphenol oxidase (PPO), arabinoxylans, fiber, and SDS sedimentation test and instrumentation. Our recent publications include a study on the distal portion of the short arm of wheat chromosome 5D and how it controls endosperm vitreosity and grain hardness, and a critical assessment of the quantification of wheat grain arabinoxylans using a phloroglucinol colorimetric assay. Some observations on the granivorous feeding behavior preferences of the house mouse were published in *Mammalia*. A study on the influence of instrument rigidity and specimen geometry on calculations of compressive strength properties of wheat endosperm was published in *Cereal Chemistry*. Two studies on the prevalence of *Puroindoline D1* and *Puroindoline b-2* variants in U.S. Pacific Northwest wheat breeding germplasm pools, and the physical mapping of *Puroindoline b-2* in wheat using the cv. Chinese Sping deletion lines were published. Other research includes phytochemical composition, anti-inflammatory, and antiproliferative activity of whole wheat flour, and the molecular characterization and diversity of *Puroindoline b-2* variants in cultivated and wild diploid wheat. Currently the lab is working on grant-funded research aimed at better understanding the fate of fiber and phytonutrients in whole wheat products during processing. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Babe, Cara, Diva, Farnum, JD, Kelse, ORCF-103, Skiles, Tubbs 06, Whit, Xerpha, Crescent, Chrystal, Amber, Gene, and Eden.

Breeding Barley Cultivars Adapted to the Pacific Northwest United States for Imidazolinone Resistance

SACHIN RUSTGI¹, DITER VON WETTSTEIN^{1,2,3}, JANET MATANGUIHAN¹, JAIME MEJÍAS¹, RICHA GEMINI¹, KEVIN M. MURPHY¹, AND PATRICK E. REISENAUER¹; ¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²SCHOOL OF MOLECULAR BIOSCIENCES; ³CENTER FOR REPRODUCTIVE BIOLOGY, WSU

Barley is a short-season, early maturing crop, which is cultivated in a variety of climates including both irrigated and dryland production areas. In fact, barley is the third largest feed grain crop produced in the United States, after corn and sorghum. However, extensive application of imidazolinone (IMI) herbicides resulted in significant drop in its production due to continuous decline in the barley acreage over the last two decades. The most likely solution to this problem is to transfer IMI-resistance from a recently characterized barley *AHAS* (acetohydroxy acid synthase) mutation to other relevant food, feed and malting barley cultivars adapted to the Pacific Northwest (PNW) United States. The *AHAS* gene encodes an essential enzyme in the branched chain amino acid synthesis pathway. The IMI herbicides bind at the substrate access channel in the catalytic subunit of the enzyme, blocking path of the substrate to the active site, impairing synthesis of leucine, isoleucine and valine leading to growth retardation in the susceptible plants, which

culminates in death. The point mutation causing a serine to asparagine substitution at the amino acid location 653 at the herbicide-binding site of the *AHAS* enzyme reduced its sensitivity to the IMI herbicides without impairing its catalytic properties.

To effectively breed for IMI-resistance it is a prerequisite to develop resources, which will allow precise transfer of the trait of interest in a single generation to the desired genotype without a need for backcrossing. Towards this end the following experiments were undertaken: i) Estimation of genetic diversity among 13 two-rowed spring barley cultivars/breeding-lines adapted to the PNW US using 61 carrier chromosome 6H-specific microsatellite markers. Based on this genotypic-information two genotypes per market class (food, feed and malting) were selected and crossed with the 'Bob' *AHAS* mutant. (ii) A micro-scale enzyme extraction and *in vitro* colorimetric enzyme activity assay for quick detection of the *AHAS* mutant allele in the segregating population was optimized. The assay, surprisingly, revealed that the mutant *AHAS* enzyme could endure 10⁷ (40 oz/acre) field recommended dose of IMI-herbicides without compromising its activity.

Building upon the above results a range of 29 to 53 crosses were made per genotype combination with Bob *AHAS* mutant. The 'WAS4' and Bob mutant crosses showing maximum genetic dissimilarity, are currently used for genetic mapping of the *AHAS* gene on barley chromosome 6H. More than 2100-2800 F₂ grains obtained per cross combination are being screened for IMI-resistance in the glasshouse. The survivors showing vigorous phenotype will be examined for carrier chromosome recovery.

In a nutshell this research will result in the development of IMI-resistant food, feed and malting barley cultivars adapted to the PNW US and will re-establish barley as a rotational crop with winter wheat.

Release of 'Lyon' and 'Muir': Two New Feed Barley Varieties from WSU

KEVIN MURPHY¹, STEVEN ULLRICH¹, MAX WOOD¹, VADIM JITKOV¹, JANET MATANGUIHAN¹, STEPHEN GUY¹, XIAMING CHEN², STEPHEN JONES³, AND BROOK BROUWER³; ¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²DEPT. OF PLANT PATHOLOGY, WSU; ³WSU NORTHWEST RESEARCH AND EXTENSION CENTER, MOUNT VERNON

Two new barley varieties, 'Lyon' and 'Muir' were approved for release in 2013. Lyon (05WA-316.K) is a spring, two-row feed barley derived from the biparental cross 'Baronesse' x 'Spaulding'. Lyon is especially well suited to intermediate (16-20") and high (>20") rainfall zones, where it yields significantly higher than Baronesse, 'Bob' and 'Lenetah', and is equal to the private variety 'Champion'. Agronomically, Lyon has a heading date similar to 'Bob' and 'Baronesse', is a day later than Champion and a day earlier than Lenetah. Plant height is similar to Baronesse and is approximately 2.5" shorter than Champion across high rainfall zone locations. Test weight is similar to Baronesse, and Lyon consistently has plump kernels in line with other common barley varieties. Lyon has been shown to be similar to Champion and Lenetah, with moderate susceptibility to stripe rust. Due to the low incidence and non-uniformity of stripe rust in spring barley, this has not been shown to negatively affect yield in our variety trials. Lyon has been shown to be moderately resistant to stem rust, with significantly lower stem rust incidence and severity than commonly grown barley varieties, including, Champion, Bob, Lenetah and Baronesse. Lyon is intended to replace Bob and Baronesse across Washington, to replace Lenetah in the high rainfall zones, and to replace Champion in stem rust prone areas or where additional cost of a private variety may be a concern.

Muir (07WA-601.6), a two-row, spring, feed barley derived from the cross 'Baronesse' x 'Bob', is primarily intended for the low-intermediate rainfall zone (12-16"). Muir has higher yields than Baronesse and Bob in the lower rainfall zones and is equal in yield to Champion and Lenetah. Muir has a higher protein content than Champion as well as an excellent disease resistance package. Muir is highly resistant to stripe rust, stem rust and leaf rust. Muir has stripe rust resistance at least equal to the resistance level of Bob, which has the best high-temperature adult-plant resistance among the currently grown cultivars. Additionally, Muir has been shown to be resistant to powdery mildew (0% infection), compared to Champion and Lenetah (30 and 40% infection, respectively). Muir is intended to replace Bob and Baronesse in low-intermediate rainfall areas, and Lenetah and Champion in stem and/or stripe rust prone environments.

Variety Selection for Management of Aluminum Toxicity

KURTIS SCHROEDER¹, MIKE PUMPHREY², ARRON CARTER², AND TIMOTHY PAULITZ³; ¹DEPT. OF PLANT PATHOLOGY, WSU; ²DEPT. OF CROP AND SOIL SCIENCES, WSU; ³USDA-ARS, ROOT DISEASE & BIOLOGICAL CONTROL RESEARCH UNIT

Soil acidification in the Pacific Northwest was documented several decades ago and continues today due primarily to the use of ammonium-based fertilizers. Recently, this reduction in soil pH has reached a level that symptoms of acute aluminum toxicity have become apparent, particularly in fields that were historically forested in Spokane County in Washington and Kootenai County in Idaho. Aluminum toxicity results in damage to roots which progresses into severe stunting and yield reductions. The damaged root symptoms are characterized by twisting and bending of the roots, stubby and short lateral roots and general poor root health. Potential solutions being explored include use of tolerant crops such as triticale or oats, or application of lime to increase the soil pH. However, one of the more immediate solutions to help alleviate yield reductions is the planting of aluminum-tolerant wheat. The major tolerance is conferred by a single gene, *ALMT*, which will make integration of this trait into desirable varieties fairly straight forward. Over the past three years, varieties from the Pacific Northwest have been screened for tolerance in either an acid soil nursery in Oklahoma or Rockford, WA. The tables below outline some of the varieties of spring and winter wheat that show the greatest promise for tolerance (shaded) and those that should be avoided if aluminum toxicity is a problem (not shaded). Data for the spring wheat plot is from Rockford, WA and was collected in 2012. In addition to the tolerance rating, the yield was also collected. The winter wheat data includes ratings obtained from the Oklahoma nursery in 2011 and 2012. An effort is currently underway to test additional spring and winter wheat varieties in a plot near Rockford, WA.

Spring wheat (Soft white)			Spring wheat (Hard spring)			Winter wheat	
Variety	Yield (bu/A)	Rating (0-5)	Variety	Yield (bu/A)	Rating (0-5)	Variety	Rating (0-5)
Babe	40	2	WA 8166	45	2	Legion	1
Whit	40	2	WA 8163	39	2	Madsen	1
WB-1035CL+	40	2	Tara 2002	39	1	WA8151	1
WA 8162	39	2	WB Hartline	36	3	WA8175	1
Nick	36	2	LCS Albany	35	2	WA8134	1.5
Alturas	32	2	Otis	34	3	ARS Amber	1.5
Alpowa	31	2	LCS Powerplay	30	2	Chukar	1.5
JD	12	4	Expresso	26	3	Xerpha	1.5
Zak	11	5	Hank	20	4	Badger	2
Wakanz	11	5	LCS Buck Pronto	18	4	Brundage 96	2
Diva	9	5	BR7030	11	4	Masami	2
Louise	8	5	Scarlet	10	4	WB-528	2
UI Stone	7	5	Glee	10	4	WA8153	2
			Jedd	9	5	Otto	2
			Bullseye	8	5	Finch	2.5
			WB-Fuzion	7	5	Legacy	3
			Kelse	7	5	Tubbs	3
			Jefferson	7	5	Eltan	4.5
			SY605 CL	5	5	Skiles	5
						Stephens	5

Winter Wheat Breeding and Genetics

A. CARTER, G. SHELTON, R. HIGGINBOTHAM, 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 good 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 2012 we evaluated over 1,500 doubled haploid lines under field conditions and planted another 2,000 for 2013 evaluation. We are continuing to develop doubled haploid populations and are increasing the number of lines produced annually. In 2012 we evaluated over 2,000 lines developed with marker selection for stripe rust and foot rot resistance. We planted an additional 1,500 lines in the field and recently completed selection of over 2,500 lines for stripe rust, foot rot, and end-use quality for 2013 planting. We have developed Imazamox resistant breeding lines in both hard and soft backgrounds which are under advanced testing in field trials. Additional breeding populations developed include those for stripe rust, nematode resistance, stem rust resistance, soil borne mosaic virus resistance, aluminum tolerance, snow mold, and various other biotic stresses. We continue our work and collaboration with the spring wheat breeding program on the USDA funded TCAP grant working on drought tolerance and stripe rust resistance. Additionally we have work progressing under field and greenhouse conditions for heat tolerance in conjunction with the spring wheat breeding program. We are collaboratively developing high-throughput field phenotyping platforms to facilitate data collection which complement our phenotyping work under growth chamber conditions. We have increased our field screening locations to include aluminum tolerance along with those for snow mold, stripe rust, and foot rot resistance. Our program has directed efforts to develop hard white winter wheat for the domestic market.



Otto (WA8092) was released in 2011 and 180,000 pounds of foundation seed sold in 2012. This cultivar is an Eltan/Madsen cross which was backcrossed to Eltan four times. Agronomically, it performs very similar to Eltan and continues to perform very well with emergence, snow mold resistance, cold tolerance, and yield potential, with improved stripe rust resistance (both seedling and adult plant) and is also resistance to eyespot foot rot. This line is targeted to the <15" rainfall zones as a replacement for Eltan.

Sprinter (WA8118) was released in 2012 and is on foundation seed increase. Limited seed will be available this fall. This line is a hard red wheat which requires vernalization for seed production. It also has the unique feature that the grain grades as hard red spring wheat and therefore must be sold as and comingled with other hard red spring wheat varieties. It has very high grain protein content and must be managed to achieve the 14% requirement for other hard red spring cultivars. It is a tall variety with early heading date, has very good end-use quality, and is targeted for late-planting situations in the state.

WA8134 (yet to be named) was released in 2013 and is on foundation seed increase. This line is a soft white wheat targeted to the high rainfall zones of the state and particularly eastern Whitman county. It has been the #1 yielding variety averaged over two years in the >20" rainfall zone and the #2 yielding variety in 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, tolerance to low pH soils (aluminum tolerance), and excellent end-use quality. Limited foundation seed will be available this fall.

Washington Extension Variety Trials 2013 – Bringing Variety Performance Information to Growers

STEPHEN GUY, VADIM JITKOV, MARY LAUVER, AND ANDREW HORTON; DEPT. OF CROP AND SOIL SCIENCES, WSU

The WSU Extension Variety Testing program provides growers, the agribusiness industry, university researchers, and other interested clientele comprehensive, objective information on the adaptation and performance of small grain and grain legume cultivars across the climatic regions of eastern Washington. The 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 Variety Testing program small grain evaluation trials in the dryland and irrigated production areas of eastern Washington are conducted at many locations: 21 for soft white and 11 for hard winter wheat; 16 for soft white and hard spring wheat; and 10 for spring barley. In addition, the WSU Variety Testing program has, since 2011, been conducting field evaluations of dry pea, lentil, and chickpea varieties in eastern Washington at four locations. Trial results are available in printed form in: [Wheat Life](#), the [Cereal Variety](#)



Kim Campbell in the 2012 Lind winter wheat variety trial presenting to growers at the field day.

Evaluation Annual Report, summarized in the WSCIA Certified Seed Buying Guides, and comprehensive results for last year and many previous years can be found on the Variety Testing Web site (<http://variety.wsu.edu>). Oral presentations, field days, and industry and extension meetings are other means used for delivering research results. Results from the Extension Variety Testing Program provide independent assessment of variety performance to support variety selection decisions by growers and for other decisions by other clientele. Growers can realize a timely economic payback using information from yield and variety performance data that is provided within days after harvest via an email list-serve. This project is made possible by contributions of land and time from farmer cooperators where trials are located, and cooperators at the WSU research units at Pullman and Lind. Partnerships with research scientists from public and private sectors are vital to make this program successful. Funding is provided by: Washington Grain Commission, Dry Pea and Lentil Council, WSU Agricultural Research Center, WSU Extension, and Washington State Crop Improvement Association.

Screening for Winter-Hardiness in a Cultivated Chickpea/Wild Relative RIL Population

JULIA PIASKOWSKI¹, GEORGE VANDEMARK¹, REBECCA MCGEE¹, HONGBIN ZHANG², SHAHAL ABBO³ AND CLARICE COYNE¹

¹USDA-ARS, PULLMAN, WA; ²DEPT. OF CROP AND SOIL SCIENCES, WSU; TEXAS A & M UNIVERSITY, COLLEGE STATION, TX;

³FACULTY OF AGRICULTURE, HEBREW UNIVERSITY OF JERUSALEM, REHOVOT, ISRAEL

As a legume, chickpea (*Cicer arietinum* L) is an integral part of cereal-based cropping systems in the Pacific Northwest and worldwide as they fix atmospheric N, breaking disease cycles, and improve cereal grain yields. However, as a spring-planted crop, the short growing season of chickpea limits its grain yield and leaves very little crop residues to combat soil erosion and contribute to soil organic matter. Furthermore, the changing climatic patterns are predicted to result in longer, wetter springs that delay planting and hotter, drier summers that can cause heat stress during flowering and pod set. The development of a fall-planted, winter chickpea could improve yields by increasing the length of the growing season, help escape late season drought, and provide additional protection from cool temperatures during seed set in the early spring. Cultivated chickpeas currently lack winter hardiness due to genetic bottlenecks and subsequent loss of critical alleles during its evolutionary history. However, alleles for winter hardiness and a vernalization requirement still exist and are prevalent in chickpea's wild progenitor, *C. reticulatum*. A recombinant inbred line (RIL) population was made between cultivated chickpea (accession ICC 4958) and *C. reticulatum* (PI 489777) that differ in their winter hardiness response. The population, consisting of 131 individuals, is being screened for differential winter hardiness responses over multiple environments in Eastern Washington: Spillman, Whitlow and Central Ferry. Cold temperatures during 2011/2012 in Central Ferry killed about 15% of whole plots and severely damaged an additional 28% of the plots (defined as over 50% of plants killed). Seventeen RILs experienced no winter kill and little to no leaf damage over the winters of 2011/2012 and 2012/2013. These lines will be assessed over additional sites and years to determine the best lines for inclusion in the ARS chickpea breeding program.



Winter-hardy chickpea



Winter-killed chickpea

Dry Pea, Lentil, and Chickpea Variety Evaluation on the Palouse: Innovation of Energy Efficient, High Value Food Crops

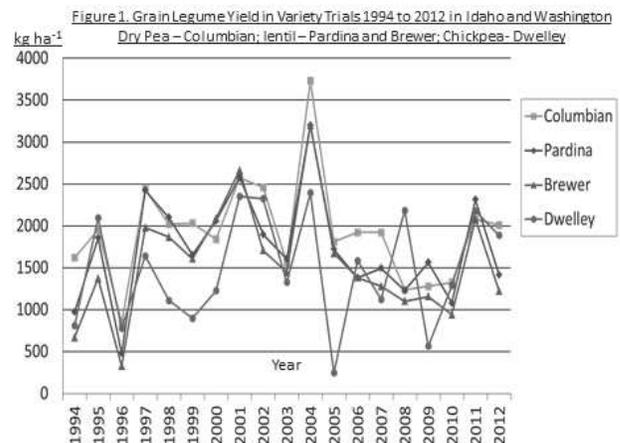
STEPHEN GUY, MARY LAUVER AND DOUG FINKELNBURG

DEPT. OF CROP AND SOIL SCIENCES, WSU; DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, U OF I, MOSCOW

Dry pea, lentil, and chickpea, grain legumes, can be direct seeded and do not require nitrogen fertilizer. They are low energy input crops and produce high quality food commodities. From 1994 to present, grain legume varieties have been evaluated for adaptation and performance in the Pacific Northwest Palouse region of Idaho and Washington. Trials were supported by the University of Idaho, Washington State University, USDA-ARS, USA Dry Pea and Lentil Council, the pulse seed industry, and private breeders. Variety testing results provided information for Extension programming to educate growers on variety performance and selection for their growing conditions including conventional and no-tillage management systems. This supports the adoption of new, improved varieties adapted for an area. Seed yield and size, and plant length and canopy height were determined. Results varied greatly depending on location, year, cultivars entered, and management. 'Columbian' green pea, 'Pardina' and 'Brewer' lentils, and 'Dwelley' chickpea were common varieties across all trials for 19 years (Fig. 1). In conventional tilled trials, Columbian yielded an average of 1925 kg ha⁻¹, Pardina and Brewer yielded, respectively 1755 and 1585 kg ha⁻¹, Dwelley yielded 1450 kg ha⁻¹. These varieties do not show an upward or downward yield trend across the study period showing no agronomic improvement in yields, unlike small grain crops grown in the same region, showing yield improvements came from genetic improvements. This successful variety evaluation program has supported growers and enhanced the pulse industry for 19 years on the Palouse. The Idaho and Washington Dry Pea and Lentil Council have provided direct funding for these programs along with funding from Washington State University and the University of Idaho.



Pea, lentil, and chickpea variety trial at Walla Walla, 2012.



Modification of Coleoptile Length in Wheat via Manipulation of the AHL Gene Family

MICHAEL M. NEFF, DAVID FAVERO, PUSHPA KOIRALA, JIWEN QIU AND JIANFEI ZHAO

DEPT. OF CROP AND SOIL SCIENCES, WSU; 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 winter wheat. The problem is especially prevalent in these areas as winter wheat is generally planted in the last part of August or early in September. During dry years these seeds need to be planted in deep furrows (up to 8") so that the developing seedling has access to ground water. To facilitate stand establishment, wheat breeders have been trying to develop varieties with long coleoptiles as seedlings while maintaining a high-yielding semi-dwarf stature as adults. Unfortunately, few mechanisms have been identified that uncouple the semi-dwarf phenotype of adult plants with reduced elongation of the coleoptile in seedlings.

The Neff lab has identified a group of plant-specific genes that, when mutated in a particular way, uncouple seedling elongation from adult size. These genes encode AHL (AT-Hook Containing, Nuclear Localized) proteins have two domains. One domain, the AT-Hook, binds AT-rich regions of DNA. The second domain is involved in protein/protein interactions. This project includes three main objectives: 1) to identify AHL family members in wheat, 2) to identify those

genes that are expressed at high levels in the coleoptile, and 3) to examine the role of both wild type and mutant genes on coleoptile elongation. To date we have identified twelve full-length wheat *AHL* sequences: *Taq1* through *Taq12*. We have shown that *Taq3* is expressed at high levels in the wheat coleoptile and that some of these *Taq* proteins behave biochemically similar to the ones we have been characterizing extensively in the model brassica *Arabidopsis*.

The third objective is critical for being able to elucidate the role of wild-type and mutant *AHL* genes in wheat seedling emergence. As such, we have been focused on establishing a successful wheat transformation protocol. In collaboration with Dr. Scot Hulbert, Dr. Jiwen Qiu (the post doc working on this project) has established a protocol for transforming wheat. We have generated over 60 putative transgenic plants and confirmed that at least 20 of them are transgenic and expressing the wild type form of *Taq3* (see figure below). Nine of the transgenic plants show the predicted short phenotype demonstrating that our knowledge of *AHL* genes based on work in *Arabidopsis* is likely to be translatable to wheat. We are currently generating transgenic wheat expressing dominant-negative mutant forms of these genes. Ultimately, naturally occurring alleles or those identified in a TILLING population may be used as non-GMO germplasm for Dr. Carter's winter wheat breeding program as well as other wheat breeding programs at WSU.

It is important to note that these transgenic approaches are just for proof-of-principal analysis. At this time GMO wheat is not being grown in Washington State. One of the most important extension/communication activities undertaken by Dr. Neff is opening the dialogue for understanding the biology behind GMOs. In the past three years, Dr. Neff has spoken with over 650 people about the biology of GMOs, from Seattle Tilth Producers' to the Tri-State Growers Convention.



Variation for Wheat Seedling Emergence from Deep Planting Depths and its Relationship with Coleoptile Length

AMITA MOHAN, WILLIAM SCHILLINGER, AND KULVINDER GILL; DEPT. OF CROP AND SOIL SCIENCES, WSU

Successful stand establishment is prerequisite for optimum crop yields. In the low-precipitation (less than 12 inch annual) region of the Inland Pacific Northwest, winter wheat is planted as deep as seven inches below the soil surface to reach adequate soil moisture for germination. To better understand the relationship of coleoptile length and other seed characteristics with emergence from deep planting (EDP), we evaluated 662 wheat varieties grown around the world since the beginning of the 20th century. Coleoptile length of collection entries ranged from 34 to 114 mm. A specialized field EDP test showed dramatic emergence differences among varieties with less than 1% of entries having any seedlings emerged on the seventh day after planting and 43% on day 8. The percentage of seeds planted that had emerged by 21 days after planting ranged from 0 to 66% among entries. A wide range of EDP within each coleoptile length class confirmed the involvement of genes other than those controlling coleoptile length. Emergence was correlated with coleoptile length, but some lines with short coleoptiles ranked among the top emergers. Coleoptiles longer than 90 mm showed no advantage for EDP and may even have a negative effect. Overall, coleoptile length accounted for only 28% of the variability in emergence among entries; much lower than the 60% or greater reported in previous studies. Seed weight had little correlation with EDP. Results show that EDP is largely controlled by yet poorly understood mechanisms other than coleoptile length.

Evaluating Winter Wheat Seedling Emergence from Deep Planting Depths

AMITA MOHAN, WILLIAM SCHILLINGER, KULVINDER GILL, STEVE SCHOFSTOLL, AND JOHN JACOBSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU

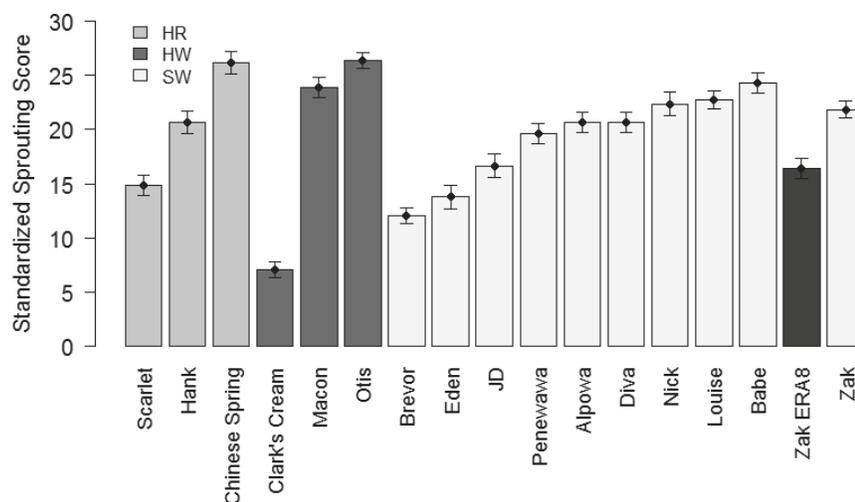
Winter wheat in the low-precipitation (less than 12 inch annual) region of the Inland Pacific Northwest is sown as deep as seven inches below the soil surface to reach adequate soil moisture for germination and emergence. Stand

establishment and grain yield potential depends upon the successful emergence through a thick soil layer covering the seed. Hence, winter wheat varieties that can emerge quickly and successfully from these deep depths under limited moisture conditions are needed. The present-day semi-dwarf cultivars in PNW contain Rht1 and Rht2 dwarfing genes that do not emerge as well as the taller varieties grown in the 1960s. The Rht mutations seem to reduce coleoptile length and thus impede seedling emergence. With the objective to transfer the emergence trait from Buchanan (hard red) to Xerpha, 14,000 BC₁F₁ seeds were developed. The BC₁F₁ seeds were first evaluated for coleoptile length and selected plants then evaluated with DNA markers. From the first batch of 2000 BC₁F₁ seeds, plants with coleoptiles longer than 80 mm were selected and evaluated for Xerpha type DNA markers. From 2000 plants, one hard red line with all the Xerpha type DNA markers and a coleoptile length of more than 100 mm was selected. This line was field tested for its emergence capabilities at WSU Dryland Research Station at Lind in the crop year 2012. Coleoptile length and emergence of this selected line was comparable to Buchanan. Seed of this line is presently being multiplied in the greenhouse and will be included in the WSU winter wheat variety-testing program at several sites in the 2013 crop year.

Genetic Variation in Preharvest Sprouting Tolerance

SHANTEL A. MARTINEZ¹, KIMBERLY GARLAND CAMPBELL², ARRON H. CARTER¹, MICHAEL O. PUMPHREY¹, STEPHEN O. GUY¹, AND CAMILLE M. STEBER²; ¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²USDA-ARS, WHEAT GENETICS, QUALITY, PHYSIOLOGY AND DISEASE RESEARCH UNIT

Preharvest Sprouting (PHS) is the germination of grain on the mother plant under cool and wet conditions. Even mild sprouting can cost farmers money, because it causes lower Falling Numbers due to starch degradation by alpha-amylase. Low Falling Numbers can also result from alpha-amylase induction due to cold shock during development. The characterization of this Late Maturity Alpha-Amylase susceptibility in Washington wheat is underway. Breeding for good sources of Late Maturity Alpha-Amylase and PHS tolerance can help to prevent problems with low falling numbers. Here we present preliminary characterization for PHS tolerance/susceptibility. Hard red (HR) wheat is typically more resistant to PHS than soft white (SW) or hard white (HW) wheat, so studies in 2011 and 2012 focused on soft white springs. A seed is considered dormant if it has the inability to germinate, even in favorable conditions. Seed dormancy likely helps to prevent preharvest sprouting in white wheat. Thus, we also looked at the ability of a dormant ABA mutant in Zak, called ZakERA8 (black bar), to improve PHS tolerance. Spike wetting tests (artificial rain) performed in 2011 and 2012 showed that there is considerable variation for PHS tolerance in Washington wheat cultivars (data from 2012 shown). We expected hard red cultivars to be more PHS tolerant, but there was just as much variation in hard red as in soft white cultivars. Cultivars such as Brevor, Eden, and JD show promising results for sources of PHS tolerance in SW springs. Cultivars Macon, Otis, and Babe are highly susceptible whereas Nick and Louise appear to have moderate PHS susceptibility. The seed dormancy from the ERA8 mutation significantly improved PHS tolerance compared to normal Zak (p-value < 0.0001) suggesting that moderate seed dormancy is a good way to avoid PHS. Alpowa was highly PHS tolerant in 2011, but only moderately tolerant in 2012. This variation between field seasons likely results from the fact that differences in environmental conditions during grain development cause differences in seed dormancy from year to year. Thus, we need to score multiple years before deciding that a cultivar is highly susceptible. These experiments have, however, identified good sources of tolerance that can be used in the breeding programs.



Multipronged Approach to Develop Nutritionally Improved, Celiac Safe, Wheat Cultivars

SACHIN RUSTGI¹, DITER VON WETTSTEIN^{1,2,3}, NII ANKRAH¹, JAIME MEJÍAS¹, RHODA BREW-APPIAH¹, SHANSHAN WEN¹, NUAN WEN¹, CLAUDIA OSORIO¹, RICHA GEMINI¹, PATRICK REISENAUER¹, JAYANTHI MOHAN¹, AND JOHN BRABB II¹

¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²SCHOOL OF MOLECULAR BIOSCIENCES; ³CENTER FOR REPRODUCTIVE BIOLOGY, WSU

Wheat supplies about 20% of the total food calories consumed worldwide, feeds approximately half of the global demand for dietary proteins, and is a national staple in many countries. In the United States, the per capita consumption of wheat exceeds that of any other single food grain. Besides being a major source of energy and nutrition it is also a major cause of frequent diet-induced health issues especially celiac disease, gluten sensitivity, food allergies, obesity, diabetes mellitus, cardiovascular disorder, and colorectal cancer. Gluten-intake in the sensitive individuals can elicit various reactions, which in combination with their respective genetic constitutions lead to diverse symptoms from gastrointestinal or neurological to fatal. These symptoms are broadly classified into gluten intolerance, sensitivity and allergy. Gluten intolerance includes celiac disease, which is one of the most common food-born enteropathies in humans, occurring in the US with an incidence of 1 in 100. The gluten-sensitivity is very wide spread and in combination with celiac disease affect >7% of the US population (21.9 million individuals; US Census Bureau as of 8/22/11). Recent advances in the understanding of the disease onset in schizophrenia and dermatitis herpetiformis (the celiac disease of skin) unveiled that gluten peptides are also elicitors for these disorders as was earlier reported for the gluten sensitivity and celiac disease.

In view of the magnitude of problem we undertook a multipronged approach to develop a natural dietary therapy for the gluten-induced disorders collectively referred as 'gluten syndrome'. The three approaches undertaken in this direction are: i) epigenetic elimination of immunogenic prolamins [namely low molecular weight (LMW) glutenins and gliadins] using transgenic and non-transgenic approaches, ii) post transcriptional silencing of immunogenic prolamins via RNA interference, and iii) post translational detoxification of prolamins by expression of 'glutenases' in wheat grains (the enzymes were selected such that they will degrade prolamins in the human gut only after consumption not within the grains).

The earlier research performed on the high-lysine barley mutant Risø 1508 (*lys3a*) revealed two-types of transcriptional regulation for the prolamins in the barley endosperm: i) the genes whose transcription depend on demethylation of their promoters in the endosperm, such as LMW glutenins and gliadins, and ii) the genes whose transcription solely depend on expression of specific transcription factors, such as high molecular weight (HMW) glutenins. Based on the functional similarity between the barley *Lys3* and *Arabidopsis DEMETER* genes, we undertook cloning of barley and wheat *DEMETER* genes. The *DEMETER* sequences obtained from the wheat genome were used to develop homoeologue specific primers that were utilized to screen for mutations in the hexaploid 'Express' and tetraploid 'Kronos' wheat TILLING populations. The screen for mutants resulted in identification of a total of 191 mutants in the Express and 77 mutants in the Kronos backgrounds. These single mutants identified in *DEMETER* homoeologues are currently being pyramided to obtain double mutants in Kronos and triple mutants in the Express backgrounds. The sequence information was also used to design one hairpin RNA and three artificial micro RNA constructs to silence wheat *DEMETER* homoeologues. Transformations using the above four RNAi constructs resulted in identification of a total of 74 transformants. Inheritance of transgene, up to the T₂ generation, has so far been confirmed in 50 out of the 74 cases. As much as 76.4% reduction in the accumulation of immunogenic prolamins was observed in the T₃ grains of these 50 transformants. Progenies of the transformants showing highly level suppression in *DEMETER* transcript abundance and accumulation of immunogenic prolamins are currently being propagated at the Cook Agronomy Farm, and in the glasshouse. These genotypes will be converted to doubled haploids (DHs), and the DHs showing elimination of specific prolamins groups will be crossed together in specific combinations to pyramid their effects in a single genotype.

For the post-transcriptional silencing of the immunogenic prolamins a chimeric hairpin construct was assembled by putting together the conserved target sequences identified for different gliadin groups and the LMW glutenins. The hairpin was provided with the endosperm specific HMW glutenin promoter, and introduced into the wheat genome by biolistic approach or via microspore electroporation based method. The T₁ grains of the selected transformants are currently being examined for their prolamins content.

For the post-translational detoxification of prolamins a combination of barley cysteine endoprotease B2 (EP-B2) and a *Flavobacterium meningosepticum* prolyl endopeptidase (Fm-PEP) was introduced into the wheat genome using the biolistic approach. The genes encoding for Fm-PEP and EP-B2 were provided with the endosperm specific HMW glutenin promoter. Integration of these genes in the wheat genome was confirmed at the T₀ and T₁ generations, and the transformants showing gene integrations are currently being investigated for the expression of enzymes. To ensure survival of these enzymes during the baking process a site-directed mutagenesis approach was followed to introduce mutations in the first and the seventh blades of the b-propeller domain of the Fm-PEP and at the junction of left and

right-domains in the EP-B2. Three mutations in the Fm-PEP showed thermostability at 90°C and retained their activity after the heat shock. Characterization of the EP-B2 mutants is currently underway.

In a nutshell our results show a great potential in obtaining non-immunogenic wheat cultivars, which will have a broad impact on the quality of lives of a vast majority of the wheat consumers.

Discovering Drought Resistance Mechanisms in Wheat

SURYA L. SHRESTHA¹, SHANTEL MARTINEZ¹, KIM GARLAND-CAMPBELL², SCOT H. HULBERT¹, AND CAMILLE M. STEBER²
¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²USDA-ARS

Wheat farms in eastern Washington are repeatedly challenged by dry growing conditions. Wheat cultivars with increased ability to yield when water is limited can improve cropping systems on the dry side of Washington both by decreasing risk and by reducing the number of fallow seasons required to obtain sufficient stored soil moisture. Drought tolerance is a complicated trait that varies with the environment and that is influenced by multiple physiological and genetic mechanisms. Examples include the ability to root deeply, if moisture is present in the lower soil profile, or good water use efficiency, where a wheat line can perform well without using as much water. We are investigating the association between specific combinations of physiological traits and productivity under drought by examining the physiology of lines in the WSU variety trials and comparing the performance of recombinant inbred line populations derived from two parents that use two different strategies to resist drought. This analysis shows that a single mechanism, like high water use efficiency, is not alone sufficient to create a high yielding cultivar. The success of water use efficiency depends upon other traits. Hard red spring lines with improved water use efficiency and yield will be selected from a cross of Australian cultivar Drysdale with Hollis this year. Lines have been selected that combine the excellent water use efficiency of soft white spring cultivar Louise with the pattern of growth and development of Alpowa that allows it to escape drought pressure. Twenty selections that outperformed both Louise and Alpowa are being evaluated this year under dry and moist conditions at the Lind and Spillman Farms.

Pre-Breeding for Root Rot Resistance Using Root Morphology Traits

PAT OKUBARA^{1,2}, AARON MAHONEY², AND SCOT HULBERT²; ¹USDA-ARS, ROOT DISEASE AND BIOLOGICAL CONTROL; ²MOLECULAR PLANT SCIENCES PROGRAM; DEPT. OF PLANT PATHOLOGY, WSU

Our goal is to identify new wheat varieties that display field resistance/tolerance to root rot diseases, such as those caused by *Rhizoctonia* and *Pythium*. We are tapping into the genetic diversity of 'synthetic' hexaploid wheats (genome composition AABBDD), which were generated at CIMMYT by artificial genome fusions of durum wheat genotypes (AABB) with wild diploid grasses (DD). Synthetic fusions can produce new combinations of genes not present in traditionally-bred hexaploid wheat. The synthetic wheat lines are screened in cool, wet soils under heavy disease pressure induced by green bridge (planting into 'green' strips) and compared with the same lines screened in strips in which the green bridge is removed ('clean' strips) (Photo 1). Six synthetic wheat lines were found that were not stunted under heavy disease pressure: two synthetic-derived lines, SPCB3104 and SPCB3220, and four synthetic lines, SYN30, SYN172, SYN182, and SYN201. We have advanced large BC₁ Louise-derived families (backcrossed once to the recurrent parent, cv. Louise) under field and/or greenhouse selection for each of the six sources of resistance. Currently, advancement is in progress for BC₂ plants of SPCB3104, SYN172, SYN201, and BC₁ plants of SYN30, SYN182 and SPCB3220. A SPCB3104 x Louise BC₁-F₇ mapping population was evaluated and scored for resistance in the field in the spring of 2012. Initial mapping using SSR markers indicated one candidate resistance locus in this population. We have finished constructing BC₁-F₈ Louise-derived SPCB3104 for rescreening in the field this year. This year's field-screened populations will be advanced by backcrossing into Louise; genotypic data will be collected using next generation



Photo 1. View of green-clean strips at the Palouse Conservation Field Station for 2013. Strips without plants are considered "clean" (green bridge removed 1 month before sowing) and "green" (plants sown into green bridge sprayed 2-3 days before planting).

genotyping platforms. The mapping population of SYN172 x Louise BC₁-F₈ will also be scored in green-clean strips this year. In addition to using green-clean comparisons, we plan to plant into 'green' strips with, and without, fungicides to create the disease pressure differential (green-green). Populations SPCB3104 x Louise BC₁-F₈, SYN30 x Louise BC₁-F₅ and SYN182 x Louise BC₁-F₅, and the six original parental synthetic lines will be evaluated in these green-green strips. In addition to field screens, we will compare the resistances of the six original synthetic lines along with the 10 best and 10 worst plants of the SPCB3104 x Louise population under controlled (greenhouse) conditions. Greenhouse assays showed that original lines SPCB3104 and SYN172 differed in numbers of seminal and lateral roots, morphology traits that can be linked to escape from the pathogen or recovery from pathogen damage. Since original lines vary widely in endogenous root development, advanced Louise-derived lines from the field will provide a common genetic background. Our cooperators are Tim Paulitz and Deven See.

Genetic Mapping of Quantitative Trait Loci Associated with Important End-Use Quality Parameters in Soft White Winter Wheat

KENDRA L. JERNIGAN¹, CRAIG F. MORRIS², MICHAEL O. PUMPHREY¹, KIMBERLY A. GARLAND-CAMPBELL², AND ARRON H. CARTER¹
¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²USDA-ARS

Soft white wheat has many different end-uses and each one requires different quality parameters. Since most of the soft white wheat grown in the Pacific Northwest (PNW) is exported, it is imperative that the wheat quality is sufficient for diverse foreign markets. Due to the time constraints associated with milling and baking tests, understanding the quantitative nature of end-use quality traits as well as identifying molecular markers will allow breeders to more efficiently select wheat cultivars with superior end-use quality. Quantitative trait loci (QTL) are regions in the wheat genome, identified through the use of molecular markers, which contain genes associated with particular traits of interest to breeders. Using 480 PNW experimental soft white wheat lines with up to 20 years of end-use quality data from the Western Wheat Quality Lab, and 90,000 single nucleotide polymorphism (SNP) markers, associations can be made between superior end-use quality phenotypes and the SNP markers. Identification of end-use quality QTL lays a foundation for wheat breeders to increase gains from selection by use of marker-assisted selection for these complex traits. Using marker-assisted selection will expedite the developmental process of wheat cultivars with improved end-use quality since breeding lines in early generations can easily be discarded if they do not have the proper genes. Continued efforts to understand the genetics of end-use quality is important in order for the PNW to maintain or even increase its market share in foreign wheat markets.

Cool Season Food Legume Breeding and Pathology

WEIDONG CHEN, REBECCA MCGEE AND GEORGE VANDEMARK
USDA-ARS, GRAIN LEGUME GENETICS AND PHYSIOLOGY RESEARCH UNIT, WSU

In the United States, pea, lentils and chickpeas are grown primarily in the Pacific Northwest (ID and WA) and Northern Plains (MT and ND). Over the past five crop seasons (2007-2012) an average of more than 1.25 million acres of these cool season food legumes were planted annually in the US with a harvested value in excess of \$330 million/year. These crops have been historically grown in rotations with wheat and barley, which confer several benefits to small grain production including disruption of cereal disease cycles and increasing availability of residual nitrogen produced by fixation of atmospheric N by rhizobacteria in root nodules. They also have had a historical importance to human diets, being high in protein and fiber, low in fat and having a low glycemic index.

Washington State University is home to the USDA-ARS Grain Legume Genetics and Pathology Research Unit. The research objectives of the unit are to develop improved cultivars and germplasm of peas, lentils, and chickpeas, and integrated strategies for controlling diseases of these crops. The objectives of the spring pea breeding program are to develop adapted cultivars with increased yield and improved levels of resistance to locally important diseases caused by soilborne fungal pathogens, foliar fungal pathogens, and viruses. Both yellow and green seeded varieties are being developed. The spring lentil breeding program addresses needs in each of six market classes: Turkish Red, Spanish Brown, Small Green, Medium Green, Large Green and Zero Tannin. The objectives of the lentil breeding programs include improving plant height and standability, yield, and improved disease resistance. The chickpea breeding program focuses on the development of new cultivars and germplasm for either the canning and fresh markets or for hummus production. Large seed size and light color are highly desirable for chickpeas used for canning and salads. Chickpeas used to make hummus must be high yielding and have resistance to *Ascochyta* blight. We also have autumn-sown pea and lentil breeding programs. The objectives of these two programs are to develop food quality pulses with very high levels of cold tolerance and disease resistance. Autumn-sown pulses will be beneficial to farmers as field work

can be shifted to the autumn, planting will not be delayed by cool, wet springs and yields will exceed those of spring planted legumes.

Spillman Farm is the site of nurseries where elite breeding lines and segregating populations are screened for resistance to several diseases including *Ascochyta* blight of chickpea and *Aphanomyces* root rot of pea and lentil. The farm is also used for examining the ability of seed treatments and foliar applications to control *Ascochyta* blight.

A Promising New Pulse Crop for Washington State: Winter-hardy Faba Bean (*Vicia faba* L.)

ERIK LANDRY², CLARICE COYNE^{1,2} AND JINGUO HU¹; ¹USDA-ARS WESTERN REGIONAL PLANT INTRODUCTION STATION; ²WSU

Winter-type faba bean (*Vicia faba* L.) has the potential to support sustainable cropping systems through opening new markets, while conserving natural resources. However, commercial cultivars are regionally unavailable. We initiated research to evaluate European winter-type lines in southeastern Washington and to discover novel winter-hardy germplasm. During the autumn of 2011 a split-block experimental design was used to test the winter hardiness of 20 lines across two planting dates (early and mid-October) and three locations (Central Ferry (CF) Research Farm, Pomeroy, WA; Spillman (SP) Agronomy Farm, Pullman, WA; Tukey Orchard (TO), Pullman, WA). Percent survival, time to flower, branching, height and yield were compiled and analyzed for significant LS-means and Pearson correlation coefficients using PROC MIXED and PROC CORR (SAS, 9.2), respectively. Dependent variables were significantly affected by entry, planting date and location as well as their interactions. Across entry, the warmer CF location had a higher overall survival rate (84.1%; TO 58.5; SP 54), branch number (5.1; SP 3.2; TO 2.8) and yield (6282.5 kg/ha; TO 4109.64; SP 2477.93) than the two colder Pullman locations. The low yield at SP was suspected to be a result of late harvest and indehiscence or 'pod shattering'. The early-October plantings overall had slightly higher survival (66.8% vs. 64.4) and overall branching (3.9 vs. 3.4) but not yield as compared to the mid-October plantings. Survival ($r=0.73$), number of branches at harvest ($r=0.47$) and pod number ($r=0.42$) correlated with yield across environments. The two European cultivars 'Côte d'Or' and 'Striker' had the highest overall survival and were among the highest branching, but had lower per plant pod counts, resulting in loss of yield potential, when compared to another European cultivar 'Hiverna' a less hardy, but higher branching and pod number entry (Table 1). We are continuing to develop novel faba bean germplasm with enhanced winter hardiness by selecting plants from the National Plant Germplasm System (NPGS Bulk) that have higher winter survival, branch number, indehiscence, pod set and yield than European check cultivars. Through selecting faba bean with dependable winter hardiness and high yield this project will address some of the agronomic concerns facing a new winter pulse in southeastern Washington.



Table 1. Percent of overwinter survival, number of branches per plant at harvest, pod number, yield (g) per plant and plot yield extrapolated to kg/ha from four of 20 autumn planted faba bean entries (2011-12 season). All dependent variables were separated by location (Central Ferry (CF) Research Farm, Pomeroy, WA; Spillman (SP) Agronomy Farm, Pullman, WA; Tukey Orchard (TO), Pullman, WA) except branches and pod number, which did not have a significant location x entry effect. Standard errors (se) separate entry means ($p<0.05$).

ENTRY	SURVIVAL (%)			BRANCHES AT HARVEST	PER PLANT POD (#)	PER PLANT YIELD (G)			PLOT YIELD (KG/HA)		
	RZ	CF	SP			RZ	CF	SP	RZ	CF	SP
CÔTE D'OR	83	89	73	3.6	38.5	41.4	50.1	31.7	4804.1	5015.9	3581.1
STRIKER	78	94	72	3.6	33.6	43.4	48.4	27.7	4721.8	5361.8	3150.9
HIVERNA	61	86	56	3.9	47.3	58.3	61.6	42.8	4890.8	6884.5	3024.2
NPGS BULK	31	82	33	4.1	46.5	63.3	78.4	18.9	2695.5	7855.3	880.2
	SE= 3.9			SE=0.2	SE=3.4	SE=4.9			SE=363.8		

Part 2. Pathology and Entomology

Suppression of Downy Brome (Cheatgrass) in Wheat Using a Soil Bacterium

ANN KENNEDY AND JEREMY HANSEN, LAND MANAGEMENT & WATER CONSERVATION RESEARCH UNIT, USDA-ARS; TAMI STUBBS, DEPT. OF CROP AND SOIL SCIENCES, WSU

Downy brome, or cheatgrass, is a winter annual grass weed that thrives in most soils, is very competitive, and has a negative effect on crop growth. At least 15 million acres of cropland in the west are infested with some level of downy brome. Herbicides are available, but most are expensive, vary in effectiveness, limit crop rotation options and do not reduce the seed bank. Seed bank longevity is underestimated and some downy brome seeds can remain in the soil for years. A dense mat of downy brome residue accelerates wildfire, which is devastating to standing crops, and leaves the soil more vulnerable to erosion and runoff. Several *Pseudomonas fluorescens* (*P.f.*) strains native to Washington soils inhibit downy brome in the field. The inhibitory effect occurs for several years after bacterial application, with increasing weed reduction in subsequent years. The bacterium establishes in the soil and works to reduce the downy brome seed bank and downy brome seedling growth. Survival of the bacteria and colonization of roots and residue in soil are critical to success of this biological control agent. Winter wheat fields at multiple locations in eastern Washington were selected for application of *P.f.* in fall of 2011. Reductions in downy brome populations are shown in Table 1.

Table 1. Inhibition of downy brome populations in winter wheat by a *Pseudomonas fluorescens* strain sprayed onto the soil surface. All counts were taken in 2012.

Location	Percent downy brome inhibition
Bickleton	52
Colton	64
Dusty	50
Fairfield	62
Kahlotus	72
Lind	18
Lind Field Station	56
Reardan	44
Washtucna	49

Inhibition of downy brome by the bacterium ranged from 72% in the first year plot at Kahlotus, to 18% in the first year plot at Lind. Previous work in rangeland has shown that the bacteria work gradually over a number of years to reduce the seed bank and inhibit the germinating plants, therefore the treatments will be studied across three years, and monitoring of plots will continue past the funding period. A long-range goal (10 years or more) for this research is to pave the way for developing additional biological herbicides against weeds such as ventenata, rattail fescue, Italian ryegrass and feral rye.

Control of Rusts of Wheat and Barley in 2012

X.M. CHEN, A.M. WAN, M.N. WANG, K.C. EVANS, Y.M. LIU, J. GARNER, L. HOU, Y. LU, AND J.Y. FENG
USDA-ARS WHEAT GENETICS, QUALITY, PHYSIOLOGY, AND DISEASE RESEARCH UNIT; DEPT. OF PLANT PATHOLOGY, WSU

In 2012, the relatively severe stripe rust epidemic was accurately forecasted using our predication models and rusts were monitored throughout the crop growth season. Barley stripe rust did not cause significant damage. Leaf rust was not significant while stem rust was widespread in both wheat and barley fields in the Palouse region. Rust updates were provided to growers during the crop season, guiding on-time applications of fungicides, which reduced major stripe rust damage. We identified 23 races of the wheat stripe rust pathogen and 7 races of the barley stripe rust pathogen, and determined race frequencies and distributions in the US. We characterized more than 370 isolates of the wheat and barley stripe rust pathogens collected throughout the U.S. using a standard set of 20 simple sequence repeat (SSR) markers to determine the population structures of the rust populations. We developed more than 100 single-nucleotide polymorphism (SNP) markers based on the rust pathogen secreted protein genes for identifying genes involving in pathogenicity and virulence. We determined that Oregon grapes (*Mahonia* spp.) can be infected by the wheat stripe rust pathogen under artificial inoculation conditions, and used the sexual reproduction systems on barberry and

mahonia to establish a genetic system for studying the biology of the rust pathogen. We evaluated more than 20,000 wheat and barley entries for resistance to stripe rust. As results of the germplasm tests, a couple of wheat and barley varieties were released in Washington State and several wheat varieties were registered in other states. We provided seed of the 70 stripe rust resistant wheat germplasm lines recently developed in our programs to various breeding programs. We published studies on new stripe rust resistance genes *Yr52* and *Yr53* in wheat; and mapped two quantitative trait loci (QTL) for high-temperature adult-plant (HTAP) resistance in spring wheat germplasm PI 192252 and twelve QTL for all-stage and HTAP resistance to stripe rust in winter wheat variety Druchamp. We tested the efficacies of 14 seed-treatment fungicide formulations in both greenhouse and field, and evaluated 31 foliar fungicides in fields for control of stripe rust. The results of our fungicide tests and yield loss tests of major currently grown varieties are used for guiding rust management.

Ecology and Biology of Wireworms in Washington Dryland Wheat Cropping Systems

IVAN MILOSAVLJEVIC¹, AARON D. ESSER², KEITH S. PIKE³, AND DAVID W. CROWDER¹

¹DEPT. OF ENTOMOLOGY; WSU; ²WSU EXTENSION, LINCOLN-ADAMS AREA; ³IAREC, WSU PROSSER

Wheat is the highest dollar-value cereal crop in the Pacific Northwest, contributing over \$4 billion annually to the region's economy. Wireworms, the larval stage of click beetles, are one of the most damaging insect pests of wheat. Wireworms are soil-dwelling insects that feed on crop roots, seeds, and stems, resulting in increased weed pressure and reduced stands, yields, and profits. When wireworm populations reach high densities, the yields of entire crop fields can be lost. Major crops affected in the Pacific Northwest (PNW) include cereals (wheat, barley, rye), potatoes, corn, onions, legumes, and grapes, although damage to cereals is often most severe (Fig. 1). For decades wireworms have been effectively controlled with inexpensive and potent broad-spectrum insecticides. However, the recent resurgence of wireworms can be attributed to the removal of many conventional insecticides that were used to control them, and the ineffectiveness of their second-generation replacements. Moreover, the "low pest status" of wireworms resulted in little research on the biology and ecology of these pests for nearly 40 years. Unfortunately, we lack fundamental knowledge to develop effective management strategies.

Our preliminary results from insecticide trials showed that currently available insecticides do not significantly eliminate wireworms from fields. Moreover, our results suggest that the different wireworm species may vary in their susceptibility to various chemistries. What is needed is a better method for growers to assess their risk and determine when to treat their seed, and which products to use for various species. Therefore, recognizing species is important for understanding variations in damage and control due to differences in species biology, feeding behavior, insecticide susceptibilities, and crop impacts.

In 2012, we conducted a preliminary large-scale field survey of wireworms in cereal fields in east-central Washington. A total of 9 species were detected, although the community was dominated by two species *Limonius californicus* and *L. infuscatus*. *L. californicus* was the dominant species in the irrigated region of east-central Washington while *L. infuscatus* was the dominant species in the non-irrigated region of eastern Washington. This indicates that these two species may be the most significant wireworm species for growers in the east-central Washington.

Our results provide novel information on wireworm species present in the east-central Washington as well as the ecological factors that promote their presence, fundamental knowledge needed for developing more effective integrated pest management strategies to help resolve this very important increasing problem.



Fig. 1. Wireworm damage to wheat

Controlling Wireworms with Thiamethoxam Insecticides in Wheat

A.D. ESSER¹, K.S. PIKE², M. SHEFFELS³, AND S. COFFMAN³

¹WSU EXTENSION, LINCOLN-ADAMS AREA; ²IAREC, WSU PROSSER; ³WHEAT PRODUCER, WILBUR

Wireworm (*Limonius* spp.) populations and crop damage increased in wheat (*Triticum aestivum* L.) production across eastern Washington. At the inception of this project thiamethoxam, a seed applied neonicotinoid insecticide for wireworm control, was used primarily at 0.07 g ai/100 kg. The goal of this project is twofold; (i) to determine if

increased long-term use of higher rates of thiamethoxam can improve yield and reduce wireworm populations, and (ii) determine if incorporating no-till fallow into the rotation can reduce wireworm populations. In 2008 an on-farm test (OFT) was established near Davenport, WA to examine spring wheat treated with 0, 10, 20 and 39 g ai thiamethoxam/100 kg impact on grain yield and economic return over costs. A no-till fallow system was also included as a treatment. In 2009 a second OFT was established near Wilbur, WA. The OFT were maintained four years with the treatments being sequential each year. Both locations were randomized complete block designs with four replications.



Wireworm populations were measured by placing four modified solar bait traps in the plots each spring (April) prior to seeding. Within the insecticide treatments, a significant location x treatment interaction was detected. At the location near Davenport, yield and economic return over costs was increased 30 and 24 percent. However, wireworm populations were not significantly different among insecticide treatments. At the location near Wilbur, yield and economic return over costs were increased only four percent and wireworm populations decreased 80 percent with increased insecticide rate. Some of this interaction may be related to the wireworm species present. At Davenport *Limonius californicus* (Mannerheim) is the predominate species and at Wilbur *Limonius infuscatus* (Motschulsky) is the predominate species. Within the

no-till fallow system, a significant location x treatment interaction was not detected meaning both locations had a similar response. Overall at both locations, incorporating a no-till fallow system into rotation averaged 53 percent less wireworms than a spring wheat cropping system with seed applied insecticides.

Parasitic Weed Dodder Found on Chickpea in Washington

WEIDONG CHEN, FRANK M. DUGAN, AND REBECCA MCGEE, USDA-ARS

Dodders are widespread parasitic plants on many crops worldwide, but had not been previously observed on chickpea in the United States until 2012. In July 2012, a chickpea field in south-eastern Washington was found parasitized by dodders. These parasitic plants consist of orange-colored, leafless, curling stems bearing only minute scales in place of leaves. The stems of dodder wrap around chickpea plants and penetrate chickpea stems with nutrient sucking structures called haustoria. They produce gray to reddish brown minute seeds in abundance. The seeds may germinate immediately after they fall to the ground or they may remain dormant until the next growing season. Field symptoms included orange-colored colonies on the chickpea canopy, leaf-less twining stems wrapped around chickpea stems and spreading between chickpea plants. The dodder found on chickpea in Washington was identified as *Cuscuta pentagona* based on morphological characters and confirmed by ITS DNA sequences. Dodder has been historically a regional problem on alfalfa. Although chickpea has been cultivated in the Palouse region for over 20 years, to our knowledge this is the first time dodder has been observed on chickpea in North America.

Dodders, once established, are difficult to control because they produce abundant tiny seeds that can persist in soil for many years. To prevent establishment of dodders on chickpea, chickpea growers should carefully scout for dodder in a field by looking for orange-colored patches in the chickpea canopy. The patches often enlarge during the growing season. In large infestations, manage the disease by killing infected chickpea plants using an herbicide before dodders produce seeds. In small infestations, manually pull infested chickpea plants and place them in plastic bags before moving them from the field. It is important to avoid contact between detached dodder stems and uninfected chickpea plants; detached dodder stems can initiate new infection. Early detection and action is key in preventing and managing the disease.



Stemphylium Blight – a New Disease of Lentil in the Palouse

WEIDONG CHEN AND GEORGE VANDEMARK, USDA-ARS

Stemphylium blight of lentil, caused by the fungus *Stemphylium botryosum*, has historically been a destructive disease of lentils in Bangladesh and India. The disease has been reported on lentils in Canada and recently observed in North Dakota. The disease was observed in the Palouse region for the first time in 2012. Unlike *Ascochyta* blight, *Stemphylium* blight is favored by warm temperature and occurs usually late in the growing season (near and after canopy closure). At disease onset, stems are healthy, but leaflets exhibit angular zones of light brown to tan discoloration. Under conditions favorable for the disease (warm and humid), lesions quickly coalesce to cover entire leaflets, leaf drop occurs, and plants are left defoliated. Often, only the terminal leaves at the tops of plants remain. As the disease progresses, tan to light brown stem lesions develop from the tips of diseased compound leaves and defoliated branches. Besides leaves and stems, the pathogen also infects flowers, resulting in incomplete flower development. Besides reducing yield, *Stemphylium* blight can result in small and discolored seeds. The pathogen can infect or infest seed, but seed-to-seedling transmission of the disease has not been demonstrated.

The disease can be managed with fungicides and the use of tolerant varieties. Fungicide Headline has been recommended for managing the disease in Canada. Because the disease is new here, no specific control measures are available for this disease in the Palouse region. Its continued occurrence, likelihood of pervasiveness and direct impact on yield remain unknown. In 2013 we will increase monitoring of fields in the Palouse region for this disease. Additional sources of resistance in Spanish Brown lentil lines will also be identified that will be used as parental materials to develop new varieties that combine desirable agronomic and seed quality traits with enhanced resistance to *Stemphylium* blight.



Managing Risks of Virus Infections in Pulse Crops in the Palouse Region

SANFORD D. EIGENBRODE¹, DIANA ROBERTS², ED BECHINSKI¹, DAMON HUSEBYE¹, ALEXANDER KARASEV¹, KEVIN MCPHEE³, AND BRADLEY STOKES¹; ¹DIVISION OF ENTOMOLOGY, U OF I; ²WSU EXTENSION, SPOKANE; ³NORTH DAKOTA STATE UNIVERSITY

The Palouse region of eastern Washington and north Idaho is important for dry pea and lentil production. Annual infestations of pea aphid (*Acyrtosiphon pisum*) and some of the viruses they carry, *Pea enation mosaic virus* (PEMV) and *Bean leaf roll virus* (BLRV) vary from year to year. Heavy aphid infestations may cause heavy crop loss, especially when one or both viruses reach epidemic proportions.

Some farmers apply insecticides routinely to avoid crop damage, while others defer treatment until aphid numbers warrant the cost of treatment. This USDA grant-funded project provided several tools that improve the management options available to producers. This information is also posted to the Aphid Tracker website at www.cals.uidaho.edu/aphidtracker/.

1) Decision Tools: Project scientists used 5 years of field data to develop the following online calculators at www.cals.uidaho.edu/aphidtracker/ to help producers decide about seed treatments and early season sprays for aphid control:

- The first calculator helps growers decide on treatments for pea seed
- The second calculator helps growers decide whether to spray their fields early for aphid
- The third calculates an Economic Injury Level for aphids pre-bloom

2) Aphid and Virus Early Warning System: During the USDA-funded project, an extensive network of pan trap locations was used to monitor aphid arrival. Pending continued funding, this work is reduced to 8 sites across the Palouse. Aphids collected are tested to determine if they carried PEMV/BLRV. These sites are also surveyed twice per season for the presence of PEMV/BLRV in the pulse crop itself. The data are integrated into Geographic Information System (GIS) data layers and made available online. Email listservs are used to alert farmers and crop consultants of aphid infestations and whether they carry virus – which greatly influences potential damage to legume crops and the aphid population levels at which growers should apply insecticide. To sign up for email alerts, contact Diana Roberts at robertsd@wsu.edu.

3) **Accelerated Breeding for Virus Resistance in Pea and Lentil:** Plant breeders at North Dakota State University are developing pea and lentil varieties with resistance to PEMV and BLRV, using marker-assisted selection to augment the breeding process. They are also improving diagnostic tools that verify virus presence and disease reaction. These varieties will be useful additions to forecasting and decision tools to help reduce the severity of virus outbreaks.

Rhizobacterial Community Structure and Function in a Dryland Agroecosystem

¹O. MAVRODI¹, D. MAVRODI¹, R. BONSALE¹, J. PAREJKO², D. WELLER³, K. BREAKWELL⁴, I. PAULSEN⁴, AND L.S. THOMASHOW³:
¹DEPT. OF PLANT PATHOLOGY, WSU; ²MOLECULAR AND CELLULAR BIOLOGY, WSU; ³USDA-ARS; ⁴DEPT. OF CHEMISTRY AND BIOMOLECULAR SCIENCES, MACQUARIE UNIVERSITY, SYDNEY, AUSTRALIA

We recently discovered large populations of phenazine-producing (Phz⁺) *Pseudomonas* strains and concentrations of the antibiotic phenazine-1-carboxylic acid (PCA) of up to 1.6 µg g⁻¹ of root plus rhizosphere soil on roots of non-irrigated cereals grown over more than a million hectares of the Columbia Plateau of central Washington State. To test the hypothesis that these Phz⁺ populations are enriched specifically under dryland conditions, we established adjacent irrigated and nonirrigated plots of wheat at the Washington State University Dryland Research Station at Lind, Washington in March of 2011. We monitored population densities and rhizosphere colonization frequencies of indigenous Phz⁺ bacteria, as well as rhizosphere concentrations of PCA seven times during the 2011 and 2012 growing seasons. With or without irrigation, Phz⁺ bacterial populations followed the same trend till the end of June in 2011 and middle of May in 2012, and then populations in the irrigated plots declined significantly as compared to those in the nonirrigated plots. Colonization frequencies of wheat plants by Phz⁺ bacteria were higher in dryland plots compared to irrigated plots after the fifth and second samplings in 2011 and 2012, respectively. The PCA recovered from roots followed the bacterial population trend. Water potential of soil at 10 and 20 cm depth reached -500 and -400 Kpa in the dryland plots, respectively, and was fully saturated in the irrigated plots. As a first step towards understanding the molecular mechanisms involved in survival of Phz⁺ bacteria under dryland conditions, we have sequenced *P. fluorescens* 2-79, a well-studied biocontrol strain isolated over 30 years ago from the Lind site. Samples for a global analysis of bacterial community structure in the rhizosphere of wheat from isolated rhizosphere DNA are currently being processed. The expected results of these analyses will provide insight into the major phylogenetic groups represented in each community, reveal how dryland and irrigated samples differ in species diversity and composition, and enable us to determine whether these differences can be correlated with soil moisture and wheat growth stage.

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

TIM MURRAY, HENRY WETZEL III AND DANILO VERA; DEPT. OF PLANT PATHOLOGY, WSU

Eyespot (strawbreaker foot rot) and Cephalosporium stripe are important diseases of winter wheat in the Pacific Northwest. These diseases occur across a wide range of the wheat-producing area 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 Variety testing website (<http://variety.wsu.edu/archive.htm>). Because Tilt and Topsin-M are the only fungicides registered for eyespot control, we also test potential new fungicides when new materials are available.



Symptoms of Cephalosporium stripe of wheat. Note the long, yellow stripes in the leaf blade with brownish discoloration.



Symptoms of eyespot in a wheat crown. Note the brown discoloration on the stems.

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, 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.



Snowmold on wheat immediately after snow melt. Note the cobweb-like covering on the plants.

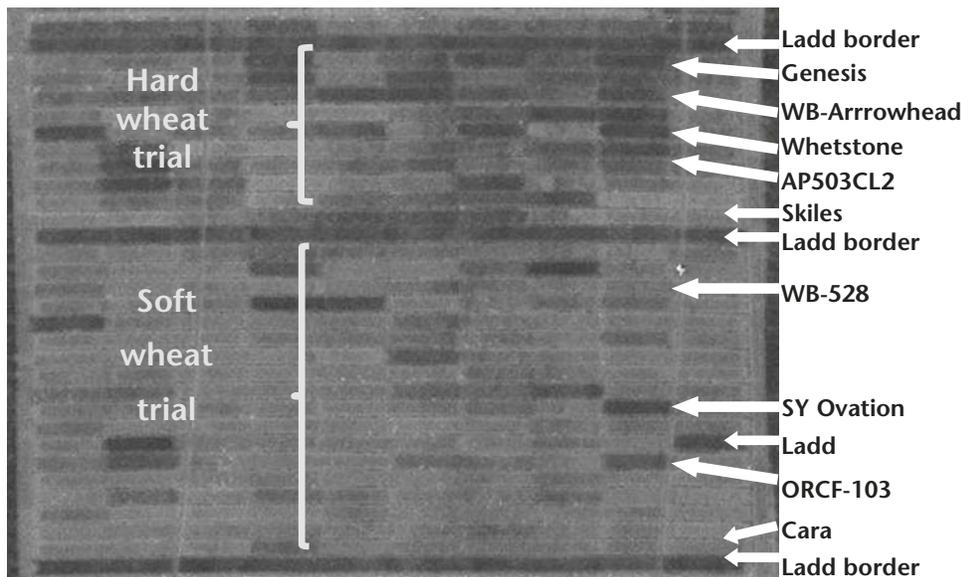
Soilborne wheat mosaic (SBWM) is a new problem for Washington wheat growers that was first recognized in the Walla Walla area in 2008; however, SBWM is a chronic problem in other wheat-producing areas of the U.S. including the Great Plains and northeastern states. SBWM is caused by a virus that is transmitted by a fungal-like organism that lives in soil. Roots are infected in the fall and symptoms appear in early spring. Because the virus lives in soil, the disease occurs in the same spots within fields each year and can be moved with soil on farm implements, shoes, or tires. So far, the problem is limited to the Walla Walla area and adjacent counties in Oregon. Planting a resistant variety is the best control, but little is known about our varieties. We are collaborating with the Oregon State University Variety Testing program to screen PNW wheat varieties for resistance in field plots near Hermiston, OR. A few varieties from the PNW have good resistance, with the hard red wheats having better resistance than the soft wheats. This information will help breeders develop new varieties that are resistant to SBWM. Variety ratings will be available on the WSU Variety Testing website.



Yellow patches of Soilborne wheat mosaic in a field.



Plants infected with Soilborne wheat mosaic are stunted and have a mosaic pattern on the leaves. Symptoms disappear as weather warms, but yield loss still occurs.



Aerial photograph of 2013 Soilborne wheat mosaic variety trial near Hermiston, OR. Dark green plots are more resistant than light green plots.

Natural Suppression of *Rhizoctonia* Bare Patch in a Long-Term No-Till Cropping Systems Experiment

WILLIAM SCHILLINGER¹, TIMOTHY PAULITZ², RON JIRAVA³, STEVE SCHOFSTOLL¹, JOHN JACOBSEN¹, TIM SMITH¹, AND HARRY SCHAFER¹
¹DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND; ²USDA-ARS; ³WHEAT GROWER, RITZVILLE

The soil-borne fungus *Rhizoctonia solani* AG-8 is a major concern for farmers who practice no-till in the inland Pacific Northwest, USA. Bare patches caused by *Rhizoctonia* first appeared in 1999 during year 3 of a 15-year no-till cropping systems experiment near Ritzville, WA (10.6 inch annual precipitation). The extent and pattern of patches were mapped each year from 1999-2012 at the 20-acre study site with a backpack-mounted global positioning system equipped with mapping software. Bare patches appeared in winter and spring wheat, spring barley, yellow mustard, and safflower. At its peak in years 5 to 7, bare patches occupied as much as 18% of total plot area. The area of bare patches began to decline in year 8 and reached near zero levels by year 11 (Fig 1). No measurable patches were present in years 12 to 15. Patch area was significantly greater in continuous annual monoculture spring wheat (SW) compared to SW grown in a 2-year rotation with spring barley (SB). Additionally, the 15-year average grain yield for SW in rotation with SB was significantly greater than for continuous SW (Fig 2). Russian thistle, a troublesome broadleaf weed with aggressive and fast-growing tap root, was the only plant that grew within patches. This study provides the first direct evidence of natural suppression of *Rhizoctonia* bare patch with long-term no-till in North America, and the first in the world literature to document natural suppression for crops other than monoculture wheat.

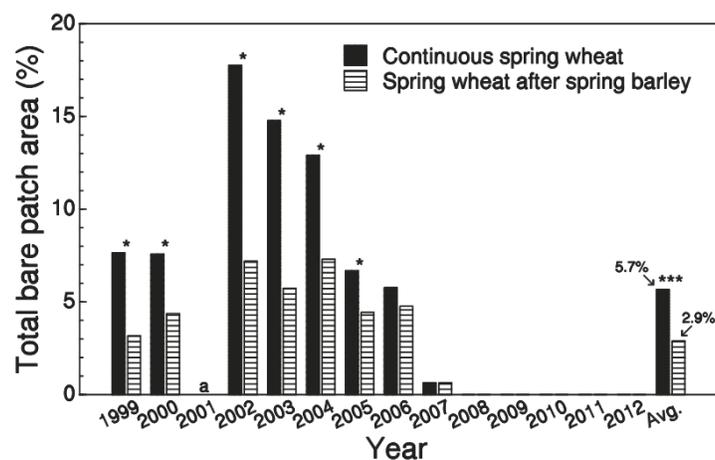


Fig. 1. Total bare patch area caused by *Rhizoctonia solani* AG-8 was significantly greater during years 3 to 9 (1999 to 2005) in continuous annual spring wheat (SW) compared to SW grown in a 2-year rotation with spring barley. The crops were grown no-till in all years. At its peak in 2002, bare patches occupied as much as 18% of total plot area. Bare patch area began to slowly decline in 2003 and, by 2008 and thereafter, was nearly totally suppressed. ^a Patch area was not measured in 2001 due to severe drought which made it difficult to discern bare patches from water stressed crops. *** Significantly different at $P < 0.001$.

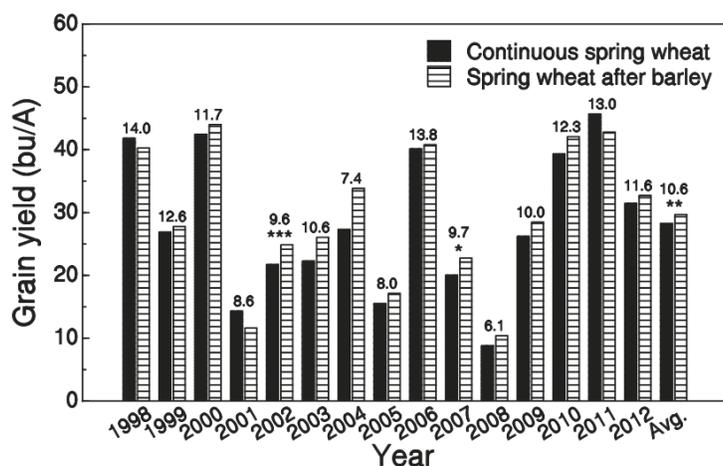


Fig. 2. Grain yield of continuous annual spring wheat (SW) compared to SW grown in a 2-year SW-spring barley (SB) rotation with all crops grown no-till. Within-year grain yield differences between treatments were significantly different only in 2002 and 2007, but highly significant ($P < 0.01$) differences in grain yield occurred when averaged over the 15 years (28.2 versus 29.6 bu/acre). Numbers over the bars each year are crop-year (1 Sept. – 31 Aug.) precipitation as well as the 15-year average. *, **, *** Significantly different at $P < 0.05$, 0.01, and 0.001, respectively.

Part 3. Agronomy, Economics, and Sustainability

Row Spacing Experiments for Deep-Furrow Planting of Winter Wheat

W.F. SCHILLINGER¹, S.B. WUEST², J.A. JACOBSEN¹, S.E. SCHOFSTOLL¹, AND D. SCHAFER³

¹DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND; ²USDA-ARS, PENDLETON, OR; ³GROWER COLLABORATOR, RITZVILLE

Row spacing experiments were conducted at Lind, Ritzville, and Pendleton, OR during the 2011 and 2012 crop years. The objective of these experiments is to determine whether row spacing can be extended beyond the traditional 16 and 18 inches without detrimental effects on winter wheat yield and weed control. Row spacing treatments in the experiment are 16, 18, 20, 22, 24, and 32 inches. All treatments are replicated four times and planted in 100 x 16-ft strips.

In 2011, winter wheat grain yields at Lind ranged from 29 to 35 bu/acre (Fig. 1) with no significant differences among treatments. Grain yields were relatively low because we were unable to apply an air application of fungicide to control stripe rust as the Lind Station is home to many wheat breeding nurseries and the breeders do not want fungicide applied to their material. At Ritzville in 2011, wheat grain yield ranged from 63 to 76 bu/acre (Fig. 1). The 16 and 18 inch spacing treatments produced significantly higher grain yield than the 20, 22, 24, and 32 inch spacing treatments. At Pendleton, 2011 grain yields were essentially identical for the 16, 18, 20, 22, and 24-inch row spacing (i.e., only yield from the 32-inch row spacing was significantly lower than the rest, Fig. 1). Yield at Pendleton ranged from 64 to 73 bu/acre.

In the 2012 crop year, we had drill opener issues at Lind and yield data were not collected from that site. Yields at the Ritzville site in 2012 ranged from 70 to 81 bu/acre with identical yields for the 16, 18, and 20-inch row spacing treatments (Fig. 1), but with yields declining sequentially with row spacing 22 inches and wider. A similar trend occurred at Pendleton in 2012 with grain yields from the 16, 18, and 20 treatments being almost the same, but with a gradual decline with wider spacing (Fig. 1).

Yield component data (data not presented) show that the number of heads per unit area declined with increasing row spacing. Keep in mind that all treatments received the same number of seeds per unit length of row, but not the same number of seeds per acre because the metering flutes on the HZ drill cannot be precisely adjusted. This means that while we planted 50 lbs/acre of seed on the 16-inch row spacing, the planting rate for the 32-inch row spacing treatment was only 25 lbs/acre. We were unable to plant the same number of seeds per acre since the metering flutes of the John Deere HZ drill used in this experiment are not precise enough to calibrate for small planting rate changes. We have addressed this problem by purchasing a special Raven seed metering device (funded by Ritzville wheat farmer Bill Heinemann) and, for the 2013 crop year, have row spacing experiments with both the same number of seeds per row and the same planting rate (i.e., 50 lbs) per acre for all row-spacing treatments at all three sites.

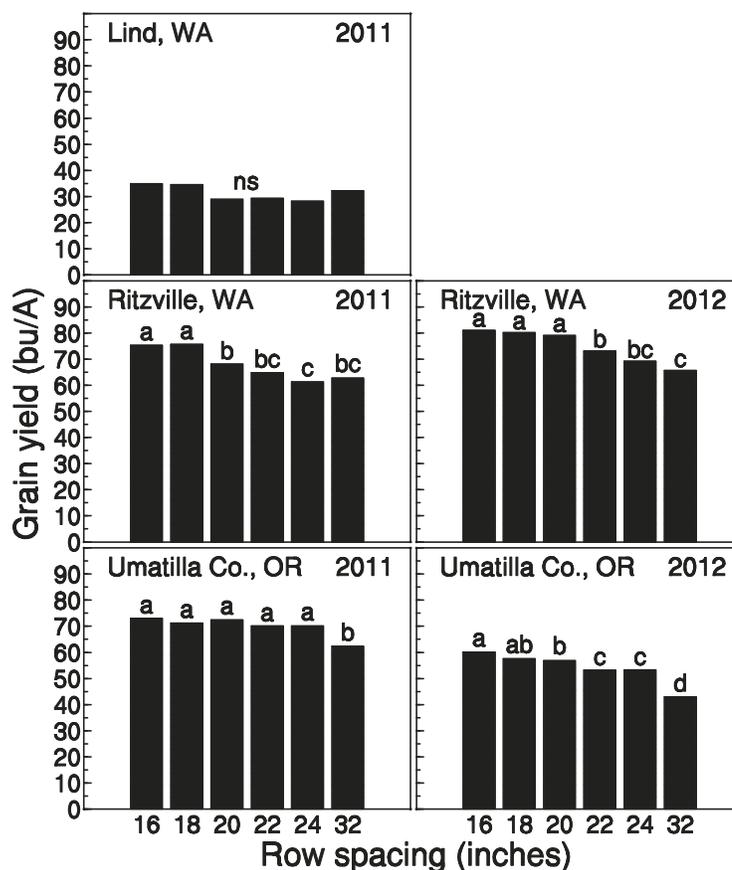


Fig. 1. Winter wheat grain yield as affected by six different row spacing treatments from five experiments conducted at three locations over two years. To date, there have been no grain yield differences between the 16 and 18-inch row spacing and only slight to no yield reduction at 20-inch row spacing. Within-site grain yields followed by a different letter are significantly different at the 5% probability level. ns = not significantly different.

Integrated Weed Management in Dryland Wheat and Barley

DREW LYON AND ROD ROOD, DEPT. OF CROP AND SOIL SCIENCES, WSU

Integrated weed management attempts to combine a number of weed control tactics to keep weeds at a manageable level. These tactics include preventative, cultural, mechanical (tillage), and chemical methods. Conservation tillage cropping systems greatly reduce or completely eliminate the use of tillage for weed control. Organic cropping systems eliminate herbicides for weed control. When one or more weed control tactics are eliminated or greatly limited in a production system, the remaining tactics become more critical to the success of that system. For example, effective weed control in conservation tillage cropping systems must be achieved through judicious integration of preventative, cultural, and chemical weed management tactics. Preventing the introduction of weed seeds or vegetative reproduction propagules into a field is always the best weed control practice. Crop rotation is a cultural practice that likely has the greatest impact on weed population and diversity. Crop rotation is a critical component of successful conservation tillage production systems because it helps to reduce the system's dependence on a narrow range of herbicide options, thus reducing the selection pressure for herbicide-resistant weeds.

Increased incidence of herbicide resistance in several major weed species, including Italian ryegrass (*Lolium multiflorum*), Russian-thistle (*Salsola tragus*), horseweed (*Conyza canadensis*), and prickly lettuce (*Lactuca serriola*) are increasing the cost and decreasing the efficacy of weed control with herbicides in small grain production systems of eastern Washington. Rattail fescue (*Vulpia myuros*) and scouringrush (*Equisetum hyemale*) are two increasingly troublesome weeds that are not easily controlled with herbicides and that are threatening the adoption of conservation tillage systems in eastern Washington. Herbicide resistance in weeds is becoming a threat to soil conservation gains throughout the US as growers turn to tillage in a desperate attempt to control herbicide-resistant weeds.

I started my job with Washington State University in September of 2012. I have begun a series of herbicide efficacy trials in winter and spring wheat, but the results will not be known until after the 2013 harvest. I also plan to initiate some integrated weed management trials in the fall of 2013 to look at the impact of crop rotation and tillage systems on the control of troublesome weeds such as rattail fescue and possibly scouringrush. I also hope to do some work with Russian-thistle in the drier rainfall zones looking at phenotypes and how these might be related to weed control with herbicides. I look forward to providing new information and Extension resources for the important weed control issues that face wheat and barley growers in eastern Washington.

Cover Cropping for the Intermediate Precipitation Zone of Dryland Eastern Washington

D.E. ROBERTS¹, F.J. FLEMING², C. GROSS², T. RUSH², E. WARNER², C. LANEY², B. DOBBINS², D. DOBBINS², R. VOLD², A. ESSER¹, D.P. APPEL¹, AND J. CLAPPERTON³; ¹WSU EXTENSION, SPOKANE; ²DRYLAND GRAIN FARMER; ³RHIZOTERRA INC

Some local farmers recall that their grandfathers used cover crops to improve soil fertility before the advent of modern, inorganic fertilizers. Cover crops are sprayed down or tilled into the soil, but no plant material is removed from the field. The benefits of cover crops apply to all cropping systems; conventional, organic, and direct seeding.

In eastern Washington, recent research with single-species cover crops has seldom proven them both agronomic and economically beneficial. Cover crop cocktails (CCC) are a recent innovation from the Midwest. The CCC is a mix of broadleaf and grass species that include cool and warm season types. Legumes fix atmospheric nitrogen and tap-rooted crops penetrate hard pan soil layers.

Recently, farmers from the intermediate rainfall area started working with WSU Extension on CCCs. **Results are preliminary, but we have not seen the same results as Midwest growers.**

In 2011, each farmer planted about 5 acres of a 9-way, predominantly cool season CCC mix in the spring on ground slated to be fallow (no-till or tillage fallow). We had large, replicated plots on the Wilke Farm at Davenport. Despite a wet spring, the CCC mix did not develop the same levels of biomass as in the Midwest. It sucked the soil dry, so winter wheat did not establish well after the CCC that fall. Spring wheat following the CCC at the Wilke Farm had an average yield. We will track yields and nutrients to document effects of the CCC.

In 2012, the group used a CCC of largely warm season species. Results are pending **This work on cover crop cocktails is another instance of not being able to use Midwest farming "recipes" without substantial tweaking to adapt them to our area. We believe we need to find cover and/or companion crops that are better suited to our winter rainfall systems.**

One experiment showing promise on the Wilke Farm is growing sweet clover (used widely as a cover crop years ago) as a companion crop with spring barley. The two crops were seeded together last spring and the barley was harvested in August. The sweet clover (nitrogen-fixing legume) is a biennial so it remained short under the barley canopy. It overwintered and will be sprayed out prior to flowering and followed with cereal grains.

We recommend that farmers limit CCC experiments to small areas (5-10 acres) as the seed can be costly and their benefits for the Inland Northwest are not yet proven.

Soil Conservation Survey Results for 584 Pacific Northwest Farmers in 2010

STEPHANIE KANE AND J.D. WULFHORST, SOCIAL SCIENCE RESEARCH UNIT, U OF I; PENNY DIEBEL, AGRICULTURAL AND RESOURCE ECONOMICS, OSU; AND DOUG YOUNG, SCHOOL OF ECONOMIC SCIENCES, WSU

From 1976 to 2009, the three Pacific Northwest (PNW) states received over \$30 million in federal funding for the Solutions to Environmental and Economic Problems (STEEP) Project. The goal of STEEP was to develop profitable cropping systems that would reduce soil erosion for dryland agricultural producers. We conducted a survey with responses from 584 farmers in six counties during 2010. The survey included three counties with high adoption of direct seeding, namely Lewis, ID; Wasco, OR, and Columbia, WA and three low adopters, Latah, ID; Umatilla, OR; and Whitman, WA. A lower bound estimate of the response rate to the mail questionnaire was 32.5 percent, but most results were statistically significant. This abstract highlights only a few survey results. Contact dlyoung@wsu.edu for more detailed reports.

As shown in Figure 1, most respondents (66 percent) felt that soil erosion had decreased substantially in the PNW over the past 30 years, with an additional 14 percent stating it had decreased slightly over the same time period. Within the past five years, 32 percent of producers felt that soil erosion decreased substantially, and 31 percent felt it had decreased slightly, indicating that producers perceived more substantive changes in soil erosion over the 30 year period rather than the five-year period.

A plurality of respondents perceived that the greatest threat from soil erosion was loss of top soil. Twenty-four percent of producers stated that this was a serious or moderate concern. However, over half of the respondents stated that soil erosion had not cut production or profitability.

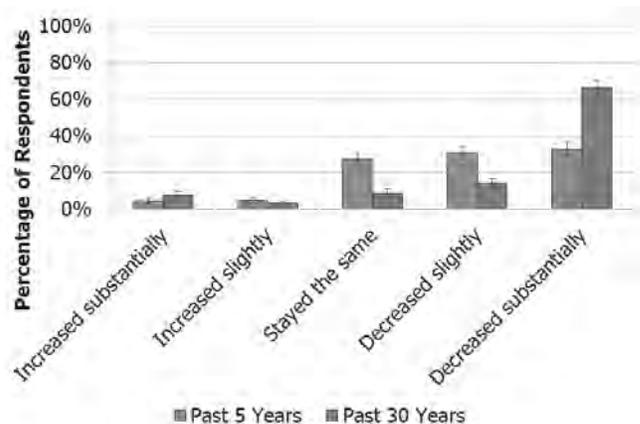


Fig. 1. Perceptions of soil erosion over time

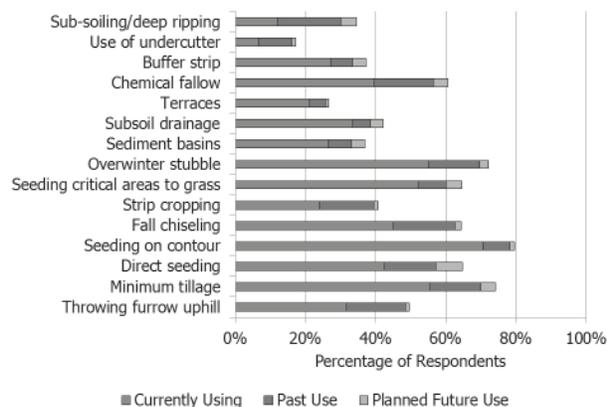


Fig. 2. Utilization of different erosion control practices in a 2010 survey of 584 farmers in six PNW Counties

Respondents stated that they most often relied on research results, government incentives, and input from other farmers when making decisions about erosion control practices. The type of farmer-to-farmer interactions perceived to be most influential were informal conversations and those at local field days, meetings, and tours.

As displayed in Figure 2, the most common erosion control practices cited in the 2010 survey were seeding on the contour (70 percent), leaving stubble over winter (55 percent) and minimum tillage (56 percent). Just over 40 percent of respondents reported currently using some degree of direct seeding. Of course, use of particular practices varied by agro-climatic zone.

Evaluation of Deep-Furrow Drill Prototypes for Conservation Wheat-Fallow Farming

BILL SCHILLINGER¹, JOHN JACOBSEN¹, PAUL BUCHHOLTZ², STEVE SCHOFSTOLL¹, BRUCE SAUER¹, BRIAN FODE¹, AND CINDY WARRINER¹
¹DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND; ²THE MCGREGOR COMPANY, COLFAX, WA

We have completed the second year of a three-year field experiment to evaluate several deep-furrow drill prototypes to determine their suitability for planting winter wheat into tilled summer fallow under high surface residue conditions. Four deep-furrow drill prototypes were evaluated in 2012. Large 30-inch-diameter coulters were added in front of each of the openers of the WSU Lind HZ-type drill and slightly larger offset spider wheels were added to the McGregor HZ-type drill compared to the version tested in 2011. The WSU Lind 150-type shovel-opener drill was operated with solid packer wheels on 17-inch spacing in 2012.

The 5-acre field site for 2012-2013 is located 10 miles NW of Ritzville on the Eric Maier farm. Annual precipitation at the site averages 11.5 inches. To prepare the experiment, stubble for half of the field during the 2011 winter wheat harvest was cut at 14-inch height and the other half of the area was cut at 22-inch height. The yield of the 2011 winter wheat crop was 68 bu/acre. The quantity of aboveground residue measured in May (before undercutting) by clipping, gathering, and then drying averaged 6200 lbs/acre for the 22-inch-tall stubble and 5750 lbs/acre for the 14-inch-tall stubble.

The field testing of prototypes was conducted on August 29, 2012. The WSU Lind 150-type drill on 17-inch row spacing with staggered shovel-type openers operated very effectively with no plugging issues (Fig. 1). This is largely due to a much greater ground clearance of the frame as well as greater distance between the ranks of openers compared to the International 150 drill currently used by growers.



Fig. 1. WSU Lind drill with shovel-type openers on two ranks. This prototype has a 17-inch row spacing, solid packer wheels, and the frame is located high off the ground to allow clearance of high quantities of residue. We have had no plugging problems with this prototype in two years of testing.

We have found it difficult to pass through high quantities of residue with the WSU Lind and McGregor HZ-type prototypes in tilled summer fallow when row spacing is just 16 inches. The openers are all in a line on the HZ-type prototypes with the openers tucked between split-packer wheels. There is not enough room between the packer wheels at 16-inch row spacing for the residue and soil to pass. Adaptations such as the McGregor Company offset spider wheel in front of each opener somewhat facilitates residue clearance by cutting and otherwise pinning residue, but the effectiveness of the spider wheel is reduced when residue is damp. The large coulters in front of each opener on the WSU Lind HZ-type drill was not effective when row spacing was only 16 inches.

Spreading row spacing of the WSU Lind HZ-type drill to 20 inches, combined with a large coulters located in front and two inches to the side of each seed opener to effectively cut and/or pin residue, was effective when the residue was both damp and dry allowing for the drill to operate effectively at speeds greater than three mph. Row spacing experiments

have (to date) shown that row spacing can generally be widened to 20 inches with little to no decline in winter wheat grain yield compared to the standard 16 and 18-inch row spacing currently used by growers.

The major take-home messages from the 2012 experiment are:

1. A shovel-type drill with openers on two ranks with high frame clearance has been highly successful with no plugging problems (Fig 1). In the Principal Investigator's opinion, this design is ready to be produced commercially by a manufacturer.
2. We have not been successful passing through high quantities of residue in tilled summer fallow with HZ-type drills on 16-inch row spacing even with offset spider wheels (McGregor Co.) or large coulters (WSU Lind) in front of individual seed openers. There simply is not enough room for passage of soil and residue at this narrow row spacing.

3. An HZ-type drill with 20-inch row spacing with a large coulter in front and two inches to the side of each seed boot operated effectively with no plugging issues.
4. Row spacing experiments, to date, show no significant grain yield differences between 16 and 18-inch row spacing and little-to-no grain yield difference when row spacing is extended to 20 inches.

Watch a five minute YouTube video of the drill prototypes in the 2012 field experiment at the following link : <http://lindstation.wsu.edu/videos/>

No-Till and Conventional Tillage Fallow Winter Wheat Production Comparison in the Dryland Cropping Region of Eastern Washington

A.D. ESSER,¹ AND R. JONES²; ¹WSU EXTENSION, LINCOLN-ADAMS AREA; ²WHEAT PRODUCER, WILBUR, WA

A 2-year rotation of winter wheat (WW) (*Triticum aestivum* L.) on tillage-based summer fallow (SF) has been a standard practice for producers in the dryland (< 14 inch annual precipitation) cropping region of eastern Washington for more than 100 years. This practice has been profitable but it comes at a cost of soil loss through wind and water erosion. Producers have examined alternative methods including no-till farming systems for maintaining or increasing profitability and reducing soil erosion. A series of on-farm tests in a 12-to 14-inch precipitation zone were completed over a 5-year period examining WW established under three fallow treatments: (i) conventional, (ii) no-till early (planted at the same time as the conventional treatment), and (iii) no-till late (planting was delayed one month). Conventional tillage encompassed a glyphosate application, a chisel sweep, and two cultiweeding operations for fertilization and weed control and planting with deep furrow hoe drills. No-till included as many as four herbicide applications for weed control and seeding and fertilization with a no-till hoe drill. Conventional tillage increased seed zone water (0-8") but no differences were detected between treatments in total water to a depth of 3 feet. Less soil compaction was detected in the no-till treatments at a depth of 10-16 inches compared to conventional tillage. There were differences in grain yield between conventional and no-till early, averaging 70 bu/acre. No-till late produced 20% less yield. Economic return above variable costs was similar to yield with no differences between conventional and no-till early and lower when seeding was delayed. This study shows that producers in the 12-to 14-inch precipitation zone could convert to a soil-saving no-till early planting system with no economic hardship compared to their conventional tillage-based system.

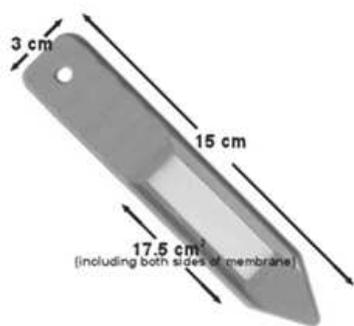
Straw Management and Crop Rotation Alternatives to Burning Wheat Stubble: Assessing Economic and Environmental Trade-offs

GERARD BIRKHAUSER, DEPT. OF CROP AND SOIL SCIENCES, WSU; DAVID HUGGINS, USDA-ARS; TIM PAULTZ, USDA-ARS; AND KATE PAINTER, U OF I

Farmer incentives for burning wheat residues are facilitating establishment of the next crop, decreasing incidence of soil-borne disease, decreasing N tie-up by decomposing cereal residues, and quicker seedling growth. Some disincentives of residue burning to growers are negative impacts on overall soil organic matter levels, loss of nutrients (e.g. N, P and S), and increased hazard of soil erosion if burning is combined with too much tillage. Our objective is to assess wheat residue burning effects in direct-seed systems on soil organic matter, residue C and nutrient (N, P, S) losses, and soil condition and erosion estimates. The impact of crop rotations and sequences on wheat straw management and root pathogens will be evaluated. This ongoing 4-year study, funded by WA Department of Ecology, Agricultural Burning Practices and Research Task Force has found:



- Losses from burning were: 2,010 lbs C/ac and 12 lbs N/ac (fall burn) and 1,271 lbs C/ac and 11 lbs N/ac (spring burn).
- Amount of winter wheat residue N lost to burning was 40% (spring) and 33% (fall).
- Fall burning of winter wheat residue increased early season soil N availability, spring wheat growth and development, and spring wheat N uptake as compared to no burning.
- In spring wheat, less Fusarium Crown Rot occurred in treatments with burning, and higher disease occurred with N fertilizer.
- Aboveground spring wheat N uptake at early stage (tillering) was 112% greater in fall burned as compared to control plots.
- Field deployed Plant Root Simulator (PRS) probes had 40% more $\mu\text{g N } 10 \text{ cm}^{-2} 7 \text{ days}^{-1}$ in fall burned as compared to control plots.



Residue lost comparison over four seasons.

Season	PreBurn (lb/ac)	PostBurn (lb/ac)	Residue Loss to Burn (%)
Spring 2012	7,152	1,832	74
Fall 2011	10,264	2,302	78
Spring 2010	5,166	2,353	55
Fall 2009	8,092	3,064	62

Fertilizer replacement costs for nutrient losses during burning of winter wheat residue.

Residue	Fall Burn Nutrient Loss (\$/ac)	Spring Burn Nutrient Loss (\$/ac)
Nutrients		
N (0.45 \$/lb)	5.27	4.95
P ₂ O ₅ (0.73 \$/lb)	1.72	1.20
S (0.47 \$/lb)	1.23	0.66
Total Nutrient Replacement Cost	8.22	6.81

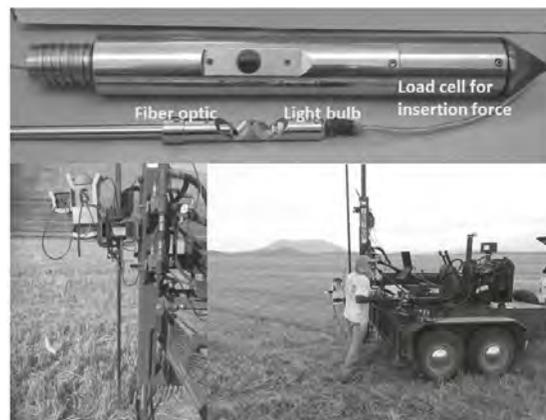


Development of a VisNIR Penetrometer for *in situ* Soil Characterization and Site Specific Management

MATTEO POGGIO, ROSS S. BRICKLEMYER, AND DAVID J. BROWN; DEPT. OF CROP AND SOIL SCIENCES, WSU

New soil-sensing technologies have the potential to improve site-specific management, reducing negative environmental impacts and increasing grower profits. Spatially distributed soil information is required to delineate useful management zones. While soil properties can sometimes be inferred from yield maps and landscape characteristics, more direct soil characterization allows for more precise crop management. Conventional methodologies for soil analysis based on in-laboratory procedures are expensive and time consuming. Visible – Near Infrared (VisNIR) diffuse reflectance spectroscopy is a widely recognized methodology for rapid and inexpensive in-laboratory soil analysis. This method has been used successfully under controlled conditions to estimate a range of soil properties such as clay content, mineralogy, and soil organic carbon. *In situ* deployment of VisNIR analysis could enhance site-specific management, by

providing spatially sense soil information at a relatively low cost. We have designed a penetrometer-mounted fore-optic that allows rapid interrogation of undisturbed soils in the field. Our field-deployable penetrometer is capable of simultaneously collecting insertion force and soil spectra, with reflected light transmitted via a fiber optic cable to a full-range VisNIR spectrometer (Agrispec®, Analytical Spectral Devices Inc., CO, USA). We evaluated the optical performance of the VisNIR penetrometer under controlled conditions by comparing spectra of dried and sieved soil samples with spectra obtained using a commercial fore-optic. Under controlled conditions, the two fore-optics yielded comparable spectra. Furthermore, spectra obtained from the VisNIR penetrometer were used to accurately predict soil clay content and soil organic carbon. In the next phase of this project, we are conducting field tests of the VisNIR penetrometer.



Carbohydrate and Ion Concentration Variation in Wheat Sap During Three Cold Temperature Treatments

DANIEL Z. SKINNER AND BRIAN S. BELLINGER

Exposing wheat (*Triticum aestivum* L.) plants to a low, above-freezing, or slightly below-freezing temperature initiates cold acclimation, a complex process resulting in increased tolerance of subsequent freezing to potentially damaging temperatures. Acclimation at slightly subfreezing temperatures (subzero acclimation, SZA) is more effective than acclimation at low, above-freezing temperatures. Allowing the plants to thaw at 3°C for 24 h after SZA results in even greater freezing tolerance. This study was undertaken to quantify changes that occur within the cell during exposure to these low-temperature treatments. The concentrations of fructans (polymers of fructose) and simple carbohydrates, and the ions Ca²⁺, Cl⁻, K⁺, NO₃⁻, and PO₄³⁻ were monitored. Concentration of fructans decreased during SZA and during the 3°C thaw following SZA. The concentration of Ca²⁺ and Cl⁻ increased while that of K⁺, NO₃⁻, and PO₄³⁻ decreased during 5 weeks of acclimation at 3°C. The concentration of Ca²⁺ and Cl⁻ increased further during SZA while the concentration of the other ions remained unchanged. During thawing after SZA, the concentration of Cl⁻ remained elevated while that of Ca²⁺ and K⁺ decreased. These results suggest processes leading to increased freezing tolerance are initiated during SZA and that unique processes also are initiated during thawing following SZA. The ions and carbohydrates examined in this study may serve as bio-indicators of wheat genotypes that are especially able to effect these processes, providing identification of possible new sources of improved freezing tolerance.

Benefits and Challenges of Multidisciplinary Research Involving Agricultural Economists and Agricultural Scientists

SIÂN MOONEY, ECONOMICS, BOISE STATE UNIVERSITY; DOUGLAS YOUNG, SCHOOL OF ECONOMIC SCIENCES, WSU; KELLY COBOURN AND SAMIA ISLAM, ECONOMICS, BOISE STATE UNIVERSITY

This abstract details the rewards and barriers to participating in multidisciplinary research (MDR). We emailed an Internet survey to 1,205 agricultural and applied economists at U.S. universities. A total of 309 individuals completed or partially completed the survey for a response rate of 26 percent. While modest, this rate compares favorably to other Internet surveys.

Funding agencies often plead for MDR in requests for proposals for large grants aimed at solving socially important agricultural and environmental problems. However, different administrative levels of U.S. universities were perceived as sending contradictory signals regarding rewards from MDR. This discrepancy is echoed by the verbatim comments of two responding economists:

"The biggest obstacle is the contradictory expectations---narrow disciplinary based evaluation within departments---but multidisciplinary expectations at the College/University level."

"I am close to the end of my career. During my career, MDR has been punished rather than rewarded. Maybe this is changing. It remains to be seen whether criteria for promotion and raises will adjust."

Although the scope and breadth of questions addressed by applied economists are changing over time, institutional incentives and reward structures have been slow to adjust to these changes.

The results in Table 1 detail some other challenges encountered in MDR. Despite the challenges, the results show that economists are optimistic overall about MDR.

Table 1. Internal Challenges and Perceived Professional Rewards over Time for Multidisciplinary Research (MDR) by Applied Economists: 2011 Survey

	Disagree/Strongly Disagree	Neither Agree nor Disagree	Agree/Strongly Agree
<u>Internal Challenges</u>			
1. Reconciling differing research methodologies is an obstacle to MDR ^a	23%	24%	53%
2. Reconciling different vocabularies is an obstacle to MDR ^b	20%	21%	60%
3. Obtaining data from other scientists on a timely basis is an obstacle to MDR ^a	29%	30%	41%
4. Shared authorship in MDR can be an obstacle to professional advancement ^c	50%	25%	25%
<u>Professional Rewards over Time</u>			
5. The professional rewards for economists from involvement in MDR HAVE increased over time ^d	20%	25%	54%
6. The professional rewards for economists from involvement in MDR are LIKELY TO increase in the future ^d	6%	27%	67%
7. Increased involvement by economists in MDR could positively affect the employment prospects for economists in the future ^d	2%	13%	85%
8. The overall benefits of MDR outweigh the costs ^e	4%	16%	80%

^aN =
=

247. ^bN = 246. ^cN = 245. ^dN = 280. ^eN = 244. N indicate sample sizes for individual results.

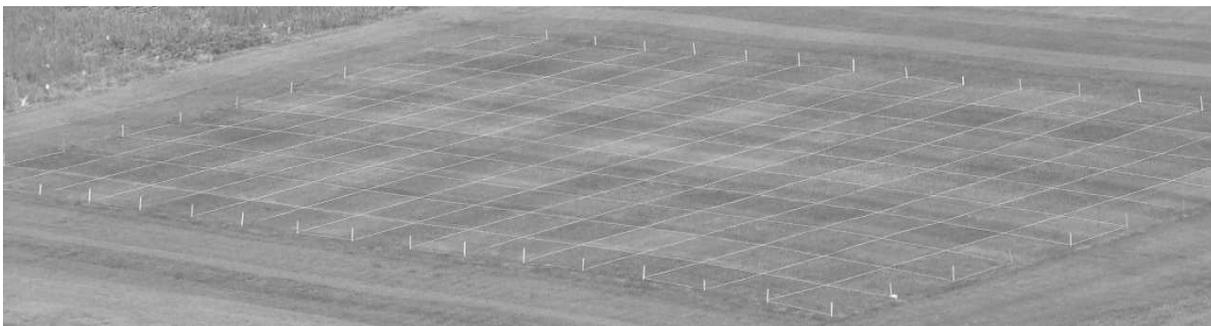
Kentucky Bluegrass Evaluation for Turf and Seed Production without Field Burning

W.J. JOHNSTON¹, R.C. JOHNSON², C.T. GOLOB¹, K.L. DODSON¹, AND G.K. STAHNKE¹

¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²WESTERN REGIONAL PLANT INTRODUCTION STATION, WSU

Field burning of Kentucky bluegrass (*Poa pratensis* L.) post-harvest residue has been eliminated in Washington. The objective of our study was to develop bluegrasses that have sustainable seed yield without post-harvest field burning and still maintain acceptable turfgrass quality. This long-term study consisted of 10 Kentucky bluegrass entries; eight are

USDA/ARS Plant Introduction (PI) accessions and two are commercial cultivars ('Kenblue' and 'Midnight'). The selected PI accessions, in previous research, had expressed high seed yield without burning of post-harvest residue and good turfgrass quality. Several agronomic yield parameters were then evaluated over a 2-yr period and individual plants were reselected within each accession, or check, with the highest seed weight, highest seeds/head, highest heads/area, and highest seed yield. Remnant seed of the original USDA/ARS population were also included. Turfgrass plots were established in 2006 at Pullman and 2010 at Puyallup, WA. Seed production plots (irrigated and non-irrigated) were established in 2007 at Pullman, WA. The turfgrass trials were evaluated according to NTEP (National Turfgrass Evaluation Program) protocol to determine turfgrass quality. Seed production plots were harvested (2008-2011) and clean seed yields were determined.



Turfgrass evaluation at Pullman, WA.

Results indicated that reselection for seed yield components had a variable response and seed yield was primarily dependent on accession. Among the 50 entries, PI 368241, selection heads/area, showed the most promise of being able to provide long-term turfgrass seed yield without field burning in both non-irrigated and irrigated seed production (Table 1). Kenblue, selection seed/head, had good seed yield and fair turfgrass quality at Pullman. PI 371775, selection seed/head, had good turfgrass quality while maintaining good seed yield with irrigation. Although Kentucky bluegrass is not recommended as a turfgrass for western WA, PI 371775 showed acceptable turfgrass quality at Puyallup. These three selections are currently in seed increase at Pullman and germplasm will be released by 2014.

Table 1. Non-burn Kentucky bluegrass germplasm turfgrass quality and seed yield.

Cultivar or PI#	Selection parameter	Turfgrass quality*		Seed yield (lbs/A)	
		5-yr mean	3-yr mean	4-yr mean	4-yr mean
		Pullman	Puyallup	Dryland	Irrigated
Midnight	Elite-type check	7.1 a**	5.3 a	136 c	243 d
Kenblue	Common-type check	5.3 c	4.7 b	398 b	608 c
Kenblue	Seeds/head	5.4 c	4.4 b	795 a	995 ab
371775	Seeds/head	6.1 b	5.4 a	404 b	800 bc
368241	Heads/area	5.1 d	4.7 b	893 a	1102 a

*Turfgrass quality rated 1 to 9; 9 = excellent.

**Means within columns followed by the same letter are not significantly different. LSD $P = 0.05$.

Part 4. Bioenergy Cropping Systems Research

The "Oilseed Based" Washington State Biofuels Cropping Systems (WBCS) Project

WILLIAM L. PAN, DEPT. OF CROP AND SOIL SCIENCES, WSU

First funded by the WA State Legislature in 2008 with support from WSDA, WA Dept. Commerce and the WSU Energy Program, the WBCS statewide project has supported more than 70 WSU and USDA ARS researchers, extension faculty and staff, and graduate students, addressing the wide variation of cropping conditions and systems of WA state. Current researchers are conducting new oilseed production research and technology development. Core state funding is leveraged with federal funding of PNW oilseed research from core USDA ARS, USDA NIFA (REACCH, Sun Grant), National Science Foundation (NSPIRE) and US Environmental Protection Agency (RACC).

The WBCS Extension leads, coordinates and links to growers, ag suppliers, grain storage and transporters, government policy makers, oilseed processors and end users are facilitating integrated expansion of feedstock production and end use for biodiesel, animal feed, and potentially future food grade oil and specialty chemicals in Washington State.

Over the past 5 years, WA oilseed production, WA processing facilities and WA biodiesel use have significantly increased over the past five years. A statewide oilseed crushing has increased to 350,000 T/y and processing capacity has grown to 109 MGY (<http://css.wsu.edu/biofuels/files/2013/02/Lang-WSU-Oilseed-Production-Workshop-Jan-2013.pdf>). Urban demand for state produced biodiesel is connecting western and eastern WA on numerous planes. For example, the Seattle/Islands Ferry system has aggressively set goals, tested and increased use of in-state biodiesel, resulting in a four-fold increase in biodiesel use over the past four years. Good for the ferry passenger health and the environment, while promoting WA businesses and supporting progressive farmers.

Oilseed feedstock production is specifically identified in Governor Inslee's 2013-2015 Strategic Budget Plan to "encourage the growth of oilseed farms" (<http://www.ofm.wa.gov/budget13inslee/presspacket.pdf>). The research and extension abstracts below represent the hard work and dedication of statewide faculty, staff and students towards this vision for oilseed diversification of our wheat-based cropping systems.

Oilseed Extension and Outreach Activities and Outcomes

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

The faculty and staff involved with the Extension and outreach portion of the Washington State Biofuels Cropping Systems Research and Extension Project (WBCS) and related dedicated to 1) the transfer of research results to farmers and industry to improve oilseed production practices, 2) bringing questions from new and experience oilseed producers to the researchers to answer through innovative research, and 3) creating and participating in events where oilseeds are featured. Field days, Extension publications, farm visits, the WBCS website (<http://css.wsu.edu/biofuels>), presentations at local and national meetings, and the annual WSU Oilseed Production and Marketing Conference are the primary means of education to reach these goals throughout the year.

Attendance at oilseed-related events surpassed 2000 people last year. Collaboration with industry resulted in presentations at several more industry field tours last year. The 2013 Oilseed Conference attracted over 200 attendees, with a significant increase in the number of speakers, sponsors, and financial support. Nearly all WBCS faculty were presenters at the event. Responses to onsite clicker surveys indicated 42% of participants attended a previous oilseed workshop, and 71% of those learned a principle or practice that helped them with oilseed production, and that increased to 93% of attendees of the 2013 conference. The survey also indicated 39% of oilseed growers in attendance experienced an 11-20% increase in wheat yield following an oilseed, while 14% of the growers saw a 14% increase in wheat yield.

We have developed separate email list serves for growers, industry, educators, and agency to send information as deemed necessary throughout the year, e.g. field day notices, oilseed insurance updates, oilseed delivery points in the PNW, and new publications. The WBCS website has a steadily increasing number of visits; in 2012 there were more than 2500 visits from 21 countries, 31 states, and 45 cities in Washington. Since last summer, Extension fact sheets

about camelina production, winter canola in rotation with winter wheat, and a second set of case studies of oilseed producers were published. A concerted effort is being made the rest of this year to publish fact sheets covering a range of topics from the WBCS project, such as oilseed diseases, biennial/dual purpose winter canola, case studies of irrigated canola producers, enterprise budgets, wide row canola spacing for spring canola, oil quality analysis, and more.

Recently released data from USDA-NASS shows a projected increase of canola acreage in WA from 15,000 acres in 2012 to 25,000 acres 2013, a reflection of strong markets, favorable growing conditions, and the extension and outreach efforts of the WBCS and its affiliate projects. Future plans are to coordinate regional oilseed extension and research efforts more closely, as outlined in a recently submitted PNW Oilseed grant proposal submitted to USDA NIFA, which would involve Montana, Idaho, Washington and Oregon.



Winter Canola Production in the Low- to Intermediate-Rainfall Zones of the Pacific Northwest

DENNIS ROE, DEPT. OF CROP AND SOIL SCIENCES, WSU; FRANK L. YOUNG, PI, USDA-ARS; DALE K. WHALEY, WSU EXTENSION, DOUGLAS CO; AND WILLIAM L. PAN, DEPT. OF CROP AND SOIL SCIENCES, WSU

Background: Approximately 60% of the rainfed production area of the PNW is in the winter wheat/summer fallow system. This system is plagued by winter annual grass weeds such as jointed goatgrass, feral rye, and downy brome. Several years ago a grower in Douglas County, WA experienced a \$1.45/bu dockage in his winter wheat because of feral rye contamination. Growers have become increasingly interested in producing winter canola in this region to improve pest management strategies, diversify markets (food, fuel, and feedstock), and increase sustainability. However, winter canola stand establishment is an impediment to growers in the non-irrigated, low- to intermediate-rainfall zones. Previous funding from the WBCS allowed us to initiate the first-ever winter canola seeding date and rate studies in these zones to improve canola emergence and stand establishment. Data indicate that the optimum time to plant winter canola in the fallow region is between July 25 and August 25 and most importantly when "Mother Nature tells you", i.e., when cooler temperatures (85°F) are forecast after planting. At the present time, there has been no research on winter canola variety trials in the wheat/fallow region. The U of I conducts variety trials in the irrigated area, high rainfall annual cropping region, and the high-end of the intermediate rainfall zone. Varieties that tolerate cold temperatures and open winters need to be found for this region to reduce production risks. As with winter canola, very little spring canola research has been conducted in the wheat/fallow region with the exception of determining the effect of planting methods on spring canola establishment, yield, and oil quality. In the PNW, winter annual grass weeds (especially feral rye) are a major problem in winter wheat. The only effective control measure for feral rye in the

growing crop is to use imazamox resistant winter wheat varieties. However, research in the southern Great Plains has shown great variation in feral rye tolerance to imazamox. Therefore crop and chemical rotation are important strategies for the management of feral rye.

Results: In the PNW, where feral rye is considered a noxious weed in WA, very little research has been conducted on its biology, ecology, and management. Thus far, one study in 1977 evaluated paraquat and barban for control of feral rye in winter wheat and a second study in 1984 evaluated the effect of various herbicides on feral rye seed germination. Since then no research has been conducted with feral rye in PNW crops. With the introduction of winter canola into the winter wheat/fallow region an opportunity exists for growers to better manage feral rye in their production systems. In north central WA a study is being conducted to evaluate these three herbicides on a natural stand of feral rye in winter canola. In the 2010-2011 growing season feral rye seed production was decreased 79%, 99% and 100% by spring applications of clethodim, quizalofop, and glyphosate respectively. Winter canola treated with these three herbicides increased yield 31% to 33% compared to the nontreated canola yield. In the 2011-2012 growing season the most effective treatments were when quizalofop and glyphosate were split-applied in the fall and spring. These treatments decreased greatly feral rye plant population and seed population and increased substantially canola yield compared to the nontreated check.

Spring Canola Production at the WSU Wilke Research and Extension Farm

AARON ESSER, WSU EXTENSION, LINCOLN-ADAMS AREA

The WSU Wilke Research and Extension Farm is a 320 acres facility located on the eastern edge of Davenport, WA. This farm is a direct seeded cropping system that utilizes no-till fallow, winter wheat, and spring cereals. Broadleaf crops also remain a viable option and are substituted when conditions warrant. Because of cereal rye infestations, 'DKL51-45' roundup ready spring canola was seeded into Plot 1 instead of no-till fallow. It was seeded and fertilized in one pass with a SeedMaster direct seed hoe drill on 12" spacing on May 2, 2012 at 2.6 lb/ac, and treated with Prosper FX. Anhydrous ammonium was applied below the seed at 51-0-0-0 and liquid ammonium thiosulfate, 11-37 and NACHURS was applied at a rate of 9-15-1-9 with the seed. Prior to seeding canola on April 21, 32.0 oz/ac RT3 herbicide, 1.5 qt/100 gal Alliance, and 1.0 qt/100 gal Activate was applied. Roundup PowerMax® was applied on June 8 at 16 oz/ac with 15 lb/100 AMS Max®. On June 15, Assure II was applied at 8.0 oz/ac with 1 qt/100 non-ionic surfactant. On August 11, 16 oz/ac Spodnam was applied by airplane to help reduce pod shatter. Weed control in the spring canola was very good, and a heavy lady bug population helped eliminate the need for insecticide application in the crop. The crop was harvested with our John Deere 6622 combine on August 28. The canola yielded 1,542 lb/ac, was marked at \$0.29/lb and generated \$447.50 gross economic return. Total input costs that includes seed, fertilizer, herbicides and pod sealant totaled \$106.09/ac. Overall spring canola was the second most profitable crop on the farm in 2013 and returned \$82.46 and \$113.33/ac more than spring barley and spring wheat, respectively.

Winter Canola Rotation Benefit Experiment in the Intermediate Precipitation Zone

WILLIAM SCHILLINGER¹, HAL JOHNSON², JOHN JACOBSEN¹, STEVE SCHOFSTOLL¹, ANN KENNEDY³, AND TIMOTHY PAULITZ³
¹DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND; ² COOPERATING GROWER, REARDAN; ³USDA-ARS

Acronyms used: NTF, no-till summer fallow; SW, spring wheat; WC, winter canola; WW, winter wheat

The objective of this long-term experiment is to determine the benefits of winter canola (WC) grown in a 3-year WC-spring wheat (SW)-no-till fallow (NTF) rotation compared to the traditional winter wheat (WW)-SW-NTF rotation in the intermediate precipitation zone on water dynamics, grain yield of the subsequent SW crop, and soil microbial changes.

The study was initiated in August 2007 on deep, productive soils at the Hal Johnson farm west of Reardan, WA. Annual precipitation averages 18 inches. We are comparing a WC-SW-NFT rotation with the more traditional WW-SW-NTF system. All crops are direct seeded with a Kile hoe-opener drill. The experimental design is a randomized complete block with six replications. Individual plot size is 100 ft x 16 ft. Fertilizer application rate is based on soil test results. In addition to WC, WW, and SW grain yield (determined using a plot combine), we measure soil water content in all plots (i) just after harvest in August, (ii) in early April, and (iii) in NTF in August. Plant diseases and microbial attributes are assessed by Tim Paulitz and Ann Kennedy, respectively.

Excellent WC and WW grain yields were achieved in 2012. Winter canola averaged 3720 lbs/acre and WW 105 bushels/acre. On August 15, 2012 the price offered at Reardan for WC was 29 cents/pound and, for soft white WW, \$8.10/ bushel. Gross returns are, therefore, reported here as \$1079/acre for WC versus \$851/acre for WW.

Spring wheat grain yields in 2012 were significantly greater (57 versus 41 bu/acre) when the previous (i.e., 2011) crop was WW compared to WC (Fig. 1). What was the cause of these grain yield differences? There was 1.3 inches more soil water after the WC harvest compared to after WW harvest (Fig. 1). Similarly, at time of planting SW in April, the WC stubble had 1.4 inches greater soil water than WW stubble (Fig. 1). The difference in SW grain yields was likely due to soil water use by volunteer WC in SW. The late-spring broadleaf weed herbicide application in SW stunted, but did not completely kill the volunteer WC. Volunteer WC did not produce additional biomass, but plants stayed green throughout the growing season. In 2011, we had the opposite situation in regards to soil water with WC stubble having 1.1 inch less water in the 6-ft profile compared to WW stubble at time of SW planting. Yet, 2011 SW grain yield was significantly greater following WC compared to WW (64 versus 52 bushels/acre) (Fig. 1) with excellent weed control. There were no visual differences in SW foliar or root disease expression in either 2011 or 2012.

Averaged over five years, there are no significant differences in soil water use of WC compared to WW (Fig. 1). Similarly, there are no significant differences in soil water content in April on WC versus WW stubble (Fig. 1). The 4-year average SW grain yield following WC and WW is 53 and 58 bushels/acre, respectively (Fig. 1), which is not statistically different at the 5% probability level. In summary, our data (to date) indicate that, on average: (i) WC and WW use the same amount of soil water, (ii) over-winter soil water recharge is about the same on WC and WW stubble, and (iii) subsequent SW grain yield will be about the same following WC and WW.

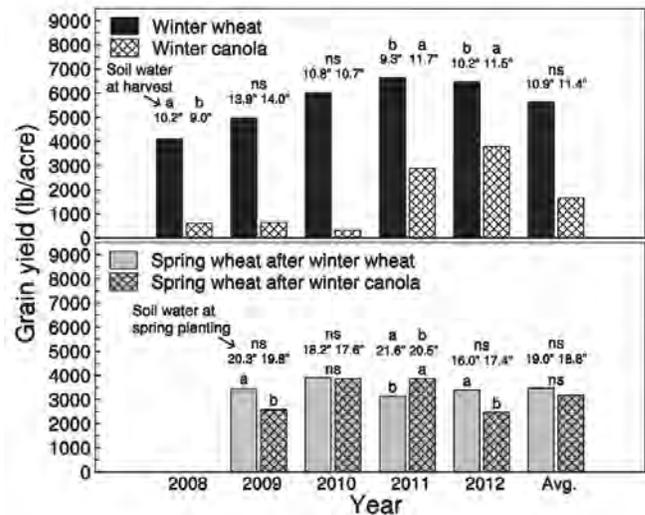


Fig. 1. Top: Winter wheat and winter canola grain yields from 2008 to 2012 and the 5-year average. Bottom: Spring wheat grain yields as affected by previous crop (either WW or WC) from 2009 to 2012 and the 4-year average. Numerical values above bars are total water content in the 6-foot soil profile. Within-year soil water values with different letters indicate significant differences at the 5% probability level. Letters above spring wheat grain yield bars indicate significant differences at the 5% probability level. ns = no significant differences.

Economic Returns to Canola Rotations in Eastern Washington

VICKI A. MCCrackEN AND JENNY R. CONNOLLY, SCHOOL OF ECONOMIC SCIENCES, WSU

Inclusion of canola into cropping systems may offer agronomic benefits to farms that translate into improved overall farm profitability over time. Research and grower experience suggests that canola can help improve weed and disease control, soil structure, moisture penetration, and nutrient availability, which may contribute to increases in wheat yields observed following canola in a rotation. Favorable current prices for canola and potential demand in regional food, feed, and biofuel markets may also make canola a profitable alternative crop in Washington.

We compare economic returns of cropping systems that incorporate canola with the returns to traditional cropping systems for three distinct growing regions in eastern Washington: 1) high-intermediate rainfall, 2) low rainfall, and 3) deep-well irrigated. We consider both conventional and reduced tillage systems in the low rainfall region. Returns are estimated using typical yields for each cropping region and costs of production and output prices for 2012. Sensitivity analysis was performed for yields and output prices.

All rotation systems considered resulted in positive returns, although the inclusion of canola raised input costs. In scenarios where average or low canola yields were considered, rotations with canola had positive returns but sometimes second to traditional cropping systems using average 2012 prices. However, when rotational impacts from canola were

considered, rotations with canola provided the highest returns. For example, Table 1 compares the net returns from a traditional winter wheat – fallow rotation to net returns from a rotation with winter canola grown every other cycle, where the second scenario includes a boost in wheat yield.

Table 1. <17" Rainfall Region: Winter Canola every other WW-Fallow cycle Reduced Tillage, Yield Impact Scenarios

ROTATION/Scenario	Returns	Returns
	over Total	over Variable
	Costs	Costs
	(\$/ac/yr)	(\$/ac/yr)
Baseline – SWWW (50 bu/ac), WC (1500 lb/ac)		
CF, WW, CF, WW	\$28	\$117
CF, WW, CF, WC	\$25	\$114
Rotational impact on wheat yield (+20% WW)		
CF, WW, CF, WW	\$28	\$117
CF, WW, CF, WC	\$45	\$134

Double-Cropping Dual Purpose Irrigated Biennial Canola with Green Pea

KEYFALEW GIRMA DESTA.¹, HAROLD P. COLLINS², ROMULUS OKOTH OKWANYI¹ AND WILLIAM LEE PAN³

¹WSU IAREC, Prosser; ²VEGETABLE AND FORAGE CROP RESEARCH UNIT-ARS, PROSSER; DEPT. OF CROP AND SOIL SCIENCES, WSU

Growers are reluctant to convert cropland to sole biofuel feedstock such as canola due to the low oil yield and economic return compared to other higher value crops such as wheat. However, when planted as a biodiesel crop, canola can play a significant role in curbing the foreign import of petroleum-based fuel and can contribute to a reduction in greenhouse gas emissions. Double cropping dual purpose canola with green pea may justify the expansion of canola in Pacific Northwest. The green pea-biennial canola- double-crop system can provide new opportunities for growers in the region through i) providing additional annual farm income with the production of green pea and canola forage, ii) protecting the soil from wind erosion through vulnerable periods (late summer through spring) with crop coverage, iii) producing canola seed in the subsequent year for oil (biofuel or food) and high-protein meal (animal feed), and (iv) preventing the decline of soil health while enhancing soil and water quality. The objectives of the current study were to assess the feasibility and estimate the overall profitability of the double-crop dual purpose canola, quantify the N contribution from green pea to succeeding canola, and assess potential soil and water quality impacts of the double-crop system. The study was initiated in USDA-ARS research site located near Paterson, WA in spring 2012. The experiment was conducted in a split-plot design with 4 replications. Main plots were stand management (simulated canola grazing or no grazing) treatments. Subplots were 3 x 3 factorial combinations of N (0, 50, 100, and 200 lbs/ac) and S (0, 30, and 60 lbs/ac) fertilizer rates. The subplots were 20 ft x 50 ft. The project is in its first year of implementation, and data collection is in progress. However, preliminary results showed that average green pea (shelled) yield was 6.5 ton/A; uniform across replicates. Sixteen-percent moisture adjusted canola dry matter yield cut at rosette growth stage 29 was 1900 lbs/A. The inorganic N in the soil prior to pea planting was 2 lbs/A, much lower than what was documented before canola planting (22 lbs/A). Average crude protein of canola forage harvested at growth stage 19 (BBCH scale) was 30% with average digestible neutral detergent fiber of 29%. Total digestible nutrients constituted about 75% of dry matter. Producers will be able to use the information generated from this project and incorporate the green pea-biennial canola double-crop system into the traditional one crop-per-year system. In the intermediate-term, growers will adopt the double-crop system and customize it to their situation. The N contribution from the green pea to the biennial canola crop would result in fertilizer savings for the grower.



Management of Fresh Wheat Residue for Irrigated Winter Canola Production

WILLIAM SCHILLINGER¹, TIMOTHY PAULITZ², JEFF SCHIBEL³, KURT SCHROEDER⁴, JOHN JACOBSEN¹, AND STEVE SCHOFSTOLL¹.

¹DEPT. OF CROP AND SOIL SCIENCES, WSU; ²USDA-ARS; ³COLLABORATING GROWER, ODESSA; ⁴DEPT. OF PLANT PATHOLOGY, WSU

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

Four winter wheat stubble management treatments were established in August and September 2012 at the Jeff Schibel farm SW of Odessa, WA. The experiment is embedded in a circle of irrigated winter canola belonging to Mr. Schibel. Irrigated WW stubble in the plot area was burned in treatments I and III (below) on August 20 and irrigation water immediately applied to promote germination of volunteer wheat. Glyphosate was applied to the entire plot at a rate of 24 oz/acre on September 4. Land was prepared as required by protocols for each treatment (i.e., straw chopping, disking, moldboard plowing; see list of treatments below) on September 4-6. Winter canola was planted and fertilized in one pass on September 7 using a Kile no-till hoe drill. Assure II herbicide for grass weed control was applied on October 6. All field equipment used in establishment of the experiment was transported to the site from the WSU Dryland Research Station. Treatments established at the Schibel site are: (i) stubble burned + disked, (ii) stubble chopped + moldboard plowed, (iii) stubble burned, then direct seeded and, (iv) direct seeding into standing and undisturbed stubble. Experimental design is a randomized complete block with four replications of each treatment for a total of 16 plots. Individual treatment plot widths range from 8-to 10-ft depending on the tillage implement (if any) used. All plots are 100 ft long. Application of irrigation water, which will total about 15 inches for the crop year, is managed by Mr. Schibel.

As this experiment was initiated 2012, there is yet little data to report. Winter canola stand establishment in all treatments is satisfactory (Fig. 1). We obtained good control of volunteer WW with Assure II grass weed herbicide applied at a half rate (8 oz/acre) to the entire experiment on October 6. Plant and soil samples from all treatments were obtained on October 23, 2012 and again on April 24, 2013. These samples are currently being processed for fungal root pathogens in the laboratory. We suspect that *Rhizoctonia solani* AG 2-1 may be a limiting factor in establishment of WC in fresh WW residue. In a previous study conducted at Lind, WA, removing the pathogen significantly increased WC stands and dry weights. Leaving the straw intact on the soil surface (which is done in a direct-seed system), did not increase disease or reduce plant dry weights. If fresh WW straw had an allelopathic effect, we would have expected that WW residue on the surface would have leached compounds and reduced WC growth, but this did not happen. However, incorporating fresh WW straw into the soil can immobilize N, because of the high C/N ratio of the straw.



Fig. 1. Collaborating grower Jeff Schibel inspecting winter canola that was direct seeded into newly-harvested (i.e., fresh) irrigated wheat stubble. The stubble in this treatment was left standing and undisturbed prior to planting winter canola. Photo was taken in April 2013.

Nitrogen Use By Pacific Northwest Dryland Canola (*Brassica napus*)

TAI MCCLELLAN MAAZ, BILL PAN, ASHLEY HAMMAC, AND RICH KOENIG, DEPT. OF CROP AND SOIL SCIENCES, WSU

Nitrogen (N) fertility recommendations vary widely within canola production regions including the Pacific Northwest. Canola has a high N uptake efficiency (unit of total plant N per unit of supplied N) but a low N utilization efficiency (unit of grain per unit of total plant N), leading to an overall low N use efficiency (NUE) (unit of grain produced per unit of N supplied) compared to wheat. Therefore, canola is able to take up nitrogen from the soil very well, but is poorer

at allocating that nitrogen to its seeds. Calculations for estimating the N requirement for canola based upon maximum theoretical yields have proven unsuccessful in our region. Recent research indicates that spring canola can root up to 5 ft, and efficiently scavenges high levels of residual soil N thereby minimizing responses to N fertilizer. Though rainfall gradient largely determines yield potential of canola in Pacific Northwest, yields at economically optimum N supply (EONS) are consistently lower than maximum theoretical yields and reached at a relatively lower total N supply (Fig. 1). The N requirement of canola at EONS can vary among years, but a single unit N requirement (UNR) of 11 kg N per kg seed was determined by considering multiple years and locations within a rainfall gradient.

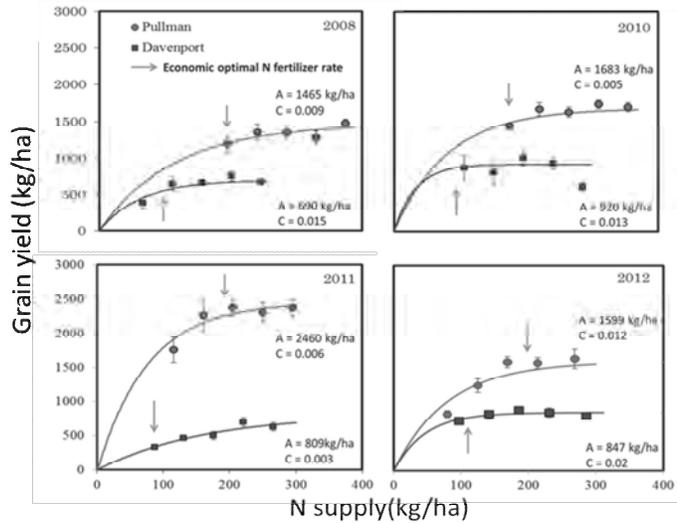


Fig. 1. Maximum yields (A) and efficiency factors (C) for spring canola at Pullman, WA, and Davenport, WA.

Assessing Crop Rotational Nitrogen Use Efficiency Using an N Balance Approach

TAI MCCLELLAN MAAZ, BILL PAN, ASHLEY HAMMAC, AND FRANK YOUNG; DEPT. OF CROP AND SOIL SCIENCES, WSU; USDA-ARS

In annual cropping systems, N use efficiency is typically estimated on a single crop basis. However, this approach ignores the dynamic nature of N cycling within multi-year crop rotations featuring a diverse set of crops. We developed a component analysis of NUE of an entire cropping sequence of featuring canola (spring canola-spring pea-winter wheat). This approach provided insight into the propensity of cropping systems to retain and recycle N within a rotation by factoring in crop yields, grain and residue N, fertilizer N, N mineralization estimates, and changes in soil residual inorganic N within the intermediate and high rainfall zones of Eastern WA. The inclusion of peas led to positive N balances (N output exceeding N inputs) due biological N fixation (Fig. 1). Interestingly, N balances were also more positive for sequences that received higher rates of N fertilization during its spring canola cropping. This result suggests elevated N mineralization due to the return of canola residues with higher N concentrations, as well as contributions of fertilizer carry-over to the overall rotational NUE. By tracking changes in soil N supply between crops, the rotational NUE will help us evaluate and adopt alternative cropping systems with the propensity to retain and recycle N within a rotation.

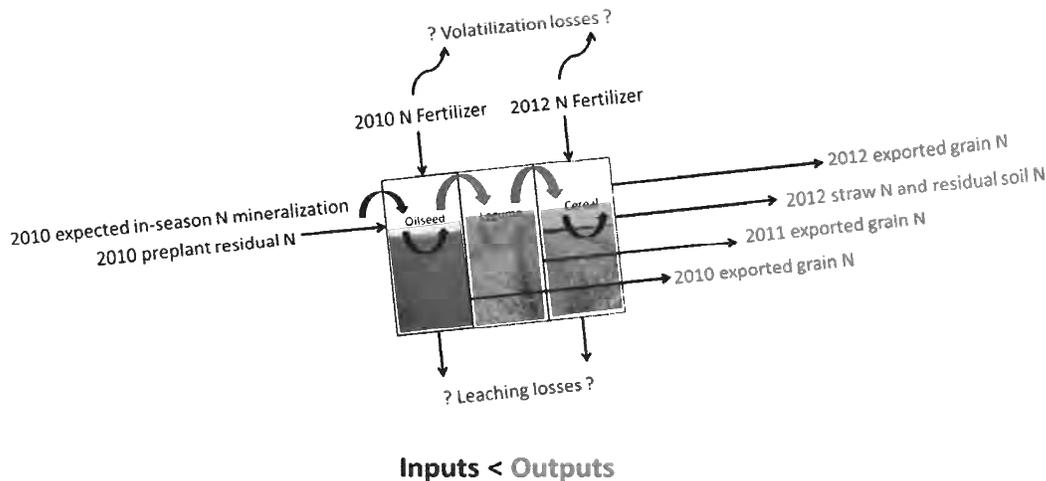
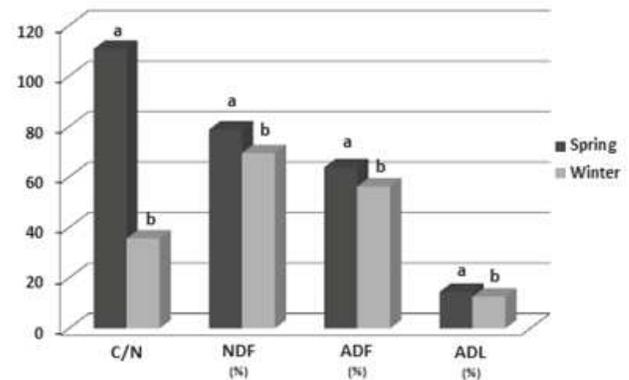


Fig 1. A positive N balance indicates N gains in the cropping system due to biological N fixation or enhanced N mineralization during the cropping sequence.

Residue Decomposition of Canola Cultivars

TAMI STUBBS, DEPT. OF CROP AND SOIL SCIENCES, WSU; ANN KENNEDY AND JEREMY HANSEN, LAND MGMT. & WATER CONSERVATION RESEARCH UNIT, USDA-ARS

Little is known about the residue characteristics of spring and winter canola cultivars, and how those factors affect decomposition and soil quality. Winter canola residue was collected from Univ. of Idaho Canola Variety Trials at Odessa, WA (irrigated site), Moscow and Genesee, ID and spring canola residue was collected at Davenport and Colfax, WA and Moscow, ID after harvest in 2011 and 2012. Residue was analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), carbon (C) and nitrogen (N). The goal of this research was to quantify the cultivar traits and factors controlling residue decomposition of canola cultivars currently or potentially planted by growers in the Pacific Northwest. Stalks of canola residue contained higher NDF, ADF, ADL and C/N than litter (small stalks, leaves, pods); and spring canola residue contained higher NDF, ADF, ADL and C/N than winter canola residue (Fig. 1; $P < 0.05$).



$P < 0.05$

Fig. 1. 2011-12 spring and winter canola residue fiber components, C and N

Higher NDF, ADF, ADL and C/N are indicators of slower decomposition. In general, when moving from lower rainfall locations to higher rainfall, canola plant fiber, C and N increased ($P < 0.05$), indicating residue from higher rainfall locations would be expected to decompose more slowly. Winter and spring cultivars vary in their fiber, C and N components, and further investigation is needed to confirm those results. Characterization of root residues and laboratory decomposition studies are ongoing. We believe this to be the first work to characterize canola root and shoot residue composition and decomposition among types, locations, cultivars and years. The data collected will be used to better predict residue decomposition in the field, examine canola cultivars for their contributions to soil fertility and soil quality, and assist growers in identifying traits for residue management. Information on residue traits and decomposition will be useful in developing alternative uses for canola residue, such as biofuel. Marketing opportunities for oilseed crops are increasing, and information on residue decomposition will be useful to growers who wish to incorporate canola into their rotations in both conventional and conservation farming systems.

Oilseed Root Characteristics: Implications for Water and Nutrient Management

W. PAN, A. HAMMAC, T. MCCLELLAN, I. MADSEN, L. GRAVES, K. SOWERS AND L. YOUNG; DEPT. OF CROP AND SOIL SCIENCES, WSU

Canola and camelina have distinctly different root systems compared to the cereal crops grown in the PNW. Some of these differences should be considered when designing soil and fertilizer management schemes for maximizing water and nutrient use efficiencies. Root morphology and activity analysis was accomplished with in-soil digital scanning, and root excavation and monolith construction at Ralston, WA, and pre-plant vs. post-harvest soil water and nitrate analysis of extraction depths at Wilke and Pullman. A primary difference in the root morphology can be seen immediately following germination. The oilseeds initiate one main tap root radical with vertical directional growth, and horizontally-oriented lateral branches. In contrast, wheat and barley exhibit a multiple seminal axes root system with each axis





exhibiting different directional growth angles. The single tap root exhibits greater potential seedling susceptibility to ammonium toxicity from banded fertilizer. Depth of rooting, water and N extraction appears to be similar to that of cereal crops, to depths of at least 4 ft for winter and spring canola. Tap root thickening occurs in winter canola from 1 inch wide at base, tapering to 1 mm diameter at 1 ft depth, potentially creating vertical macropores for postharvest water infiltration and soil water storage. Oilseed root hairs are longer, but less dense than wheat, flax or lentil, suggesting oilseeds may have greater ability to extract soil immobile nutrients such as ammonium, phosphate and potassium.

A Comparison of Oilseed and Grass Crop Residue Silicon and Fiber Composition and Impacts on Soil Quality

T.L. BEARD^A, K. BORRELLI^A, W.L. PAN^A, AND C. XIAO^B; ^ADEPT. OF CROP AND SOIL SCIENCES, WSU; ^BWA DEPT. OF ECOLOGY

Arid and semi-arid agronomic regions that have adopted conservation management practices, such as reduced tillage, may be prone to soil crusting. Surface crusting is predominantly caused by the combination of raindrop impact and excessive Si in the soil. It can reduce water infiltration, enhance runoff & erosion, and interfere with seed germination. Structural components (e.g. lignin and silicon (Si)) vary between crop types. Grasses such as wheat tend to have higher levels of Si and lower amounts of lignin when compared to oilseeds. When such residue is left on the soil surface these components, specifically Si, may contribute to soil crusting. The main goal of this research is to characterize specific structural components in crop residue from several species of oilseed and grass crops and to understand the potential of such residues to resist degradation and impact soil crusting.

Wheat (*Triticum aestivum* L.) and canola (*Brassica napus* L.) residues from field and greenhouse experiments were analyzed for neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), total carbon (C), nitrogen (N) and Si. Fiber and Si varied among crop types and an inverse relationship between ADL and Si was found. Wheat had high Si (1.2 g/100g) and low ADL (10.8%), whereas canola had high ADL (13.0%) and low Si (0.1 g/100g).

Table 1. Fiber, C:N, and Si amounts for wheat and canola residues.

Crop	%NDF	%ADF	%ADL	C:N	Silicon (g/100g)
Wheat	85.5 a	70.0 a	10.8 b	178.8 a	1.2 a
Canola	76.7 b	61.4 b	13.0 a	117.0 b	0.1 b

In order to compare the effects of rotation history, a soil incubation was conducted with two soil types. The first soil was collected from a field traditionally grown in a winter wheat-fallow rotation and the second soil was collected from a spring canola-fallow rotation. Initial values of soil Si were significantly higher in the soil collected from the wheat field when compared to the canola field. Three rates of silica solution (SiO₂) representative of amounts that would be found in wheat and canola residues were added to each soil type. High amounts of Si solution and soil Si had a positive effect on soil crust thickness (Fig. 1)

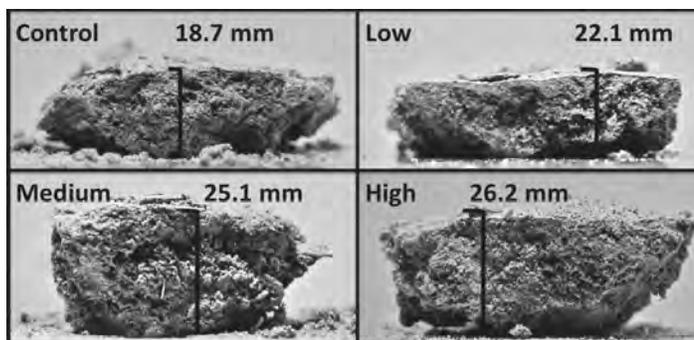


Fig. 1. Visual representation of crust thickness for each treatment.

and surface resistance (Fig. 2), suggesting that crops high in Si have the ability to contribute to soil crusting. Therefore, it may be beneficial to consider crops with lower amounts of Si when planning crop rotations in areas where soil crusting can be a concern. Further research on this topic will include conducting a field survey on comparable fields this summer.

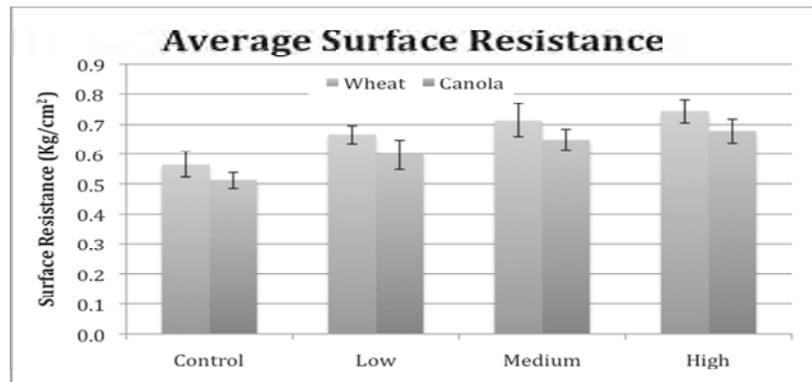


Fig. 2. Average surface resistance of wheat and canola soil per treatment.

Emerging Diseases of Canola and Camelina in the Pacific Northwest

TIM PAULITZ, SCOT HULBERT, EBRAHEIM BABIKER AND KURT SCHROEDER; USDA-ARS; DEPT. OF PLANT PATHOLOGY, WSU

Blackleg, caused by the fungus *Leptosphaeria maculans*, is the most economically important disease of canola in North America and world-wide. It is endemic in the Midwest, southern US and the prairie provinces of Canada. However, Washington and Idaho have been considered blackleg free, which gives them an advantage in producing disease-free seed. The lack of the disease has also greatly simplified canola breeding for the northwest compared to other areas. The situation will change radically if the disease becomes established. The disease is also a big part of the reason that canola production has been banned from key brassica seed crop production areas of the northwest, like Skagit Valley and parts of the Columbia Basin and Willamette Valley. If the disease moved to those areas, it would be economically devastating.

In Aug. 2011, we detected the disease in samples from Bonner's Ferry in N. Idaho. All putative blackleg isolates were identified as *L. maculans*. Koch's postulates were performed in the greenhouse in Manitoba on susceptible varieties, with cotyledon inoculation and all isolates gave a high level of disease, showing a high level of virulence. Additional testing will be done to determine the race structure of the isolate. Growers should become aware of the dangers of planting non-certified seed that has not been tested with a phytosanitary certificate, especially if seed is traded among growers or imported from Canada.

A downy mildew disease was observed in most camelina fields and breeding plots monitored in 2010, 2011 and 2012. This has been the only prevalent disease or pest problem noted in camelina production in recent years. Efforts to determine the causal agent and epidemiology of the disease were therefore undertaken. Symptoms were not observed until plants were flowering. Symptoms often included dark colored stunted branches or racemes that developed poorly and sometimes white sporulation (figure below). We suspected the pathogen could be a downy mildew, performed DNA assays which confirmed that the causal pathogen was *Hyaloperonospora camelinae*. To determine whether *H. camelinae* is a seed-transmitted pathogen, seeds collected from infected plants were planted in growing mix and grown in a growth chamber. Disease symptoms were observed in 96% of the seedlings grown from seed from infected plants and only 3% of the seedlings grown from seed from asymptomatic plants. This indicates that *H. camelinae* is a seed-transmitted pathogen. Seeds treated with mefenoxam, a fungicide specific for Oomycetes, significantly reduced the incidence of the disease.



Analysis of Fatty Acid Content in Oilseeds

LYDIA BAXTER-POTTER^A, IAN C. BURKE^A, E. P. FUERST^A, STEPHEN GUY^A, THOMAS G. CHASTAIN^B, DONALD J. WYSOCKI^C, AND WILLIAM F. SCHILLINGER^A; ^ADEPT. OF CROP AND SOIL SCIENCES, WSU; ^BDEPT. OF CROP AND SOIL SCIENCE, OSU; CORVALLIS, OR; ^CDEPT. OF CROP AND SOIL SCIENCE, OSU, CBARC, PENDLETON, OR

Fatty acids obtained from oilseeds are used for several purposes including biodiesel and human consumption. Fatty acid content and abundance can be influenced by environmental factors, particularly during seed development. The objectives of our project were to determine the cold press oil yield, total oil content, and fatty acid content of oilseed crops from camelina seed samples produced in field trials across the Pacific Northwest.

Camelina seed samples of the varieties Blaine Creek, Calena, Celina, Cheyenne, and Columbia were provided by other researchers from Pendleton, Washington (2010), Corvallis, Oregon (2010), and Pullman, Washington (2009, 2010). The oil yield for each sample was determined using an oil extractor, delivering data to estimate industrial scale yields. University of Idaho determined total oil content by nuclear magnetic resonance (NMR). Fatty acid composition was determined by application of methyl-esterification process and subsequent gas chromatography/flame ionization detection (GC-FID), with verification by gas chromatograph/mass spectrometry (GC-MS).

Camelina varieties harvested in Pullman during 2010 have similar percent oil content by weight. GP48 had the lowest percent oil and Ligena had the highest. Location and variety influenced yield of acid content. The least variation was in linoleic acid content (difference of 0.2 %) in the Celina variety at Corvallis. The greatest variation was in linolenic acid content (difference of 5.25%) in the Cheyenne variety at the Pullman 2009 site. Average oleic acid content was highest (19.4%) in the Blaine Creek variety from the Pullman 2010 study, and samples taken from Pendleton in 2010 had overall highest average oleic acid content (18.92%). Camelina varieties were ranked differently in the two harvest years for the Pullman site (2009 and 2010) by order of the varieties' percent oleic acid content. Concentrations of linoleic acid were highest in the Blaine Creek variety, except at Pendleton in 2010. All varieties at Corvallis had decreased linoleic acid production (average of less than 16%) compared to other sites, possibly due to more summer moisture. The decrease is countered in the concentration of linolenic acid (highest average of 32.5%), where it is highest at Corvallis compared to other sites. Linolenic acid is present in comparatively high concentrations across all four sites. Eicosenic acid content was consistent and low across varieties and sites. Further analysis of these data will provide growers a more informed plan for optimizing fatty acid production based on variety selection and location of production.

Rotational Influence of Brassica Biofuel and Other Crops on Winter Wheat

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

Growing Brassica oilseed crops in eastern Washington must fit within the regional rotational cropping systems. When grown, broadleaf crops usually precede winter wheat in rotation and studies worldwide have shown the benefit to winter wheat when following a broadleaf crop. The potential economic benefit of these crops should include the rotational effect of these crops on winter wheat.

These studies are two year crop sequence studies on eight spring crops (spring wheat, spring barley, dry pea, lentil, camelina, yellow mustard, oriental mustard, and canola) planted in year 1 followed by winter wheat (year 2) grown



2012 Rotation study spring crops planted to winter wheat for 2013 at Cook Farm, Pullman, WA

across all year 1 spring crops. The year 2 winter wheat planted within each of the previous spring crop areas is divided into sub-plots receiving fertilizer rates of 32, 64, 96, 128, 160 lbs N/acre applied in a split-plot, factorial design. Results from five years of spring crop comparisons are in Table 1. Preliminary conclusions are:

- ⇒ Performance variability among spring crop is high and varies over years.
- ⇒ Some crops, barley and camelina, are more consistent across years.
- ⇒ Market prices and yields will guide spring crop selection for growers.
- ⇒ Winter wheat performance following spring crops is best after pea and lentil, followed by brassicas, and both are better than after wheat or barley.
- ⇒ Wheat fertilizer response is best after legumes followed closely by brassica crops.
- ⇒ With results showing wheat performance after spring crops, growers can give rotational benefits to biofuel crops from better winter wheat performance and low N fertilizer inputs.

Table 1. Spring Crop Seed Yields, 2008 Moscow, 2009 – 2012 Pullman.

Spring Crop	2008	2009	2010	2011	2012	2008-2012 Ave.	Avg. % Variation
	----- lbs/acre -----						
Spring Wheat	3750	3915	1700	2770	3020	3030	21.2
Spring Barley	4625	5485	3520	4145	4610	4480	11.5
Dry Pea	1830	245	840	2565	1020	1300	55.2
Lentil	1075	740	480	1850	860	1000	36.9
Camelina	1895	2585	1715	1530	1820	1910	14.2
Yellow Mustard	1390	1635	695	1415	1430	1310	19.0
Oriental Mustard	915	2290	700	1750	1570	1445	35.3
Canola	700	1610	670	1395	860	1050	34.8
Average	2025	2315	1290	2175	1900	1940	28.5
LSD (0.05)	515	765	750	455	523		

Safflower Oilseed Production under Deficit Irrigation and Variable N Fertilization

HAL COLLINS¹, BILL PAN², ASHOK ALVA¹ AND RICK BOYDSTON¹; ¹USDA-ARS, PROSSER; ²DEPT. OF CROP AND SOIL SCIENCES, WSU

The production of oilseed crops represents a unique opportunity for PNW producers to provide a biodiesel feedstock for an emerging renewable energy industry. The inclusion of oilseeds in rotation offers producers an alternative strategy to improve farm economies and gain additional benefits that improve soil and water conservation, reduce pest cycles, and diversify cropping systems. Safflower is considered a low input and drought tolerant crop, but responds well with irrigation and fertilizers. Three safflower varieties S334, S345 and CW99OL were planted in April 2008-2011 under center pivot irrigation at the USDA-ARS field site near Paterson WA (Fig. 1). Standard irrigation and deficit irrigation

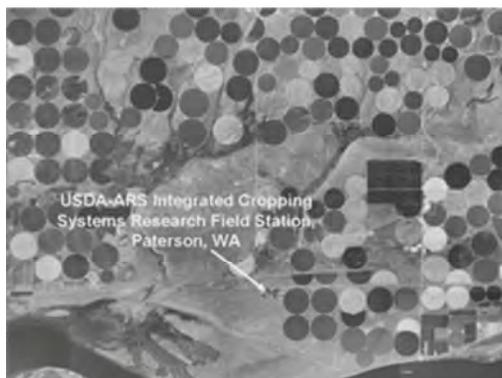


Fig. 1. USDA-ARS Paterson Field Site.

were 28 and 22 inches, respectively. The difference in water applied between the deficit irrigated and the standard water treatment was 6 inches resulting in a treatment of 80% of ET in 2009 and 8 inches, 70% of ET in 2010 and 2011. Safflower oilseed



Fig. 2. Safflower ready to harvest 2011.

yields averaged 3100 lbs ac⁻¹ among years in all treatments (Table 1). Safflower oilseed yields were significantly higher under the 100 than 145 lb N acre⁻¹ fertilizer rate in 2008. Safflower oilseed yields were not significantly different between the full and 70% ET treatments, indicating a potential 5 to 7 inch water savings using a deficit irrigation strategy depending on year. Deficit irrigation (70% of ET) had a positive effect on WUE with an average increase of 23 lb seed yield acre⁻¹ inch⁻¹ of water applied. Oil contents of the seed were 1.5 – 2.2% higher under deficit irrigation than under full irrigation following the higher yields and greater water use efficiencies.

Table 1. Yield of safflower and water use at the USDA-ARS Field Station near Paterson, Benton County, WA.

Yield	Yr	Full Irrigation				Deficit Irrigation			
		100		145		100		145	
		lb/acre	lb/ac/inch Water	lb/acre	lb/ac/inch Water	lb/acre	lb/ac/inch Water	lb/acre	lb/ac/inch Water
Cw99OL	08'	3103	107	3084	106	3250	135	3026	126
	09'	2547	88	2419	84	2819	118	2212	93
	10'	3040	103	2877	98	2934	129	3105	137
	11'	3197	118	3839	141	3170	161	2860	145
	Average	2972	104	3055	107	3043	136	2801	125
S345	08'	3370	116	3017	104	3557	148	3326	139
	09'	2326	81	2982	103	2793	117	2383	100
	10'	3028	103	3068	104	2871	127	3361	148
	11'	2826	104	3292	121	2595	132	2398	122
	Average	2888	101	3090	108	2954	131	2867	127
S334	08'	---	---	---	---	---	---	---	---
	09'	---	---	---	---	---	---	---	---
	10'	2936	100	2390	81	2978	131	2822	124
	11'	1547	57	2121	80	1207	61	1444	73
	Average	2242	31	2256	81	2093	39	2133	99

Wind Erosion Potential from Oilseed Cropping Systems

B.S. SHARRATT, USDA-ARS AND W.F. SCHILLINGER, DEPT. OF CROP AND SOIL SCIENCES, WSU

The United States Energy Independence and Security Act of 2007 mandates the use of 36 billion gallons of biofuel by 2022 with 21 billion gallons being derived from advanced biofuel feedstocks. To meet this goal, the United States Department of Agriculture developed a strategy entitled "A USDA regional roadmap to meeting the biofuels goals of the Renewable Fuels Standard by 2022" in which it is anticipated that 4.6% of the advanced biofuels would be produced in the northwestern United States. Although progress is being made in growing oilseeds for advanced biofuels, little is known concerning the impact of growing oilseed crops on environmental resources.



Fig. 1. Wind erosion assessed using a wind tunnel after sowing winter wheat at Lind, WA in August 2011.

We examined the impact of growing oilseeds in a winter wheat-summer fallow rotation on wind erosion and PM10 (particles $\leq 10\mu\text{m}$ in diameter) emissions in eastern Washington state where atmospheric PM10 is an acute environmental concern. Wind erosion and PM10 emissions were measured at the end of the fallow phase of a winter wheat-summer fallow versus a winter wheat-camelina-summer fallow rotation or a winter wheat-safflower-summer fallow rotation in 2011 and 2012. In addition, camelina and safflower were direct seeded into standing stubble of the preceding winter wheat crop. The undercutter implement, a conservation tillage tool, was used for primary tillage during fallow in all rotations. A portable wind tunnel was used to assess horizontal sediment and PM10 flux after sowing wheat (Fig. 1).

Our results indicate that total sediment and PM10 flux were as much as 200% higher from the wheat-oilseed-fallow rotation

compared with the wheat-fallow rotation (Table 1). The higher sediment and PM10 flux from the oilseed rotation was likely due to lower biomass of crop residue following the oilseed versus wheat crop.

Table 1. Horizontal sediment flux measured after sowing wheat into a winter wheat-summer fallow and winter wheat-camelina-summer fallow rotation at Lind, Washington and a winter wheat-summer fallow and winter wheat-safflower-summer fallow rotation at Ritzville, Washington.

Location	Year	Sediment flux ($\text{g m}^{-1} \text{min}^{-1}$)	
		Wheat	Oilseed
Lind	2011	68	201
	2012	310	696
Ritzville	2011	344	674
	2012	232	634

Wind erosion and PM10 emissions may be accentuated by growing oilseeds in the low precipitation drylands of the Pacific Northwest. Therefore, the practice of conservation tillage and no-tillage for residue retention will be paramount to controlling wind erosion and PM10 emissions from oilseed cropping systems in the region.

Safflower Cropping Systems Experiment in the Low-Precipitation Zone

WILLIAM SCHILLINGER¹, RON JIRAVA², JOHN JACOBSEN¹, AND STEVE SCHOFSTOLL¹

¹DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND; ²COLLABORATING GROWER, RITZVILLE

Acronyms used: SAF, Safflower; SW, Spring wheat; TF, Tilled fallow; WW, Winter wheat

The objective of this study is to evaluate safflower production potential when grown in a 3-year winter wheat-safflower-tilled summer fallow (WW-SAF-TF) rotation compared to several cereal-only rotations. The WW-SAF-TF rotation is incorporated in long-term dryland cropping systems experiment on the Ron Jirava farm located west of Ritzville, WA. Annual precipitation at the site over the past 15 years has averaged 10.6 inches.

We compare the WW-SAF-TF rotation with another 3-year rotation, winter wheat-spring wheat-tilled fallow (WW-SW-TF) and the traditional 2-year rotation of winter wheat-tilled fallow (WW-TF). Each phase of all rotations is present each year and there are four replicates. Size of individual plots is 500 ft x 30 ft. Soil water is measured in all plots after grain harvest, in early April, and from fallow in early September. Treflan, a soil-residual herbicide, is applied in March to be rain incorporated into plots that will be sown to safflower. Safflower is direct seeded (Fig. 1) at a rate of 40 lbs/acre + fertilized into standing and undisturbed winter wheat stubble in April. Grain yield is determined with a commercial-sized combine and a weigh wagon.



Fig. 1. Safflower is direct-seeded into standing and undisturbed winter wheat stubble. These safflower plants were still in the juvenile stage of growth in mid-May 2012, but grew rapidly thereafter.

Grain yield of safflower averaged 880 lbs/acre in 2012. For comparison, grain yield of spring wheat and spring barley (also planted recrop, i.e., no fallow) at the site averaged 30 bushels/acre and 1960 lbs/acre, respectively. Safflower was planted on April 9, 2012. Air and soil temperatures were cold throughout the month of April and safflower seedlings were still emerging well into the month of May. In the 2013 crop year, we chose to wait until late April to plant safflower. This allowed an additional glyphosate herbicide application just before planting and likely promoted more rapid and uniform emergence. Soil water dynamics, weeds, and effects of safflower on subsequent winter wheat grain yield are measured. Winter wheat grain yield in 2012 in the WW-SAF-TF, WW-SW-TF, and WW-TF rotations was 62, 79, and 75 bushels/acre, respectively.

Long-term Camelina Cropping Systems Experiment at Lind

W.F. SCHILLINGER, J.A. JACOBSEN, S.E. SCHOFSTOLL, B.S. SHARRATT, AND B.E. SAUER
DEPT. OF CROP AND SOIL SCIENCES, WSU; USDA-ARS

The objective of this study is to determine the long-term suitability of camelina in the typical winter wheat-summer fallow cropping zone of eastern Washington. This would allow farmers to plant crops in two out of three years (i.e., increase cropping intensity) instead of only once every other year as currently practiced.

We are currently in year five of a 9-year cropping systems experiment to evaluate camelina produced in a 3-year winter wheat-camelina-fallow rotation compared to the 2-year winter wheat-fallow rotation. Experimental design is a randomized complete block with four replicates. There are 20 plots, each 250 ft x 30 ft in size. Camelina is direct drilled + fertilized into standing wheat stubble during the first week of March. Winter wheat is planted into fallow in late August. Soil water content to a depth of six feet is measured in all 20 plots after camelina and winter wheat harvest in July and again in March, and from the eight fallow plots in late August just before planting winter wheat. Weed species in all camelina and wheat plots are identified, counted, and collected just before grain harvest and above ground dry biomass of each weed species is determined. Surface residue remaining after planting WW in both rotations is determined using the line-point method. The susceptibility of newly-planted winter wheat plots to wind erosion is determined by Brenton Sharratt using a wind tunnel.

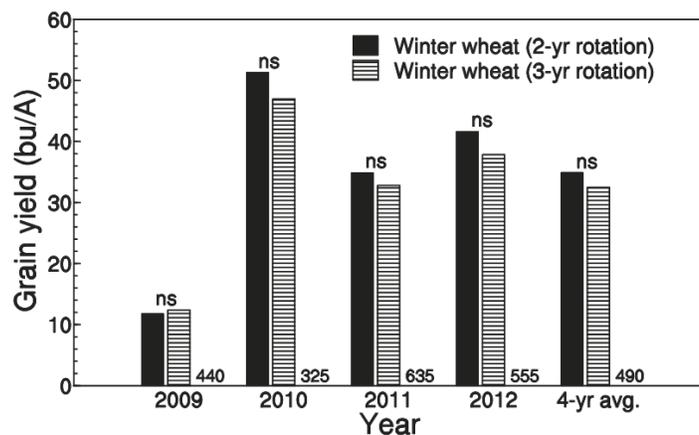


Fig. 1. Winter wheat grain yield grown in a 2-year winter wheat-fallow rotation versus a 3-year winter wheat-camelina-fallow rotation. Numerical values are camelina grain yield (lbs/acre) for each year and the 4-year average. ns = no significant differences. This long-term cropping systems experiment is conducted at the WSU Dryland Research Station near Lind.

difference being Russian thistle plants tend to be few but large in wheat and small but more numerous in camelina. The benefits of camelina in the crop rotation to control downy brome was readily apparent in 2012 where we obtained complete control of this grass weed (data not shown) with the post-emergence application of Assure II herbicide. We have learned from previous research that the best overall planting date for camelina throughout the Pacific Northwest is late February-early March. This is also the best planting window for weed control as it allows glyphosate (or other non-soil-residual herbicide) to be applied before planting to control winter-emerging broadleaf weeds.

There were no statistically significant winter wheat grain yield differences in the 2-year versus 3-year rotations in 2012 or when averaged over the four years; however, the yield bar is

Camelina grain yield in 2012 averaged 555 lbs/acre (Fig. 1 and Fig. 2). Crop year (Sept. 1 – Aug. 31) precipitation at the site was 11.09 inches (1.6 inches greater than normal for Lind). Why didn't camelina have a greater grain yield in a "wet" year? First, it was a cold spring. Secondly, only 0.24 inches of rain was received in May, a month during which camelina usually rapidly increases above-ground biomass. Our observation was that growth of camelina occurred at a slower rate in May 2012 compared to previous years. The 4-year (2009-2012) average camelina grain yield is 490 lbs/acre (Fig. 1) produced with an average 9.49 inches of crop-year precipitation.

The main weeds in camelina in 2012 were Russian thistle and tumble mustard, although the dry biomass produced by both of these weeds in 2012 was less than the 4-year average (data not shown). Over the four years, Russian thistle has produced slightly (but not significantly) more dry biomass in winter wheat than in camelina; the



Fig. 2. WSU Research Technician, John Jacobsen, in the camelina cropping systems experiment at Lind in late May, 2012.

generally slightly lower in the 3-year rotation (Fig. 1). This yield trend is likely due to soil water. Averaged over the four years, total water in fallow at the time of winter wheat planting in late August is 0.5 inches greater ($P < 0.001$) in the 2-year compared the 3-year rotation (Table 1). There are no differences in soil water content after the time of harvest of wheat and camelina nor are there differences in over-winter water gain on WW versus camelina stubble. The differences in water loss between the two fallow rotations occur during the summer ($P < 0.005$, Table 1). The average of 0.5 inches more water in the 2-year rotation would account for the 3-4 bushels/acre winter wheat grain yield increase in the 2-year rotation.

Why is greater water loss occurring during the summer in the 3-year rotation when both fallow systems are treated the same (i.e., plots are always undercut, rodweeded, and planted to winter wheat at the same time)? The answer could be that greater surface residue in the 2-year rotation provides better shading. Line-point residue measurements obtained after planting of winter wheat in 2012 showed 35% residue cover in the 2-year rotation versus 18% in the 3-year rotation ($P < 0.02$). These differences have been statistically significant every year and when averaged over the four years ($P < 0.001$, data not shown).

Table 1. Soil water content at the beginning (after harvest), early spring, and end of fallow (before planting) and associated gain or loss of water and precipitation storage efficiency (PSE = gain in soil water/precipitation) in the 6-ft soil profile in summer fallow in a 2-year winter wheat-summer fallow rotation versus a 3-year winter wheat-camelina-summer fallow rotation. The top portion of the table shows water content during the 2011-2012 fallow cycle and the bottom portion of the table shows water content for the 4-year average.

	Timing in fallow period					PSE [†] (%)
	Beginning (late Aug.)	Spring (mid Mar.)	Over-winter gain	End (late Aug.)	Mar. to Aug. water	
Soil water content (inches)						
<u>A. 2011-2012</u>						
Fallow treatment						
After winter wheat (2-yr rotation)	5.7	8.1	2.4	9.0	+ 0.9	30
After camelina (3-yr rotation)	5.8	8.6	2.8	9.1	+ 0.5	30
p-value	ns	ns	ns	Ns	ns	ns
<u>B. 4-year average</u>						
Fallow treatment						
After winter wheat (2-yr rotaion)	6.1	9.3	3.2	8.9	- 0.4	29
After camelina (3-yr rotation)	5.8	9.3	3.6	8.4	-0.9	26
p-value	ns	ns	ns	0.001	0.005	ns

Camelina: What Will it Take to Make this Crop Attractive to Pacific Northwest Growers?

W.F. SCHILLINGER, DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND

What will it take to make camelina production attractive to growers? During the past winter, I discussed this question with progressive farmers from Washington, Oregon, Idaho, Montana, and Colorado. The main factor is price. The price offered to PNW farmers for camelina seed in the past several years has ranged from \$0.12 to 0.15 per pound. During this same time period, the price offered for canola seed has been \$0.24 to 0.30 per pound (i.e., double). There are several oilseed crushing facilities in Washington and Oregon – all geared to “cold press” canola seed for oil extraction. The same crushing machinery can be used to cold press camelina seed, but crushers need certain minimum quantities of seed to keep their facilities in full-time operation.

All growers with whom I talked said they would sign contracts to produce camelina for \$0.30 per pound. Included in this price was an agreement to deliver the camelina seed to a crushing facility within a 40 mile (one way) hauling distance from their farm. Two growers said they would consider producing camelina for a guaranteed \$0.25 per pound. None of the growers interviewed would produce camelina for less than \$0.25 per pound.

Unlike canola, crop insurance for camelina is not yet available through the USDA crop insurance program. All growers interviewed mentioned the lack of crop insurance as a drawback to growing camelina, but more than half said they would be willing to take the risk due to the fact that camelina is a hardy plant and camelina seed yield for a given quantity of precipitation appears to be relatively stable and predictable.

A third factor for the slow adoption of camelina production is the US Food and Drug Administration (FDA) has not yet provided approval for camelina oil for human consumption. Approval will likely come with time but, until then, camelina oil cannot be sold in the US for human food. The FDA has approved camelina meal (a very valuable by-product after oil extraction) for up to 10% of the total ration fed to cattle and poultry.

I also discussed the question of how to increase camelina production with owners of two PNW oilseed crushing facilities. Both facilities have crushed camelina in the past and would welcome future opportunities. One plant crushed 1000 metric tons of camelina seed in 2012 with all the oil exported to other countries for human consumption. Both of the crushing plant owners stated that, if the grower required \$0.25 or 0.30 per pound to deliver camelina seed, they would sell the oil at \$0.55 or 0.60 per pound. The oil would be shipped FOB (freight on board) in totes of 275 gallons or bladders of 6,500 gallons. A dedicated food-oil rail tanker car with a capacity of 25,000 gallons would also be suitable for oil shipment. Both crushing facility owners said they could process about 35 metric tons of seed per day, but would need to have at least of three month supply seed (3200 tons) to make it worthwhile. Both owners said that they would keep the camelina meal as part of the business deal.



Bruce Sauer, in the camelina cropping systems experiment study at Lind, WA.

From discussions with farmers and crushing facility owners, the meal from camelina seed is about of equal monetary value as the oil. Cattle producers are eager to buy camelina meal because, in addition to being high in protein and vitamin E, camelina meal is also a great source of omega 3 fatty acids and energy. The combination of these attributes is beneficial in healthy weight gain for cattle.

In summary, it appears that the following are “drivers” for increasing production of camelina in the inland Pacific Northwest:

1. The farmer needs to receive \$0.30 per pound for camelina seed.
2. The crushing facility will sell camelina oil for \$0.55 to 0.60 per pound FOB.
3. Farmers will want a guaranteed price in their production contract.
4. If an individual crushing facility needs a minimum of 3200 tons of camelina seed, then between 3,000 and 12,000 acres of production need to be contracted, depending on the cropping zone (i.e., low, intermediate, or high precipitation).

Development of Herbicide Tolerant Camelina Varieties

SCOT HULBERT^{1,2} AND IAN BURKE²; ¹DEPT. OF PLANT PATHOLOGY; ²DEPT. OF CROP AND SOIL SCIENCES, WSU

Camelina is a low input oilseed crop that we and others are trying to develop as a rotation crop for wheat, especially in the low-intermediate rainfall areas where few good rotation crops are available. One hindrance of establishing Camelina production in the Pacific Northwest has been its intolerance to residual levels of commonly used herbicides, especially group 2 herbicides (imidazolinones and sulfonylureas), which can damage subsequent camelina crops for several years. The problem is exacerbated by the growing popularity of Clearfield wheat varieties which are commonly sprayed with Beyond, an imidazolinone herbicide. We have generated a mutant line that is tolerant to both types of herbicides. Breeding populations established from the mutant were unaffected by the herbicide when planted after a Clearfield wheat crop to which four times the labeled rates of beyond had been applied. Plants in the control camelina variety plots (non-mutant) were generally destroyed except for occasional plants that set seed (Table 1). This demonstrated the utility of the mutation in reducing risk of including camelina in crop rotations without restricting the use of these herbicides.

Table 1. Plot yields of camelina varieties and the herbicide tolerant (HT) line planted in Pullman after wheat plots sprayed with different rates of Beyond herbicide.

<u>Camelina line</u>	<u>Rate*</u>	<u>Yield/plot</u>
Calena	0X	305
Cheyenne	0X	300
HT line	0X	302
Calena	1X	233
Cheyenne	1X	254
HT line	1X	308
Calena	2X	113
Cheyenne	2X	134
HT line	2X	308
Calena	4X	7
Cheyenne	4X	8
HT line	4X	319

* 0X = no beyond application. 1X, 2X, 4X are one, two and four times the recommended rate of Beyond herbicide sprayed on the previous seasons winter wheat crop.

No public or private camelina breeding programs are present in the region so we have begun a breeding program to make high yielding, high oil varieties that are adapted to PNW growing conditions and herbicide tolerant. Our original mutant line has been crossed to several camelina lines that have performed well in regional variety tests. This summer (2013) will be the second year of testing several hundred advanced lines made from these crosses. We hope to release a herbicide tolerant variety to potential growers in 2015.

In addition to yield and oil content we are collecting germplasm and evaluating lines for several important agronomic traits. Stand establishment is one of the biggest problems with camelina production because the seed is very small and only emerges from very shallow plantings. There is considerable variation for seed size in camelina germplasm so we hope to make larger seeded varieties in the future. We are beginning a study to determine if this will have an adverse effect on oil content. Another important trait is rapid early season growth which should make stands more competitive with weeds, another problem with camelina production. Some camelina lines with larger seeds also have more vigorous seedlings. There are currently no broadleaf herbicides registered for camelina production. The herbicide sethoxydim (Poast®) has recently been registered for postemergence application to control grass weeds but provides little control of broadleaf weeds. Since we had good success in finding mutants tolerant to group 2 herbicides, we are beginning to select for mutations that provide resistance to other broadleaf herbicides. This may allow us to add to our weed control tools for this emerging crop.



Variation for seed size in camelina germplasm

For additional information on camelina production, see <http://cru.cahe.wsu.edu/CEPublications/FS073E/FS073E.pdf>

Increasing Seed Size and Seedling Emergence in the Brassicas *Arabidopsis* and Camelina

MICHAEL M. NEFF, DAVID FAVERO, PUSHPA KOIRALA, JIWEN QIU AND JIANFEI ZHAO
DEPT. OF CROP AND SOIL SCIENCES, WSU; AND 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. Unfortunately, few mechanisms have been identified that uncouple adult stature from seedling height. The Neff lab has identified a group of plant-specific genes that, when mutated in particular ways, increase seed size and seedling height without adversely affecting adult stature. These genes encode AHL (AT-Hook Containing, Nuclear Localized) proteins. In the Brassica *Arabidopsis thaliana*,

we have identified a unique mutation (*sob3-6*) in one of these genes, *SOB3/AHL29*, that expresses a protein with a disrupted DNA-binding domain and a normal protein/protein interaction domain. In *Arabidopsis*, this dominant-negative mutation confers normal adult plants that produce larger seeds and seedlings with hypocotyl stems that are up to twice as long as the wild type. We have recently identified two more types of dominant-negative mutations that lead to the same *sob3-6-like* seedlings, which are larger than the wild type (Fig. 1). One of these dominant-negative mutations is caused by the complete removal of the DNA binding domain. The second dominant-negative mutation is caused by the removal of six amino acids that are necessary for AHL interactions with DNA-binding transcription factors. We have also shown that expressing *sob3-6* in the Brassica *Camelina sativa* leads to larger seeds and taller seedlings with no negative impact on adult size. With this 30% increase in hypocotyl length in camelina, we have shown that these larger seeds and taller seedlings can dramatically enhance emergence from deep planting (8 cm) in dry soil (Fig. 2). We are currently identifying AHL-interacting factors to further understand how these DNA-binding proteins regulate seeding development and emergence in dry soils.

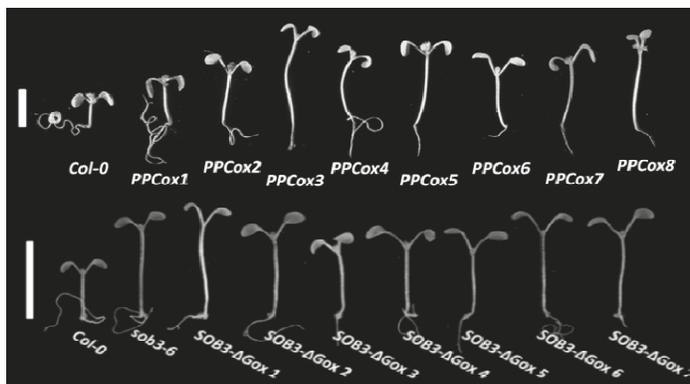


Fig. 1. Over-expressing an AHL protein in *Arabidopsis* lacking the AT-hook domain leads to taller seedlings (top). The same phenotype can be obtained with an AHL protein that lacks six amino acids (bottom). Scale Bars = 1 cm. Adapted from Zhao et al. (in review PNAS).

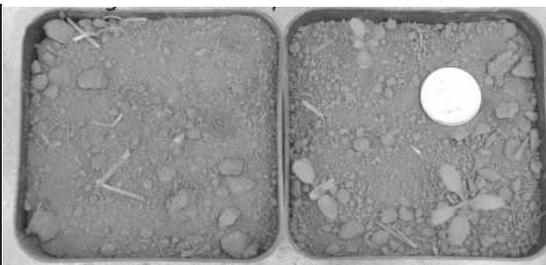


Fig. 2. *Camelina* expressing the *sob3-6* mutation emerge from deep planting in dry soil. Non-transgenic (left) and transgenic (right) seeds were planted on 1 cm of moist Palouse silt/loam and covered with 8 cm of dry silt/loam. All seeds germinated. 5 of 10 transgenic seeds emerged, 3 survived. Experiment repeated twice.

International Commitment

WILLIAM L. PAN, DEPT. OF CROP AND SOIL SCIENCES, WSU

Prior to his service as Chair of CSS, Pan accompanied then Chair Dr. Tom Lumpkin on trips to China, Egypt and central Asia. Upon leaving WSU, Tom became a global agricultural leader, and as he turned over the departmental reigns, Bill promised to continue the department's active engagement with international projects and programs. This commitment extended a CSS commitment to wheat breeding collaborations in central Asia, and a new project on Iraq Agricultural Extension Revitalization (IAER). Pan co-designed and coordinated training sessions with WSU International Programs for Iraqi Extension personnel. A highlight experience for Pan was a trip to Baghdad shortly after the fall of Saddam Hussein. Transportation was complements of the US military via C130 cargo plane, a gunner-manned transport helo, and an armored ground vehicle through one the most contested 6 miles in the world at the time between the Baghdad airport and the US Green Zone surrounding Saddam Hussein's captured lavish palace. The US was preparing to evacuate the palace and return it to the people of Iraq. Training sessions focused initially on dryland agronomy and soil fertility, then expanded to womens' role in agriculture, food safety, organic agriculture, grazing and forage production, and soil/water conservation. Sessions were conducted in Washington State, Egypt, Syria and Jordan. More than 60 CSS and affiliated WSU faculty, staff and students participated in the training sessions, motivating many to continue their involvement in subsequent international projects.



Iraqi Extension Specialist expresses his gratitude for the IAER training opportunity and tour of irrigation systems at WSU IAREC

Make a GIFT OF Grain!

For over a century, Washington State University has partnered with farmers—developing new crop varieties, solving problems from kernel to storage, and educating the next generation to be leaders, thinkers, and global citizens. Your gift of wheat, barley, garbanzo beans, or other crops will ensure we can continue our important work in support of Washington farmers. Please consider supporting an excellence fund for one of our most important tools—the field research farms—Cook, Lind, and Spillman. Or we welcome your support of any area at WSU including 4-H, athletics, or scholarships.



How Gifts of Grain works:

- If you *are NOT* an active, self-employed farmer, have the elevator sell your donated crop and send the check to the WSU Foundation. Your gift will be receipted and you may take a charitable deduction.
- If you *ARE* an active, self-employed farmer using cash basis accounting:
 - You may realize a greater benefit than provided by a charitable deduction by gifting grain from unsold inventory produced in the preceding year. This way you can deduct all production costs while avoiding federal income tax and self-employment tax on the fair market value of your gift.
 - To maximize the tax benefits, the WSU Foundation must be the seller of the gifted crop. Have the local grain elevator make the receipt out to the WSU Foundation and let the Foundation know what area at WSU you would like to benefit.

For more information, contact:

Office of Alumni and Friends
College of Agricultural, Human,
and Natural Resource Sciences
(509) 335-2243

www.giftsofgrain.wsu.edu

WASHINGTON STATE
 UNIVERSITY

World Class. Face to Face.

GRAIN ELEVATORS
be sure to sign up for the
Gift of Grain Challenge!





Photos: (clockwise from top left) Winter canola in full bloom at Curtis Hennings' farm near Ralston, photo courtesy of Karen Sowers; Austrian winter peas on Mike & Gerry Stubbs' farm (west of Dusty), photo courtesy of Karen Sowers; Palouse fields, photo courtesy of Sandy Neff.

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