

# 2015 Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS

CELEBRATING THE 100-YEAR ANNIVERSARY OF THE WSU DRYLAND RESEARCH STATION



WASHINGTON STATE UNIVERSITY  EXTENSION

WSU Dryland Research Station Field Day—Lind, June 11, 2015  
WSU Spillman Farm Field Day—Pullman, July 14, 2015

Department of Crop and Soil Sciences  
Technical Report 15-1

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## ***Welcome to our 2015 Field Days!***

As Chairman of the Department of Crop and Soil Sciences, I am proud to present the ***2015 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 <http://www.css.wsu.edu>. There you will find detailed information about faculty members and research programs in the Department.

Crop and Soil Sciences is growing! Since Summer 2013, we have made new hires in Agricultural Education (Dr. Candis Carraway), Soil Microbiology (Dr. Tara Sullivan), Barley and Alternative Crop Breeding (Dr. Kevin Murphy), Crop Physiology (Dr. Karen Sanguinet), and Quantitative Genetics (Dr. Zhiwu Zhang). We are near the end of a search for an Assistant Professor of Soil Nutrient and Residue Management, who will cover research and extension in dryland cropping systems. Soon we will begin a search for an Endowed Chair in Tree Fruit Soil and Rhizosphere Ecology, who will tackle soil health issues in perennial crops. We are excited to have these new faculty members join us in our efforts to solve the problems facing the agricultural industry. Our entire faculty works collaboratively with others here and worldwide to bring innovative solutions to agriculture.

We are engaged in many research activities of local, regional, national, and global importance. Our 2015 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.

Thank you for your continued support!

Sincerely,



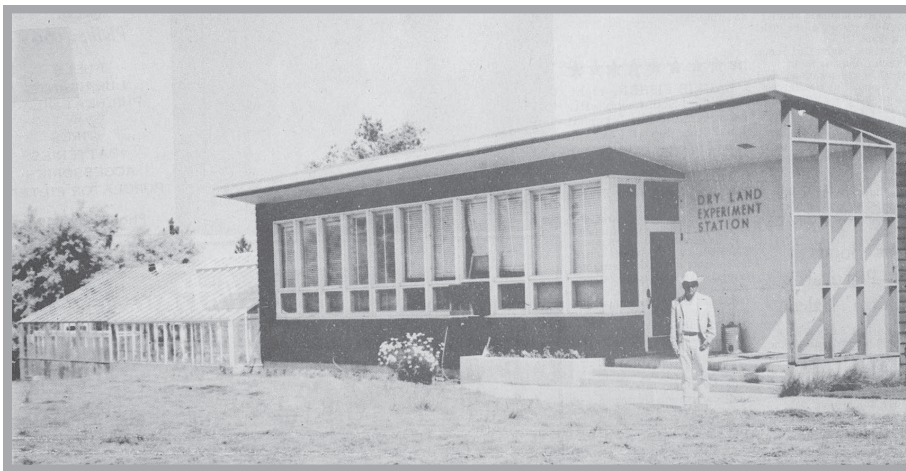
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Technical Report 15-1  
Samantha Crow and William Schillinger, Editors

## WSU Dryland Research Station Celebrates its 100-Year Anniversary

The Washington State University Dryland Research Station was created on April 1, 1915. As we look back over the past century, we find that some problems facing farmers in 1915, such as wind erosion, are still present, whereas other problems have been completely solved and progress has been truly remarkable. For example, average winter wheat grain yields in Adams County Washington in 1910 were about 10 bushels/acre compared to nearly 50 bushels/acre today.

The need for research in the dry region of east-central Washington was first expressed by pioneer farmers who arrived as early as 1878. To ensure progress and stability, the first settlers had much to learn about farming in the semiarid Inland Pacific Northwest where the climate was considerably different than anywhere else in the United States and most places in the world. Advocacy by dryland farmers and political leaders fostered public support for establishing an agricultural research station to promote the betterment of farming in the 6-to 12-inch annual precipitation zone of east-central Washington. This low-precipitation region encompasses approximately three million cropland acres, which is sixty percent of Washington's wheat production area.



Dick Nagamitsu in front of the Lind Dryland Research Station's office building in 1965. Nagamitsu worked at the Lind Station as a research technician for 38 years. Photo is from the *Lind Lens*.



Edwin Donaldson, hard red winter wheat breeder at Lind from 1972-1999.

Adams County deeded 320 acres of land near Lind for creation of the WSU Dryland Research Station. State Senator Mark Schoesler led a successful effort in 1997 to transfer ownership of 1,000 acres of adjoining state-owned farmland to the Lind Station.

The Lind Station has served as an official recording site for the U.S. National Weather Service since 1921. Average annual precipitation is 9.54 inches. The Lind Station receives less precipitation than any other state or federal dryland agriculture research facility in the United States.

Research efforts at Lind during the past century have largely centered on wheat. Wheat breeding, weeds, diseases, soil fertility, plant stand establishment, and residue management to control wind

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Lowell Rasmussen speaking on chemical weed control at the 1948 Field Day.

erosion have all received major focus. In the last several decades, research on no-till management, long-term cropping systems, adaptation of oilseed and legume crops, winter triticale agronomy, and biosolids application on soil fertility and soil quality have also been research priorities.

Annual field days have been held at the Lind Station since 1916 with

the exception of 1980 due to the Mount St. Helens eruption. Visit our website at [lindstation.wsu.edu](http://lindstation.wsu.edu) for more information, including full downloads of major publications from research conducted at the Lind Station and in farmers' fields during the past 100 years.



Walter Nelson, Superintendent of the Lind Station from 1950-1971, shown here in 1964.



WSU graduate student Mike Lindstrom presenting tillage experiment results at the 1970 Lind Field Day.

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 Schultheis, Art—Colton  
 Schultheis, Harold—Colton  
 Seney, Byron—Dayton  
 Sheffels, Jerry—Wilbur  
 Sheffels, Mark—Wilbur

Silflow, Brian—Kendrick, ID  
 Small, Mark/Seth—Walla Walla  
 Smith, Glen—Waitsburg  
 Smith, Steve—Horse Heaven Hills  
 Smith, Tim—Ritzville  
 Snyder, Jerry—Ralston  
 Sorensen, Mitch—Wilbur  
 Spangler, Dennis—Connell  
 Starkel, Doug—Odessa  
 Stubbs, Gerry/Mike—Lacrosse  
 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  
 Vowel, Jacob—Princeton, ID  
 Walli, Robert—Ritzville  
 Walters, Craig—Palouse  
 Warner, Ed—Harrington  
 Warren, Gene—Dayton  
 Wesselman, Roger—Mansfield  
 Weishaar, Robin—Odessa  
 White, Gil—Lamont  
 Whittman, John/Nick—Genesee, ID  
 Wilson, Eldon—Harrington  
 Zenner, Russ/Clint—Genesee, ID

#### 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 Conservation District  
Columbia Grain Int'l.  
Columbia River Carbonates  
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  
Helena Chemical Company  
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  
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.

Historically, the PCFS 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. 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.

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.

## 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.



William J. Spillman, breeding plots at Pullman, 1900

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 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 four 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.



Spring canola in bloom at the WSU Wilke Research and Extension Farm in 2013

The Wilke farm is split by State Highway 2. The north side has been in continuous winter or spring cereal production for approximately 20 years and being cropped without tillage for the past 15 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.

## Wheat Variety History at WSU

VARIETY.....YEAR RELEASED ..... MARKET CLASS..... BACKGROUND / NAMED AFTER

### SPILLMAN

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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

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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

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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

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

### ALLAN

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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

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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

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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

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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

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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

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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 Co.
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

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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  
 Puma ..... 2013 ..... SWW..... Alternate name for a Cougar  
 Jasper..... 2014 ..... SWW..... WSU wheat breeder William Jasper Spillman; 100th variety released by WSU

GILL

Curiosity CL+ ..... 2013 ..... SWW..... 2-Gene Clearfield variety named after Mars rover  
 Mela CL+ ..... 2013 ..... SWW..... 2-Gene Clearfield variety ideally suited for low rainfall and typical Eltan growing areas

PUMPHREY

Chet ..... 2014 ..... HRS..... Chester "Chet" Stonecipher, Waitsburg wheat grower & wheat commissioner  
 Alum ..... 2014 ..... HRS..... To honor Cougar alum's in the WA wheat industry and because it is aluminum tolerant  
 Seahawk ..... 2014 ..... SWS ..... Seattle Seahawks football team, great defense, solid offense

## 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)
Richard..... 2014	spring, 2-row, feed .....	von Wettstein/...	selection from Apex <sup>ant-499</sup> /Alexis/Baronesse/Cellar (named after Rutsgi                      Richard Wettstein)
Havener..... 2015	spring, food.....	Murphy .....	Hulless food barely named after Bob and Liz Havener

## 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.

Hampton – Green cotyledon dry pea released in 2014 by USDA-ARS. It is very high yielding and resistant to Pea Enation Mosaic Virus, Bean Leaf Roll Virus, Fusarium wilt race 1 and powdery mildew. Its name honors Dr. Richard Hampton, Oregon State University, Professor of Plant Pathology.

#### 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 as a cover crop and for wildlife food plots.

PS03101269 – Autumn-sown, green cotyledon pea released in 2013 by USDA-ARS. It is semi-leafless, has long internodes and white, unpigmented flowers and clear seed coat and colourless hilum. Released as a breeding line.

#### LENTILS

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##### Spring Lentils

###### Large Green

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

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.

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

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

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.

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

###### Medium Green

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.

Avondale – A medium green market class lentil. Avondale was released by USDA-ARS in 2013. It has yellow cotyledons and a green, unmottled seed coat. It is widely adapted to the Palouse as well as the Northern Plains.

###### Small Green

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

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

###### Spanish Brown

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.

Morena – A small Spanish Brown type. Morena was released by USDA-ARS in 2010. It has yellow cotyledons and a brown, slightly speckled seed coat.

###### Turkish Red

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.

Zero Tannin

Cedar – A red cotyledon lentil with a seed coat without tannins. The bright red colour of the cotyledons is apparent in whole, unhulled seeds.

Shasta – A yellow cotyledon lentil with a seed coat without tannins. The colour of the cotyledon is apparent in the whole lentil.

Specialty

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

Winter LentilsTurkish Red

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.

Nash—A very large seeded Café type kabuli chickpea released in 2013 by the USDA-ARS. Nash consistently produces higher yields and more 'A' size seeds compared to Sierra and Sawyer in the Palouse region of Washington and Idaho. The variety has fern type leaves.

Royal—A large seeded Café type kabuli chickpea released in 2013 by the USDA-ARS. Royal consistently produces higher yield and more 'A' type seeds compared to Sierra and Sawyer in yield trials conducted in areas of eastern Washington that annually receive 14-18" of rain. The variety has simple type leaves.

Desi Type

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



## Part 1. Agronomy and Soils

### How Much Lime to Apply?

CAROL MCFARLAND<sup>1</sup>, KENDALL KAHL<sup>1</sup>, DAVID HUGGINS<sup>2</sup>, LYNNE CARPENTER-BOGGS<sup>1</sup>, RICH KOENIG<sup>1</sup>, JOEY BLACKBURN<sup>3</sup>, KURT SCHROEDER<sup>4</sup>, AND TIM PAULTZ<sup>2</sup>

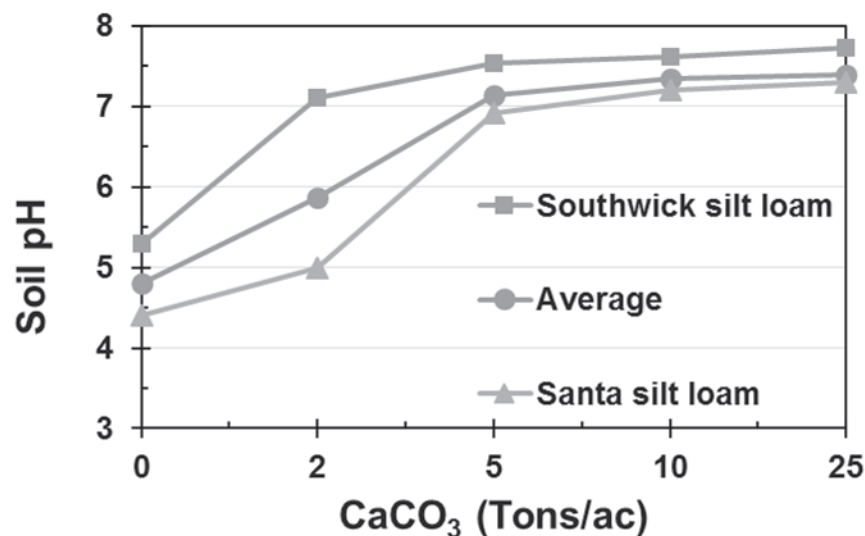
<sup>1</sup>DEPT. OF CROP AND SOIL SCIENCES, WSU; <sup>2</sup>USDA-ARS; <sup>3</sup>LOUISIANA STATE UNIVERSITY; <sup>4</sup>UNIVERSITY OF IDAHO

Soil acidification is an ongoing process in many parts of eastern Washington and northern Idaho. Researchers, farmers, crop consultants and agricultural professionals in this region have been finding pH values of 5 and even lower. These pH values, are below the tolerance thresholds of many crops common to the region.

It is well known that liming can improve key components of soil health, such as raising pH, and improving soil health, which often has direct benefits to crop performance. The properties of agricultural soils in eastern Washington and northern Idaho, which include cut-over timber soils as well as those which were natively prairie, are unique and not typical of "acid" soils. Past research suggests that the historically forested soils may be at higher risk for acidification, but may respond more quickly to lower amounts of lime because of their reduced ability to buffer changes in pH. The ability of a soil to buffer changes in pH can be used to estimate lime requirement. The use of "buffer tests" to estimate the lime required to reach a "target" pH, is standard practice in many parts of the world with a legacy of acid soils. To date, these tests have not been properly calibrated for the soils of eastern Washington and when performed, appear to overestimate the amount of lime required.

We performed a laboratory-based experiment by adding pure  $\text{CaCO}_3$  to ten agriculturally significant soils from Whitman, Latah, Spokane and Columbia counties. This experiment was designed to improve our understanding of the quantity of lime that will be required to raise these soils to a desired "target" pH under ideal conditions. The experiment is currently being re-run with lower quantities of lime. It will be used to evaluate and calibrate buffer tests and other methods of estimating lime requirement that may be more appropriate for the agriculturally significant soils of the eastern Washington and northern Idaho. Concurrent with this experiment, we are comparing four lime products commonly available in the region, to understand the time period required for the products to impact soil pH and the impact each of them may have on plant-available nutrients.

This research is part of a collaborative effort to better understand the implications and trends of anthropogenic acidification on these soils and pursue applied research that will help inform management decisions and the development of regionally suitable liming programs. Please visit the Soil and Water Resource page of the WSU Small Grains website for more information. Thanks go to the Washington Grain Commission for their support of this work!



## Value of a Sweep Application in No-Till Fallow

A.D. ESSER<sup>1</sup> AND R. BRUNNER<sup>2</sup>

<sup>1</sup>WSU EXTENSION; <sup>2</sup>WHEAT PRODUCER

Farmers across the intermediate (300-450 mm annual precipitation) cropping region of Eastern Washington traditionally use a tillage based summer fallow-winter wheat (*Triticum aestivum* L.) system. By adopting conservation tillage, farmers have increased implementation of no-till summer fallow (chemical fallow) systems to reduce erosion and increase profitability; however they have expressed concerns regarding adequate seed zone soil moisture and consistent control of tough weeds. The main objectives with this research project was to examine the value of a one-time "sweep" cultivation to improve seed zone moisture and kill weeds that can be troublesome with a cost effective herbicide application compared to a true no-till fallow system. An on-farm trial (OFT) established over four years examined the impact of a single "sweep" cultivator operation in fallow on seed zone soil moisture, yield, grain quality and economic returns. Weed data was not collected but visual observations were made. The treatments were no-till fallow (NTF) and a sweep operation replacing the second of three herbicide applications in the no-till fallow system. The OFT was a randomized complete block design with four replications.

The sweep operation did not significantly increase seed zone moisture, grain yield, test weight, or economic returns. Grain protein was less following the sweep application, averaging 9.4% compared to 9.8% in the NTF. The sweep treatment, as anticipated, was an adequate weed control operation. In conclusion the sweep operation did not increase seed zone moisture, but was effective removing weeds that can be difficult to control with a cost effective herbicide application.

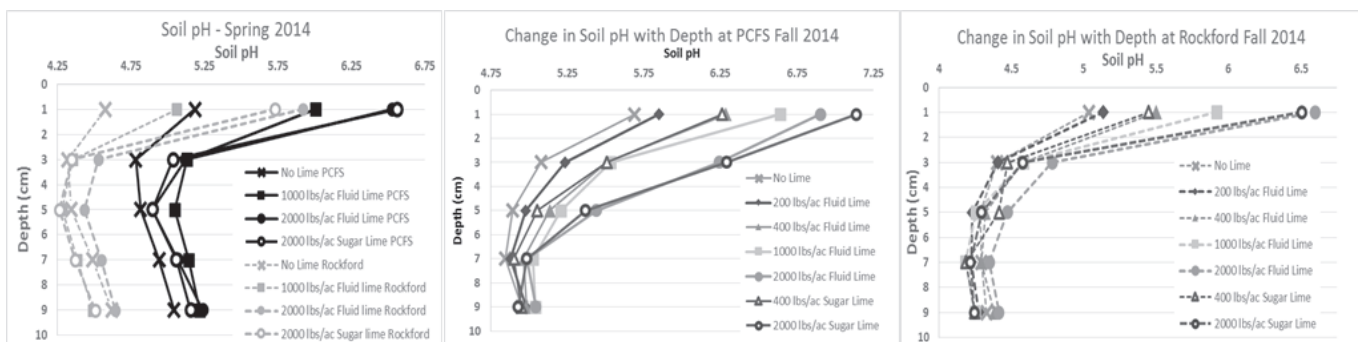
## How Surface-Applied Lime Products Affect Soil Fertility

CAROL MCFARLAND<sup>1</sup>, DAVID R. HUGGINS<sup>2</sup>, LYNNE CARPENTER-BOGGS<sup>1</sup>, RICH KOENIG<sup>1</sup>, JOEY BLACKBURN<sup>3</sup>, KURT SCHROEDER<sup>3</sup>, AND TIM PAULTZ<sup>2</sup>

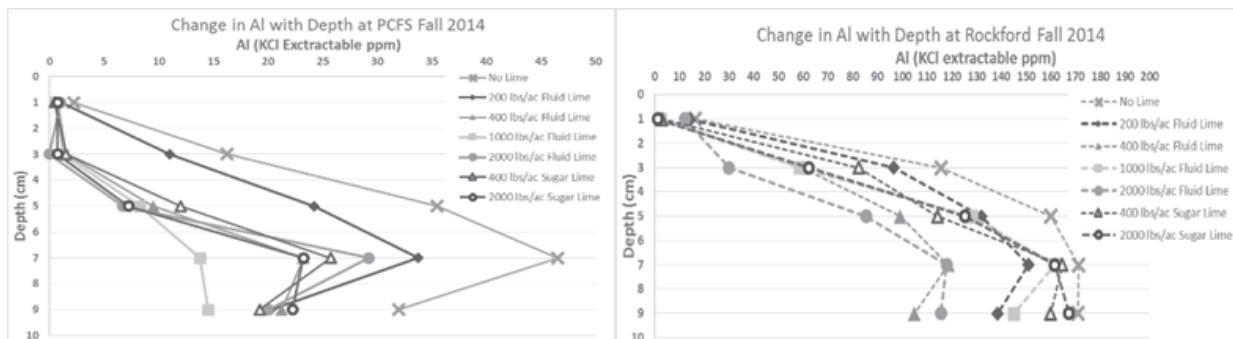
<sup>1</sup>DEPT. OF CROP AND SOIL SCIENCES, WSU; <sup>2</sup>USDA-ARS; <sup>3</sup>LOUISIANA STATE UNIVERSITY; <sup>4</sup>UNIVERSITY OF IDAHO

We are working at two no-till field sites, representing soil that developed under prairie (PCFS) and under forest (Rockford). In 2013, we fall-applied two lime sources (Fluid lime and Sugar lime) to the soil surface at rates ranging from 200 lbs/ac to 2000 lbs/ac. We seasonally monitored the effect of the lime treatments on critical soil properties. Chickpea (PCFS) and canola (Rockford) were planted in the spring of 2014. No effect from the lime treatment was seen in biomass or chickpea yield in the 2014 crop year.

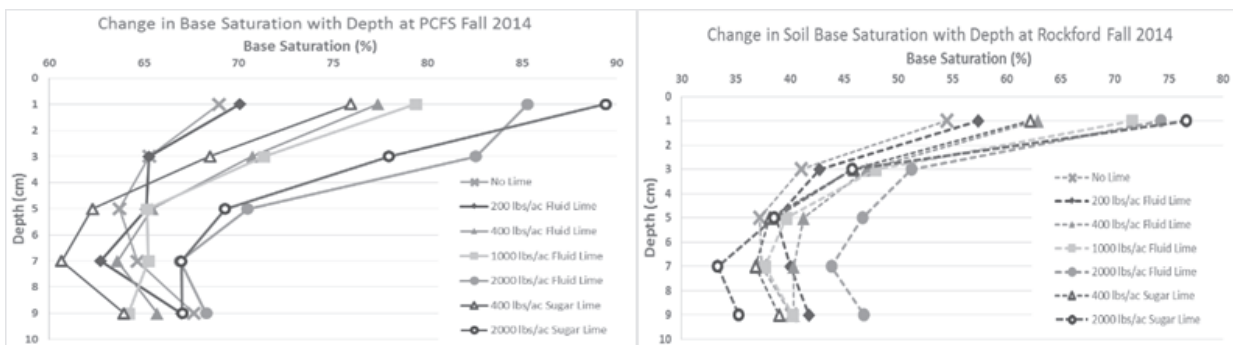
Soil pH increased at the 0-2 cm (~1") depth by surface application of lime (2000 lbs/ac) in 6 months (Spring 2014). Within 1 year, in the Fall of 2014, pH was increased at the 2-4 cm (~2") depth by 2000 lbs/ac of lime.



Aluminum (Al) is toxic to plants and can inhibit root development and often results in yellowed, stunted crop symptoms. Al was reduced at the soil surface (~1"), within 6 months of the surface application of lime at the 2000 lbs/ac rate, regardless of the lime source. In one year, soil Al was also reduced at the 2-4 cm depth, with the highest lime rate.



Base Saturation (BS) is a measure of the percent of "base cations" (Ca, Mg, Na, K) on the soil's cation exchange sites, low BS can indicate the reduced soil health due to the presence of acidity. At the highest rates, lime treatments increased BS within six months of surface application at the 0-2 cm depth, which extended into the 2-4cm depth at the PCFS site. By Fall 2014, BS was also increased in the 4-6 cm depth at PCFS.



This research is part of a collaborative effort to pursue applied research that will help inform management decisions and the development of regionally suitable liming programs. Please visit the Soil and Water Resource page of the WSU Small Grains website for more information. Thanks go to the Washington Grain Commission for their support of this work!

## Precision Nitrogen Management: Evaluating Management Zones and Optimizing Nitrogen Rates

STEPHEN TAYLOR<sup>1</sup>, DAVE HUGGINS<sup>2</sup>, DAVE BROWN<sup>1</sup>, WAYNE THOMPSON<sup>3</sup>, AND AARON ESSER<sup>3</sup>

<sup>1</sup>DEPT. OF CROP AND SOIL SCIENCES, WSU; <sup>2</sup>USDA-ARS; <sup>3</sup>WSU EXTENSION

Site-specific or precision nitrogen (N) management is proposed as a strategy to improve fertilizer use efficiencies. Current fertilizer recommendations for the dryland cropping systems of the inland Pacific Northwest (PNW) are based on uniform, whole-field applications. Studies at the WSU Cook Agronomy Farm have documented the inefficiencies of this recommendation system (Huggins et al., 2010). Unused N represented by low nitrogen use efficiencies (NUE) is a financial loss to growers and can contribute to the degradation of water and air quality. Currently, recommendations to farmers in the PNW region are largely lacking for site-specific N management as science-based decision support, monitoring, and evaluation systems are not well established.

Our goal is to continue development of science-based decision support systems for farmers that want to implement precision agriculture technologies in their N fertilizer applications. First, with the help of Aaron Esser at the WSU Wilke Research and Extension farm, we are evaluating the effectiveness of current management zones that are based on relative yield, soil type, and apparent electrical conductivity (EC<sub>a</sub>). Evaluations will assess grain yield, protein, NUE, and in-season N status of areas treated with variable rate N application as compared to areas treated with uniform rate applications.

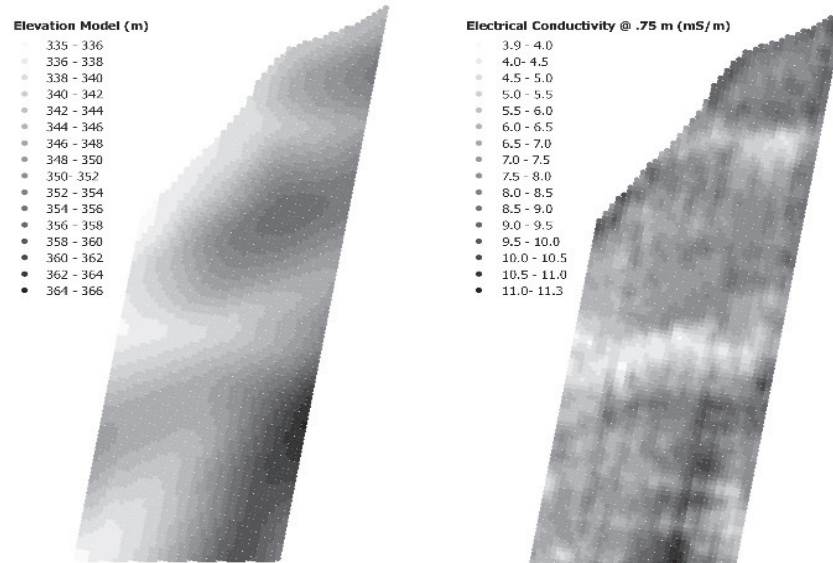


Figure 1: Elevation data visually compared to electrical conductivity data at on-farm site near Walla Walla.

Second, a 20 acre on-farm study was established near Walla Walla, WA courtesy of Mark and Seth Small in coordination with Wayne Thompson of WSU extension. An Exactrix variable rate applicator was used to apply five different N rates across the field. Spatial variability in wheat response will be analyzed at the different N rates and compared to the spatial variability in soil and terrain factors. Nitrogen response curves will be generated to find optimal N rates for winter wheat at different field locations.



Figure 2: Exactrix variable rate applicator at on-farm site near Walla Walla.

Third, because of the breadth of already existing data at the WSU Cook Agronomy Farm, data from this site will be used to perform similar analyses as those mentioned for both the Wilke Extension Farm and on-farm site near Walla Walla, WA.

This project is funded by USDA NIFA grant awards "Regional Approaches to Climate Change for Pacific Northwest Agriculture" (REACCH) and "Site-Specific Climate Friendly Farming" (SCF).

## Phenazine Antibiotic Production in the Rhizosphere Influences Iron Uptake by Wheat

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*Pseudomonas fluorescens* strains producing the antibiotic phenazine-1-carboxylic acid (PCA) are abundant in the rhizosphere of dryland, but not irrigated wheat throughout the low precipitation zone of the Columbia Plateau. Phenazines dissolve iron and manganese from insoluble oxides and promote the formation of biofilms that accumulate nutrients via precipitation of biogenic minerals such as iron phosphates. These processes could improve the delivery of recalcitrant nutrients to roots in arid soils, but the extent to which they are facilitated by phenazines and the effects upon micronutrient availability and uptake by crops are unknown. In this study we sought to establish the impact of PCA upon iron (Fe) and manganese (Mn) availability to wheat.

Virgin autoclaved Ritzville silt loam was packed into 10 x 30 cm PVC columns along with Campbell 229-L heat dissipation sensors for monitoring of soil water potentials. Columns were sown with pre-germinated wheat seeds (cv. Louise) inoculated with the PCA-producing strain *P. fluorescens* 2-79, a mutant strain 2-79Z impaired in PCA synthesis, or no bacterial inoculum, and the columns were incubated for up to four weeks. "Irrigated" treatments received regular manual injections of water into column sides to maintain sensor readings above -50 kPa. "Dryland" treatments were established by allowing the soil to dry without watering for the duration of the experiment. After incubation the columns were disassembled and Fe and Mn were extracted from fresh root-associated soil, soil collected directly from air-dried root surfaces, and plant roots and shoots, and quantified by flame atomic absorption spectrometry or microwave-plasma atomic emission spectrometry.

Under both dryland and irrigated conditions, concentrations of total free and poorly-crystalline Fe were significantly higher in rhizosphere soil from seedlings treated with strain 2-79 than from soil treated with the PCA-nonproducing strain 2-79Z, suggesting that PCA promotes the accumulation of Fe in the rhizosphere. No significant differences were observed for Fe uptake into roots colonized by PCA-producing or nonproducing strains, but Fe uptake into shoots was significantly lower in seedlings colonized by strain 2-79 than in seedlings colonized by 2-79Z. Interestingly, more Fe was present in the roots than in the shoots, probably because of Fe in associated soil, while less Mn was present in the roots than in the shoots, suggesting that Mn was more readily depleted in the rhizosphere by plant uptake than was Fe.

Given the higher iron content of rhizospheres colonized by a PCA producer as compared to those colonized by the nonproducing mutant, which in terms of mass balance cannot be accounted for solely by differences in plant uptake into roots and shoots, we suspect that PCA mobilizes Fe in soil but inhibits Fe uptake into shoots, perhaps via a mild root-toxicity effect. Since PCA is capable of accepting electrons from the respiratory chain, in sufficiently high concentrations it may transiently impact respiration or other energetically expensive processes.

## Grower Breakfast Meetings

DENNIS ROE

DEPT. OF CROP AND SOIL SCIENCES, WSU

Reaching out to growers through early morning breakfast meetings has been a way for raising awareness of recent research and grower experience. These are held for growers in seven counties in eastern Washington, from the wheat-fallow to the Palouse areas. They are usually of one to two hours duration, with a grower speaker and a scientist. Topics vary from crop management aspects to markets and economics. Examples of topics in 2015 have been growing canola in rotation with wheat, management of crop residue, fertility, weeds, equipment, pests, diseases, and insects. Local sponsors

support the meeting arrangements and costs. Attendance ranges from 20 to 50 persons. Outcomes show increased acreages of new crops and management improvements. These are expected to continue by popular demand.

Meetings at Colfax this fall and winter will be October 28, November 18, December 30, January 13, February 10, and March 2. They will be in the Colfax Methodist Church meeting room at S 109 Mill Street, in Colfax, WA. Other meetings are to be announced.

## Identifying Kentucky Bluegrass Germplasm for Seed Production without Field Burning

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With the loss of field burning of post-harvest residue in grass seed production, identifying Kentucky bluegrass germplasm that has sustainable seed yield without field burning while still maintaining acceptable turfgrass quality would be highly desirable for the turfgrass seed industry of eastern Washington. This long-term study initially evaluated 228 USDA/ARS Plant Introduction (PI) accessions for turf and agronomic parameters. Eight PIs plus 'Kenblue', evaluated in additional research, expressed high seed yield without burning of post-harvest residue and good turfgrass quality. In a space-plant nursery, several agronomic yield parameters were evaluated over a 2-year 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. Turfgrass plots were established in 2006 and seed production plots (irrigated and non-irrigated) were established in 2007 at Pullman, WA and harvested 2008 – 2011. Seed increase plots of the three best performing selections were established in 2011 and harvested 2012 – 2014.

Initial results (selection plots) indicated that PI 368241 had the most promise of being able to provide long-term turfgrass seed yield without field burning (Table 1). Kenblue, selection seed/head, had good seed yield and fair turfgrass quality (quality data not presented). PI 371775 had good turfgrass quality while maintaining good seed yield with irrigation. In seed increase plots at Pullman, the Kenblue selection showed excellent dryland seed yield over three harvests. PI371775, which has the highest turfgrass quality (data not presented), continued to produce fairly well with irrigation. PI368241 has shown a decline in seed yield over time. Plans are to harvest the seed increase plots at least one more year. A germplasm release of Kenblue, selection seeds/head, is planned for late 2015.

Table 1. Kentucky bluegrass seed yield without field burning.

Cultivar Or PI #	Selection parameter	Management	Selection plots	Seed increase plots			3-yr mean
			Seed yield (lbs/A)	Seed yield (lbs/A)			
			4-yr mean	2012	2013	2014	
Kenblue	Common-type check	dryland	398				
Kenblue	Seeds/head	dryland	795	1207	911	897	1005
368241	Heads/area	dryland	893	934	673	424	680
371775	Seeds/head	irrigated	800	729	913	842	828

## Nitrogen Loss Associated with Wind Erosion

B.S. SHARRATT<sup>1</sup> AND S. PRESSLEY<sup>2</sup>

<sup>1</sup>USDA-ARS; <sup>2</sup>WSU

Wind erosion can cause degradation of air, soil, and water resources. Degradation of these respective resources occurs as a result of suspension of sediment in the atmosphere, loss of soil from the landscape, and deposition of sediment in surface water systems. Although not well documented, wind erosion can deplete the soil resource of nitrogen (N), which is an essential nutrient for crop growth and of economic importance to land owners and managers.

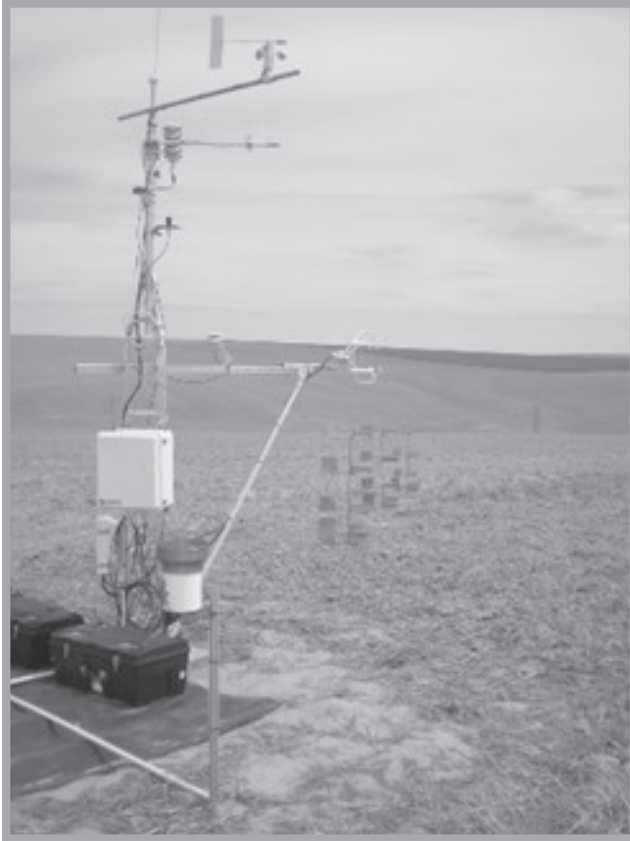


Figure 1. Monitoring wind erosion at a field site near Lind, Wa in 2012. BSNE samplers, located to the north of the meteorological tower, are installed to collect eroded sediment at various heights above the soil surface.

We examined the impact of wind erosion on N loss in eastern Washington where wind erosion is an acute environmental concern. Wind erosion was measured during the fallow phase of a winter wheat-summer fallow rotation over eight years. While the location of the experimental site varied across years, the soil type was either Ritzville silt loam or Shano silt loam. Management practices consisted of conventional or reduced tillage with aqua or anhydrous ammonia injected into the soil at the time of spring tillage. Wind-blown sediment was collected during high wind events using Big Spring Number Eight (BSNE) samplers mounted 0.1 to 1.5 m above the soil surface (Fig. 1). The N content of the sediment was analyzed by the dry combustion method.

Windblown sediment contained about 0.08% N. Nitrogen content did not vary with height above the eroding surface, which is contrary to previous studies (conducted on sandy soils) that have shown N content of sediment increases with height. The lack of any variation in N content of sediment with height was likely due to the atypical or unique uniformity in particle size of sediment with height. Nutrient loss was found to approach 2 kg N ha<sup>-1</sup> (1.8 lbs N ac<sup>-1</sup>) during singular high wind events. Although this loss of N represents <5% of that applied for crop production in the region, this loss represents 25% of that contained in the near surface layer.

## Post-Harvest Control of Russian-Thistle Following Spring Wheat

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A field study was conducted at the Lind Dryland Research Station to investigate if the time of day that herbicides are applied for post-harvest Russian-thistle control influences results. The soil at this site is a Shano silt loam. The first applications started at 5:20 AM on August 8 when air and soil temperatures were 57° F and 70° F, respectively, relative

humidity was 64%, and the wind was out of the southwest at 1 mph. The second application timing began at 3:05 PM the same day when the air and soil temperature were both at 84° F, wind was out of the southwest at 2 mph and relative humidity was 25%. Both applications were made with a backpack sprayer set to deliver 15 gpa at 3 mph and 30 psi. The Russian-thistle was 6 to 12 inches in diameter and 6 to 12 inches tall.

On September 5, four weeks after application, three treatments provided the best control of Russian-thistle whether they were applied in the morning or afternoon. These were: Gramoxone Inteon®, Gramoxone Inteon + Karmex® and Roundup PowerMax® at 64 fl oz of product per acre. When applied in the morning, there was no significant difference in control amongst these three treatments. When applied in the afternoon, there was no significant difference between the two treatments containing Gramoxon Inteon, but Russian-thistle control with Roundup PowerMax was significantly less than when Gramoxone Inteon was applied by itself at 48 fl oz of product per acre. However, if you compare Roundup PowerMax at 64 fl oz of product per acre applied in the morning with the afternoon application,



Russian-thistle control is not statistically different. In fact, no matter which herbicide treatment you look at, there is no difference in Russian-thistle control between the morning and afternoon applications.

These results are similar to those observed in a similar study conducted in 2013. The main difference between the 2103 and 2014 studies is that the Buctril® + Clarity® treatment provided much better Russian-thistle control (83-89% control four weeks after application) in 2013 than in 2014. The reason for this difference is not understood.

The time of day that an herbicide application is made for post-harvest Russian-thistle control, does not appear to affect the level of control achieved.

For more information on this and other herbicide screening studies, visit the weed research reports page ([smallgrains.wsu.edu/weed-resources/research-reports](http://smallgrains.wsu.edu/weed-resources/research-reports)) at the Wheat and Small Grains website ([smallgrains.wsu.edu](http://smallgrains.wsu.edu)).

## Wilke Research and Extension Farm

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AARON ESSER AND DEREK APPEL  
WSU EXTENSION

The WSU Wilke Research and Extension Farm is a 320-acre facility located on the eastern edge of Davenport, WA and is split (North/South) by State Hwy 2. Washington State University maintains and operates this facility. The farm is divided into 3 cropping rotations; a 3-year crop rotation (No-till Fallow, Winter Wheat, Spring Cereal), an intensified 4-year crop rotation (No-till Fallow, Spring Cereal, Spring Canola, and Winter Wheat), and a continuous cereal grain production (Spring Cereal and Winter Wheat). In 2014, the 3-year rotation, 4-year rotation, and continuous cropping averaged returns above the input costs of \$88, \$64, \$44/ac respectively. Over the last three years (2012-14), the 3-year rotation, 4-year rotation, and continuous cropping have averaged returns above input costs of \$157, \$176, and \$137/ac respectively. For complete farm results, the production report can be found on our website at <http://wilkefarm.wsu.edu/reports/Wilke-Research-2014-Operations-Report.pdf>.



## Part 2. Oilseeds and Other Alternative Crops

### Blackleg in Canola – Reason for Alarm in Washington State?

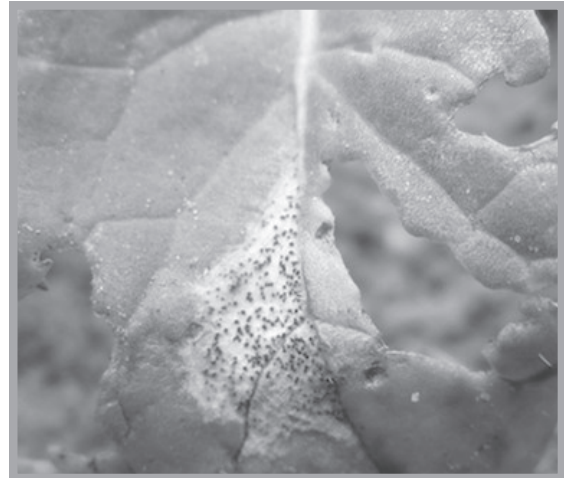
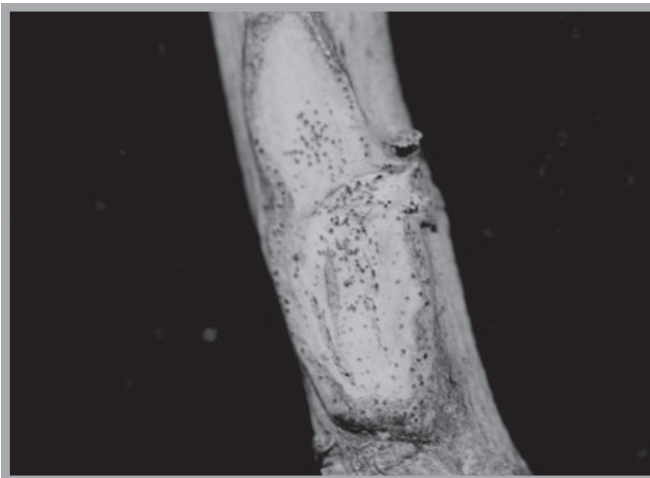
KAREN SOWERS<sup>1</sup>, TIM PAULTZ<sup>2</sup>, JIM DAVIS<sup>3</sup>, LINDSEY DU TOIT<sup>4</sup>, KURT SCHROEDER<sup>3</sup>, AND DON WYSOCKI<sup>5</sup>

<sup>1</sup>DEPT. OF CROP & SOIL SCIENCES, WSU; <sup>2</sup>USDA-ARS; <sup>3</sup>UNIVERSITY OF IDAHO; <sup>4</sup>WSU MT. VERNON NWREC; <sup>5</sup>OREGON STATE UNIVERSITY

In late March 2015, a crop consultant discovered blackleg (*Leptosphaeria maculans*, also commonly called *Phoma lingam*) in a winter canola field on the Camas Prairie in Idaho. Subsequent scouting by University of Idaho (UI) staff revealed blackleg in all but one of a dozen winter canola fields inspected from Moscow to Grangeville. An alert was immediately sent out to WSU and OSU members of a blackleg interest group that was formed after a blackleg outbreak in the Willamette Valley in 2014. Blackleg has been found in a few fields in northeast Oregon in both growing winter canola and 2014 winter canola residue. As of mid-April, more than 30 winter canola fields scouted in eight eastern Washington counties had no indication of blackleg infection. Washington state has always been blackleg-free, and the WSDA is in the process of a Rule Change that will take effect by July 2015 requiring ALL Brassica crops or cover crops containing Brassicas to go through testing, seed treatment and certification. The 'blackleg-free' certification must be clearly marked on any Brassica seed sold for any purpose. So, is there reason for alarm about blackleg, and growing canola and other brassicas in Washington state? Not alarm, but *awareness* of blackleg. In addition to regular scouting, the top three lines of defense are:

1. Crop rotation – be sure that canola, other Brassica crops, mustard family crops, weeds, and cover crops containing Brassica or mustard family species are only grown in the same field every 4 years, and control volunteers.
2. Buy blackleg resistant varieties that have been tested and certified blackleg-free and have a seed treatment (e.g. Helix Xtra, Helix Vibrance, Prosper 400 and Prosper Evergol).
3. If blackleg is discovered, consider applying fungicide (read and follow label instructions).

The Washington Oilseed Cropping Systems website ([www.css.wsu.edu/biofuels](http://www.css.wsu.edu/biofuels)) has blackleg resources including sampling protocol, fact sheets, presentations about blackleg, and PNW university contacts.



From Tim Paulitz, USDA-ARS plant pathologist in Pullman, ***“The more eyes we have out there, the better. I think the reason it went undetected in the Camas Prairie is that no one was looking for it. Let’s not let it get away in Washington!”***

## Profitability of Oilseed Crops in Dryland Eastern Washington Wheat Rotations

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SCHOOL OF ECONOMIC SCIENCES, WSU

Enterprise budgets are useful economic tools to determine scenarios in which growers would profit from growing various spring crops in rotation with winter wheat. Rotational enterprise budgets were created for the intermediate rainfall region (12"-16") to determine the profitability of spring canola rotations, irrespective of whether canola is sold in the food or fuel market. This was done by calculating the profits for various crop rotations by subtracting economic costs of production from the revenues a farmer would receive on a per acre basis. Given recent market prices and yields, the spring canola rotation was less profitable than the spring barley rotation by \$13/ac, soft white spring wheat rotation by \$20/ac, and dark northern spring wheat rotation by \$33/ac annually when assuming no rotational effects from canola.

However, when considering that incorporating canola to the rotation can increase winter wheat yields, there were price and yield scenarios in which the canola rotation would be at least as profitable as the spring barley or soft white spring wheat rotations. This is the case when a 20 percent yield increase is included for winter wheat when following canola.

Table 1. Canola Rotation Profit Subtracting Soft White Spring Wheat Rotation Profit (Allowing for Canola Price and Soft White Winter Wheat Yield Flexibility)

		SWWW yield in the canola rotation (bushels*acre <sup>-1</sup> )								
		78	80	82	84	86	88	90	92	94
Canola price (\$/CWT)	20	-26	-24	-21	-19	-16	-14	-11	-9	-6
	21	-23	-21	-18	-16	-13	-11	-8	-6	-3
	22	-20	-18	-15	-13	-10	-8	-5	-3	0
	23	-17	-14	-12	-9	-7	-4	-2	0	3
	24	-14	-11	-9	-6	-4	-1	1	3	6

## Washington Oilseed Cropping System Project – Still Going Strong

KAREN SOWERS<sup>1</sup>, TAYLOR BEARD<sup>1</sup>, DENNIS ROE<sup>1</sup>, BILL PAN<sup>1</sup>, FRANK YOUNG<sup>2</sup>, AARON ESSER<sup>1</sup>, AND BILL SCHILLINGER<sup>1</sup>  
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With each successive year of funding for the Washington Oilseed Cropping Systems (WOCS) project since 2007, the amount of information generated by field, lab and greenhouse studies increases. The Extension and outreach members of the WOCS team are tasked with delivering that information in timely, practical and understandable methods to growers, industry, agency, and other university oilseed faculty and staff in Washington state. Oilseed acreage has steadily increased in Washington since 2008, and tripled from 2012-2014, due in part to the efforts of the WOCS team. However, extreme weather conditions in late 2014 caused a dramatic decrease in canola acreage from 51,000 acres in 2014 to 30,000 acres in 2015 (USDA-NASS; Mar. 31, 2015 Prospective Plantings report), and with current market prices down slightly, the need for continued education about oilseed production and the value of crop rotations including oilseeds is all the more important. To address this need, the WOCS team is changing gears for 2015-16 to an increased emphasis on an electronic presence (Twitter, discussion forum, etc.), a written presence with the development of a WOCS-branded Extension publication series and a return to more localized, face-to-face meetings. Future collaboration with WSU Extension educators and industry affiliates will increase the reach to stakeholders in a larger geographic area, creating

more opportunities to share oilseed information. Inclusion of growers on event planning committees will be an integral part of the process to be certain that topics are chosen that are applicable to the area where outreach is being conducted. Canola acreage may be down in 2015, but the WOCS team is dedicated to the pursuit of answers to production questions and challenges to bring the acreage above and beyond 2014 levels.

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

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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 novel approach to improve stand establishment by uncoupling seedling and adult phenotypes through the manipulation of members of the AT-hook motif nuclear localized (AHL) family. When these proteins are over-expressed, the result is seedlings with shorter hypocotyls. When the activity of multiple genes is disrupted, the result is seedlings with taller hypocotyls, demonstrating that these genes control seedling height in a redundant manner. In the Brassica *Arabidopsis thaliana*, we have identified a unique allele (*sob3-6*) for one of these genes, *SOB3/AHL29*, that over-expresses a protein with a disrupted DNA-binding domain and a normal protein/protein interaction domain. In *Arabidopsis*, this mutation confers normal adult plants that produce larger seeds and seedlings with hypocotyl stems that can be more than twice as long as the wild type. The goal of this project is to enhance camelina and canola seedling emergence when they are planted deeply in low-rainfall dryland-cropping regions (generally less than 12"/year) or in wheat stubble. This can be achieved by manipulating *AHL* gene family members to develop varieties that have long hypocotyls as seedlings yet maintain normal growth characteristics as adult. This project includes three major sub-aims: 1) Continue characterizing the activity of *sob3-6-like* mutations in other *Arabidopsis AHL* genes; 2) Generate transgenic camelina and canola plants over-expressing wild-type and mutant forms of *Arabidopsis AHL* genes. 3) Identify, clone and characterize *AHL* gene family members from camelina. During this funding period, the Neff Lab has used a combination of molecular, genetic, biochemical, bioinformatics and biotechnological approaches to understand the role of *AHL* genes in plant growth and development. Our primary goal has been to characterize *AHL* genes from *Arabidopsis* and camelina, including an analysis of the evolution of this gene family. Generating transgenic *Arabidopsis* over-expressing *AHL* genes from complex genomes has been a powerful way to identify those genes with similar function as *SOB3/AHL29* and other

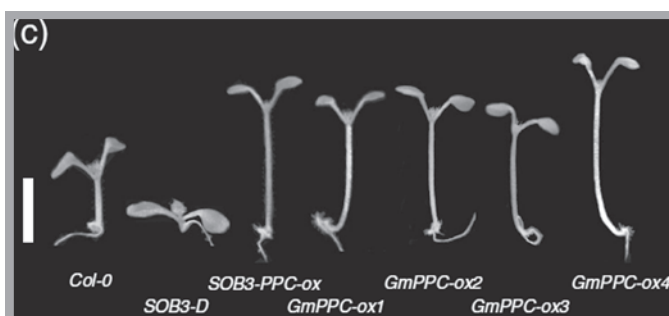


Figure 1.

family members that have been characterized previously in *Arabidopsis*. For example, as a part of our phylogenetic/evolutionary analysis we over-expressed a dominant-negative *AHL* gene from soybean (*Glycine max*) in *Arabidopsis* and demonstrated a similar long-hypocotyl phenotype to those produced when expressing various *dominant-negative sob3* alleles (Fig. 1). Zhao J, Favero D, Roalson E, Qiu J and Neff MM (2014) Insights into the evolution and diversification of the AT-hook motif containing nuclear localized gene family in land plants. BMC Plant Biology 14:266

## Deep-Banded Fertilizer Toxicity in Canola

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Stand establishment is a major challenge to increasing production of canola in Washington state, and fertilizer toxicity may be one potential cause. Previous studies have demonstrated that fertilizers can have toxic effects when banded with or below the seed. Office scanners were buried in soil in growth chamber experiments to capture images of the response of root growth to fertilizer banding. The image below (Fig. 1) shows the effects of a urea band (80 lbs N/A) on canola and wheat roots. Due to the different root architectures survivability varied between wheat and canola. The fibrous root system of wheat allowed it to survive while the canola seedlings with tap root systems died. With the high resolution images collected during these studies, symptoms of premature lateral emergence, root shrinkage, browning, and root hair dieback were observed (Fig. 2). The initial findings clearly demonstrate the toxicity deep banded fertilizers has on canola roots. Fertilizer recommendations for canola production in Washington state are currently being revised and will incorporate these results to increase the probability of successful stand establishment.

A video of time-lapse images of the root scans and more extensive commentary on roots, root hairs and fertilizer placement can be viewed at <https://www.youtube.com/watch?v=eLxaKzqGc6s>

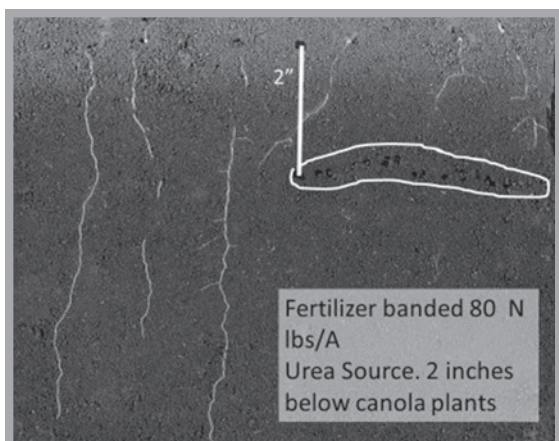


Figure 1. Urea fertilizer (80 lbs N/acre) demonstrating toxicity to the root system.

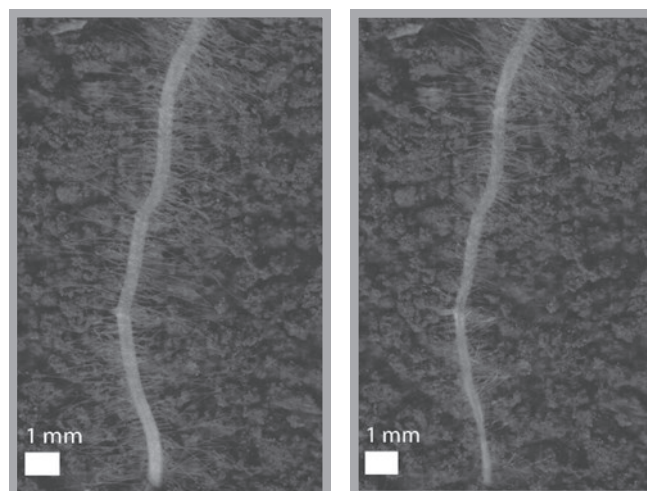


Figure 2. High resolution images of a healthy canola root (left) and a dying root showing width shrinkage, premature lateral root emergence, root browning, and root hair dieback (right).

## Canola Nitrogen Fertility Management

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Fertility management of winter canola is more complex than spring canola for a couple of reasons. First, there are more potential feed, food and fuel markets for winter canola, and each market demands quality characteristics of forage, meal and oil that can be influenced by fertility management. Second, there are more growth stages affiliated with a complex range of environments and growing season conditions, and each phase requires tailored fertility management approaches to ensure the right nutrients are available at the right time and place. Breaking it down, there are three growing seasons to manage: the vegetative growth phase I (from planting to winter dieback), the winter survival phase II and then the reproductive phase III (spring regrowth to grain harvest). In phase I, we have learned that canola seedling

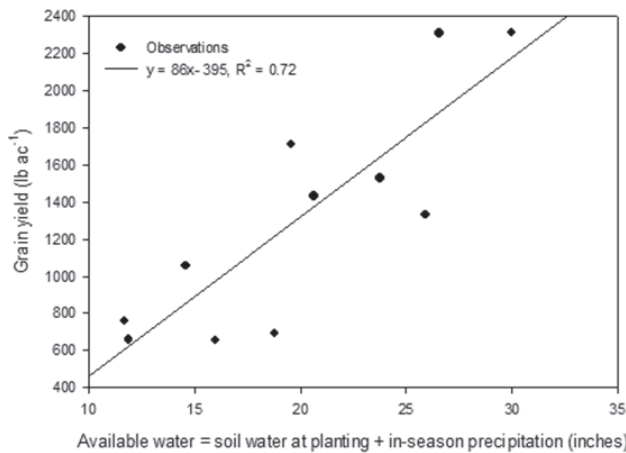


Figure 1. Available water vs spring canola yield over 11 site years.

roots are sensitive to ammonium based fertility, and we have excellent examples of root dieback from ammonia toxicity from seed or deep banded Nitrogen (N). We also have observed 30 to 130 lbs N/A vegetative N uptake during this first phase if canola is seeded late summer and plants have ample moisture and heat units to establish, using 6 inches of total moisture. In phase II, winter survivability will be affected by general plant vigor supported with balanced soil fertility, variety traits and residue management. In phase III, yield potential of a good stand of winter canola or spring canola is correlated with moisture availability (Fig. 1) and economic N supply requirements correlate with yield (Table 1). Residual soil N and estimates of N mineralization contribute to fertilizer N as a summation of total N supply. Canola is an aggressive crop that scavenges soil N, but requires a high N supply per unit of yield.

**Table 1. Total N supply requirements for spring canola yield potentials.**

Yield Potential (lb Gw/A)	600	1200	1800	2400	3000
Total N Supply (lb Ns/A)	110	140	175	205	235
UNR (lb Ns/100 lb Gw)	19	12	10	9	8
NUE (Gw/Ns)	Low-----à High				

Be alert to potentially high soil N supply when following fallow with canola compared to lower N supply following wheat. We observed an average of 183 lb soil N/A following fallow compared to 69 lb soil N/A following wheat. When soil N supply is high and yield potential is low due to low available water, little fertilizer N will be required (Fig. 2). But when yield potential is high, total N supply requirements will also be high, and fertilizer N requirements will also be higher.

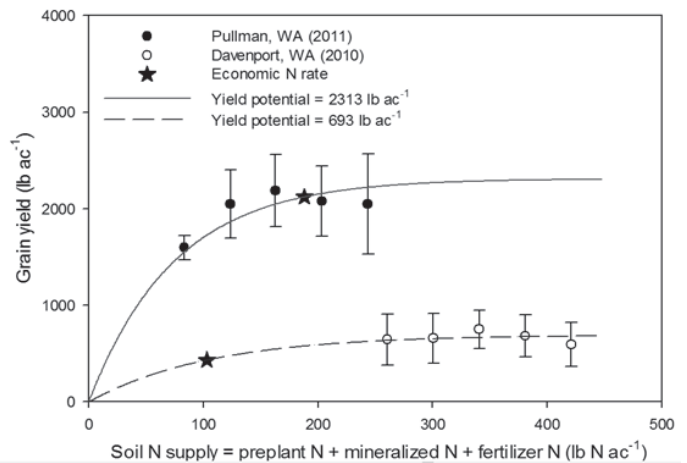


Figure 2. Examples of low yield potential, high N supply at Davenport in 2011 vs. lower N supply, high yield potential at Pullman in 2011.

### Subsoil Quality: Chemical and Physical Factors

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DEPT. OF CROP AND SOIL SCIENCES, WSU

Subsoil quality is an important factor in cropping systems due to the effects on root system growth and development, nutrient and water availability, and therefore crop yield and quality. When compaction occurs in the subsoil it can cause

roots to grow laterally instead of through the soil profile (Fig. 1). The surveying of multiple sites throughout Washington has led to the conclusion that there are two soil pans within a typical profile (Fig. 2). The first pan can be found anywhere from 2-8" below the surface. This pan has been termed the rodweeding layer and is the result of long term tillage. The second pan can be found anywhere from 9-15" below the surface. This pan has been termed the glacial pan and was formed during the Missoula floods. Soil pH affects the availability of Silicon (Si) within the soil. More acidic pH allows the Si to become available in the soil solution while higher pH levels cause Si to be adsorbed to soil particles. High amounts of Si have been linked to soil pan formation. Silicon amounts can be influenced by many factors including crop type. Grass crops such as wheat can accumulate up to 10 times as much Si as broadleaf crops. Figure 3 shows penetrometer data collected from two sites and the effects of these relationships.

Future research will continue to look at subsoil quality and possible management tools to decrease soil compaction.

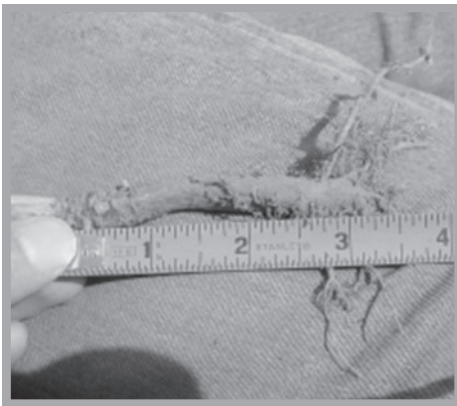


Figure 1. J-hooked canola root. J-hooking begins approximately 2.5" below the surface.

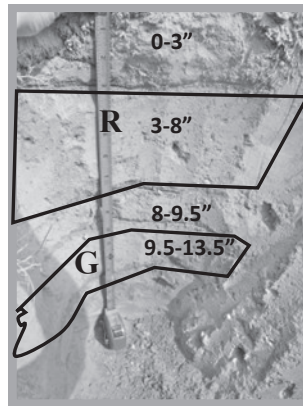


Figure 2. Soil pit displaying the impacts of management and soil formation processes. Total depth of pit was approx. 17". R= rodweeding layer, G=glacier layer.

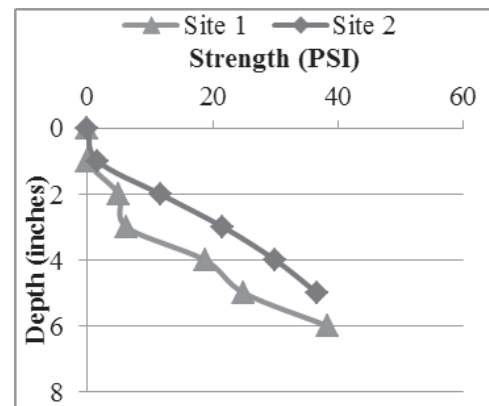


Figure 3. Penetrometer data for two sites.

## Winter Canola Water Use in Low Rainfall Areas of Eastern Washington

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An on-farm winter canola seeding date trial was initiated in the summer of 2013 in Ritzville. Clear differences in fall water use due to planting date were observed. Unfortunately, this study was terminated due to excessive winter-kill. More fall water use and increased crown height correlated to higher winter mortality (Fig. 1).

For the 2014 season, winter canola water use patterns were monitored in variety trial plots seeded around August 20 in Okanogan, Pomeroy, and Asotin. At all sites, water use was highly correlated to biomass production, Nitrogen (N) uptake, and growing degree days in a linear fashion. In terms of an extraction pattern, winter canola at Pomeroy did not utilize water stored at 4 feet until about 2 months after planting, first using water in the top 3 feet of soil. By early November, winter canola was extracting water down to 5 feet, while fall precipitation began to recharge the top foot. Fall growth and water extraction then ceased, allowing winter precipitation to fill the entire profile. This pattern was also observed in the 2013 Ritzville study. Okanogan, however, had very little extraction and it was confined to the top 3 feet of the soil profile. Okanogan canola used 3.26 inches of available water over the fall growing season. Pomeroy had a much higher initial water content than Okanogan, along with more soil nitrogen, which contributed to increased biomass accumulation and therefore more water use. At the Asotin site, soil depth was highly variable, and this factor largely

determined total profile water content. A rough planting date comparison was observed at Asotin, as the cooperating farmer planted the field surrounding the plots one month earlier (Fig. 2). Within the first 2 feet, the canola in the grower's field used 5.3 inches of water and terminated growth for winter a month earlier than the plots (which used 3.5 inches of water).

Moisture measurements will be continued in spring at all locations, and yield characteristics will be determined at harvest. This water use study will be continued next year, along with a repeated season of the planting date study in Ritzville.

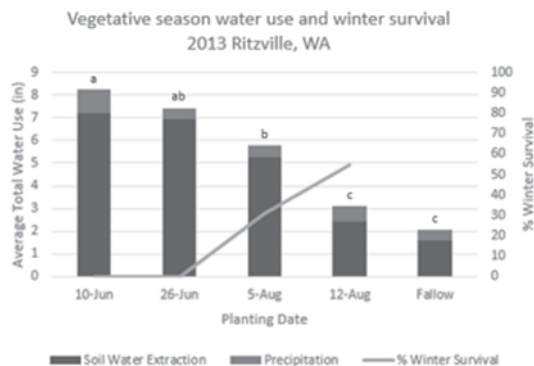


Figure 1. Average fall total water use for each planting date in Ritzville. Values marked by the same letter indicate no significant difference. Average percent of plants surviving winter is depicted as well and corresponds to the right axis.



Figure 2. Winter canola plots and surrounding field at Asotin, WA. Photo taken 10/30/14.

## Utilization of Winter Canola for Seed and Silage

STEVE FRANSEN<sup>1</sup> AND DON LLEWELLYN<sup>2</sup>

<sup>1</sup>WSU IAREC; <sup>2</sup>WSU EXTENSION

We have developed an integrated two-year study which investigates agronomic production as well as animal end use of canola to determine if it is possible to make high quality silage from canola and to determine if harvesting a forage crop in the fall affects the seed/meal yield and quality at the subsequent harvest for seed. The objectives of the study are: 1) to determine canola forage and seed yield, quality, and silage quality when grown at various N:S fertility levels; 2) determine ensiling characteristics of winter canola by field treatments; 3) reduce silage effluent with absorbents (alfalfa cubes). Roundup Ready® canola was planted in research plots on August 13, 2014 at WSU IAREC, Prosser, WA (8 lbs. PLS/acre). Eight soil N:S treatments were applied to the soil following baseline soil sampling. The N:S treatments included 100 and 200 lbs Nitrogen (N) and 0, 20, and 40 lbs Sulfur (S) for each N treatment. In addition 100-20+Agrotain® and 200-40+Agrotain® were included. All plots received 52 lbs P<sub>2</sub>O<sub>5</sub> in the fall with no additional K. One-third of the N:S was applied before planting and two-thirds was applied in April 2015. Stand counts were determined on 9/29/2014 and forage harvest commenced on October 13, 2014. Half of each plot was harvested. At harvest, DM yields were determined and experimental tube silos were filled (n = 48; 4 replications). Tube silos were emptied on 11/24-26/2014 and the pre- and post-ensiled samples were prepared for analysis. Fermentation profiles of the ensiled materials were conducted to determine the ensiling characteristics of the material. All samples will be scanned by NIRS for forage quality determination and prediction equation development and sulfur content were determined by ICP. The regrowth and the undisturbed plots will be harvested for seed in summer 2015 to determine the effect of harvesting a forage crop on seed yield and seed/meal/quality and oil content. Field results indicate no differences in initial stand count for forage vs. seed (15.8 and 16.7 plants/0.5 m<sup>2</sup>, respectively). Forage plot DM yields were similar across treatments (Table 1). Sulfur content

for 100:0 and 200:0 (N:S) were similar but lower than when S was added at 20 or 40 lbs./acre. Agrotain® DM yields were similar to no Agrotain® treatments. Forage quality and effluent analysis is under way. Significantly less effluent is observed when the alfalfa cube absorbents were added to forage canola during the ensiling process.

Table 1. Dry matter (DM) yield (tons/acre) and sulfur (S; mg/kg tissue) of winter Canola harvested October 13 and 14, 2015.

Nutrient Treatment (lbs/acre)	DM Yield (tons/acre)	S (mg S/kg tissue)
100 N : 0 S	0.95	1682.0
100 N : 20 S	0.98	3152.0
100 N : 40 S	0.99	4156.8
100 N : 20 S + Agrotain	0.60	3835.8
200 N : 0 S	0.98	1746.8
200 N : 20 S	0.94	2777.8
200 N : 40 S	1.07	3503.6
200 N : 40 S + Agrotain	0.83	3167.2
LSD <sub>0.05</sub>	NS	652.1

## Development of a Herbicide Tolerant Camelina Variety

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While markets for Camelina oil and meal are slowly growing, barriers to efficient production in the Pacific Northwest (PNW) exist. One problem is its extreme insensitivity to group 2 herbicides (imidazolinones and sulfonylureas) which have residual activity in soils for multiple years. The popularity of some group 2 herbicides, like Beyond, has grown in recent years due to the popularity of Clearfield wheat varieties. This further limits the use of camelina as a wheat rotation crop. Following the identification of a mutant line that is tolerant to both imidazolinone and sulfonylurea herbicides, we established breeding populations by crossing the mutant to camelina varieties like Calina which have performed well in the PNW. The utility of lines carrying the mutation was demonstrated by planting after Clearfield wheat to which four times the recommended rate of Beyond herbicide was applied and observing no damage or yield reduction. Advanced breeding lines carrying the herbicide tolerant (HT) trait have now been tested in several locations over the past two years and evaluated for yield and oil content. Following final testing and seed increase this season, a variety is planned for release this fall. The variety will have yield and oil content similar to Calina along with the HT trait.

Evaluation of a collection of European camelina germplasm over the last three years has indicated that gains in other traits could be made in future varieties. A Danish variety was identified that appears to have significantly higher yield potential than Calina in dryland PNW environments. Lines have also been identified with much larger seed than commercial varieties. The large seeded trait should provide more consistent emergence and faster stand establishment for better competition with weeds. Lines with significantly different fatty acid composition in the oils have also been identified. One line has lower erucic acid, comparable to canola, which has potential as an FDA-approved cooking oil. Breeding populations have been developed for the purpose of combining these traits to make varieties with larger seed and higher yield with good oil content. Advances in fatty acid composition will also enable the development of specialty varieties for expansion or flexibility in potential markets.



## Cabbage Seedpod Weevil Survey in Central-Eastern Washington

DALE K. WHALEY<sup>1</sup> AND FRANK L. YOUNG<sup>2</sup>

<sup>1</sup>WSU EXTENSION; <sup>2</sup>USDA-ARS

Winter canola acreage in central Washington continues to increase as more and more producers learn about the rotational benefits and potential profitability of this crop. Unfortunately, the number of cabbage seedpod weevils (*Ceutorhynchus obstrictus* (Marsham)) has also increased. Native to Europe, this insect pest causes damage to members of the Brassicaceae or mustard family, including cultivated crops such as canola and brown mustard. When left unmanaged, the weevil has been known to reduce canola yields by as much as 50%.

The objective of this survey was to determine the extent of cabbage seedpod weevil (CSPW) numbers in various fields across central Washington. In 2014, eighteen fields were surveyed during the month of May to determine population density levels (see table below). A heavy canvas sweep net was used taking ten 180° sweeps along field borders and at various locations within the center of the sampled fields. The "Action or Treatment Threshold" for the CSPW is 30 to 40 adults per 10 sweeps.

Eighteen out of twenty fields surveyed had varying levels of the CSPW, while three reached treatment levels. Site 16 in northern Douglas county may be the source of the original introduction of this pest based on the large number of insects collected. The next step is to look at and compare insecticide options and determine which one will work best for producers.

Location	# of Weevils Collected in 10 Sweeps
Site 1 Douglas Co.	8
Site 2 Douglas Co.	10
Site 3 Douglas Co.	3
Site 4 Douglas Co.	0
Site 5 Douglas Co.	5
Site 6 Douglas Co.	9
Site 7 Douglas Co.	5
Site 8 Douglas Co.	18
Site 9 Douglas Co.	3
Site 10 Douglas Co.	5
Site 11 Douglas Co.	13
Site 12 Douglas Co.	1
Site 13 Douglas Co.	4
Site 14 Douglas Co.	6
Site 15 Douglas Co.	5
Site 16 Douglas Co.	100
Site 17 Douglas Co.	0
Site 18 Okanogan Co.	42
Site 19 Okanogan Co.	30



## Feral Rye Management in a Winter Canola Production System

FRANK YOUNG<sup>1</sup> AND DALEY WHALEY<sup>2</sup>

<sup>1</sup>USDA-ARS; <sup>2</sup>WSU EXTENSION

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. Winter canola was seeded into conventional summer fallow by cooperating growers in a natural stand of feral rye in early September for experiment one (Bridgeport) and late August for experiment two (Okanogan). Each year glyphosate-resistant winter canola, variety 'Hy CLASS 115W', was planted at approximately 3.4 kg ha<sup>-1</sup> with 35-cm row spacing. Our data suggests that the use of split-applied quizalofop in conventional winter canola and glyphosate in glyphosate-resistant winter canola to control feral rye will allow the continued expansion of winter canola in the Pacific Northwest while delaying/preventing weed resistance.

Table 1: Effect of three herbicides on feral rye control, plant density and winter canola yield in 2014 at Okanogan, WA.

<sup>a</sup> Abbreviations: F = fall; S = spring. Treatments applied October 10, 2013 and April 10, 2014. <sup>b</sup> Rates are expressed in kg ai ha<sup>-1</sup> for clethodim and quizalofop and kg ae ha<sup>-1</sup> for glyphosate.

Treatment <sup>a</sup>	Rate <sup>b</sup>	Control of Rye		Rye Density		Canola	
		5/12/2014	6/25/2014	Yield			
	kg ha <sup>-1</sup>	%	no. m <sup>-2</sup>	kg ha <sup>-1</sup>			
Nontreated	-	-	136	0			
Clethodim (F)	0.105	70	22	745			
Clethodim (F+S)	0.105+0.105	90	0	745			
Clethodim (S)	0.105	35	106	85			
Quizalofop (F)	0.062	97	0	865			
Quizalofop (F+S)	0.062+0.062	100	0	785			
Quizalofop (S)	0.062	83	14	430			
Glyphosate (F)	0.866	96	0	840			
Glyphosate (F+S)	0.866+0.866	99	0	1040			
Glyphosate (S)	0.866	100	0	350			

## Why the Differences in Soil Water Loss During Fallow in the Lind Camelina Cropping Systems Experiment?

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We are currently in year 7 of a 9-year cropping systems experiment to evaluate camelina (C) produced in a 3-year winter wheat(WW)-C-tilled summer fallow (TSF) rotation compared to the 2-year WW-TSF rotation practiced throughout the low-precipitation zone. Experimental design is a randomized complete block with four replicates. There are 20 plots, each 250 ft x 30 ft. Camelina is direct drilled + fertilized into standing WW stubble in late February or early March. Winter wheat is planted into TSF in late August. Soil water content to a depth of six feet is measured in all 20 plots after C and WW harvest in July and again in March, and from the eight TSF plots in late August just before planting WW. Weed species in C and WW are identified, counted, and collected just before grain harvest. Surface residue remaining after planting WW into TSF is measured in both rotations using the line-point method.

Six-year average WW grain yield in the 3-year WW-C-TSF rotation is 37.1 bu/ac versus 39.5 bu/ac in the 2-year WW-TSF rotation (a 2.4 bu/ac or 6% difference). This slight WW yield decline in the 3-year rotation has occurred every year, although there have never been any statistically significant differences in WW yield between the two rotations.

The slight decline in WW grain yield in the 3-year rotation is likely due to difference in water loss in the two rotations that occur during fallow from mid-March to late-August. Although primary spring tillage with the undercutter V-sweep and any subsequent rodweedings during late spring and summer take place at the same time and at the same depth, an average of 0.5 inch of additional soil water is consistently lost in TSF after camelina compared to TSF after WW (Table 1). These values are further reflected in the precipitation storage efficiency (PSE) data in the last column of Table 1.

Table 1. Six-year-average soil water content at the beginning (after harvest), early spring, and the end of fallow (just before planting of winter wheat) and associated gain or loss of water and precipitation storage efficiency (PSE= gain in soil water/precipitation that occurred during the fallow period) in the 6-foot soil profile in summer fallow in a 2-year winter wheat-fallow rotation versus a 3-year winter wheat-camelina-fallow rotation. Average crop-year precipitation for the six fallow years from 2009-2014 = 9.42 inches. ns= no significant differences.

Fallow treatment	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)					
After winter wheat (2-yr rotation)	6.2	9.7	3.5	8.9	-0.8	27
After camelina (3-yr rotation)	6.7	10.1	3.3	8.8	-1.3	20
p-value	0.04	0.01	ns	ns	< 0.001	0.001

In 2015, we plan extensive field and laboratory testing of the surface soil mulch conditions in the 2-year and 3-year rotations to determine the cause of the consistently greater soil water losses from mid-March to late-August in the 3-year rotation. We expect the main reason may be surface residue cover, but it also could possibly be soil clod size distribution within the soil mulch. This expanded work on soil water loss will be interest to both farmers and scientists.

## Washington Extension Legume Variety Trails in 2014 and 2015: Performance Information for Superior Variety Selection

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The WSU Extension Grain Legume Variety Testing (GLVT) program provides growers, the agribusiness industry, university and USDA-ARS researchers, and other interested clientele with comprehensive, objective information on the adaptation and performance of grain legume cultivars across several different climatic growing regions in eastern Washington. The GLVT program conducts comparisons using scientifically sound methodology, produces independent results, disseminates all data to clientele, and uses uniform testing procedures across multiple locations. The replicated dryland GLVT trials in eastern Washington were grown at four locations in 2014 using spring planted varieties of dry pea, lentil, and chickpea.

Winter adapted pea and lentil evaluation trials were planted in the fall of 2014 and will provide performance information on released and experimental lines that produce food quality seed. The release of food quality, winter adapted pea and lentil varieties have the potential to significantly expand the adapted areas, especially in the lower and intermediate rainfall zones, for economical grain legume production. Growing grain legumes in a wheat rotation will increase wheat yield potential. Winter adapted pea and lentil production systems have demonstrated much higher yield potential than spring planted types.

Trial results are available in printed form in: [2014 Cereal and Grain Legume Variety Evaluation Annual Report](#), and comprehensive results for last year, and previous years, can be found on the Variety Testing Web site ([variety.wsu.edu](http://variety.wsu.edu)).

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



Farmington grain legume variety testing experiments. Chickpeas are shown behind the sign.

## Optimizing Seeding Rates for Chickpeas and Lentils in the Pacific Northwest

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Chickpeas and lentils are important commodities and rotation crops in Washington and the Pacific Northwest cereal based production systems. Varieties need to be seeded at optimal rates to maximize yield and economic returns.

Two chickpea and two lentil varieties were seeded at six rates in trials near Pullman and Walla Walla, WA for chickpea and Pullman and Farmington, WA for lentil in both 2013 and 2014. Yield, seed size, and seed cost were the primary factors considered to determine optimal seeding rates.

Seeding rate had a significant effect on the yield of Billy Bean chickpeas, the optimal rate (yield value is the greatest when seed cost is included) was 4 seeds ft<sup>-2</sup> in 2013 but 6 seeds ft<sup>-2</sup> in 2014 (Fig. 1). For Sierra chickpeas, and after considering production costs, the optimal seeding rate was 6 seeds ft<sup>-2</sup> in 2013 but similar to commonly used rates of only 3 seeds ft<sup>-2</sup> in 2014 (Fig. 2). Decreased seed size has been shown to be an indicator of plant stress and known to occur at higher seeding rates in legumes. It is an important consideration when choosing seeding rates for large-kabuli chickpeas like Sierras. Seeding rate did not significantly affect 100 seed weights of Billy Bean, and the small differences found for 100 seed weights of Sierras showed no clear relationship to seeding rate in 2013 and no difference in 2014.

**Effect of Seeding Rate on Yield of Billy Beans 2013-2014**

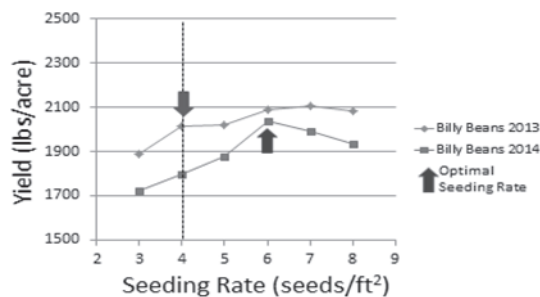


Figure 1. Billy Bean Chickpea Seed Yield Response to Seeding Rate at Walla Walla and Pullman, WA. Vertical dashed line shows the typical seeding rate.

**Effect of Seeding Rate on Yield of Sierra 2013-2014**

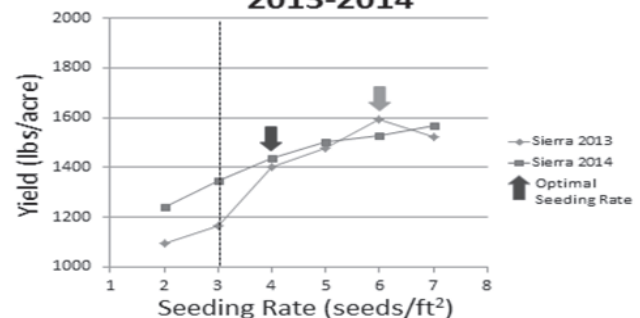


Figure 2. Sierra Chickpea Seed Yield Response to Seeding Rate at Walla Walla and Pullman, WA. Vertical dashed line shows the typical seeding rate.

Yield of Avondale lentil did not significantly change across seeding rates in 2013 but did in 2014 with 8 and 10 seeds per  $\text{ft}^{-2}$  being the optimum rates between years (Fig. 3). Considering yield and seed cost, the optimal seeding rate for Morena was 10 and 11 seeds  $\text{ft}^{-2}$  for 2013 and 2014, respectively, a consistent result (Fig. 4). The 100 seed weights were not different for Morena lentils across seeding rates, but for Avondale, lower seeding rates (6, 7, and 8 seeds  $\text{ft}^{-2}$ ) produced higher seed weights contrasted to the higher seeding rates (9, 10, and 11 seeds  $\text{ft}^{-2}$ ).

**Effect of Seeding Rate on Yield of Avondale  
2013-2014**

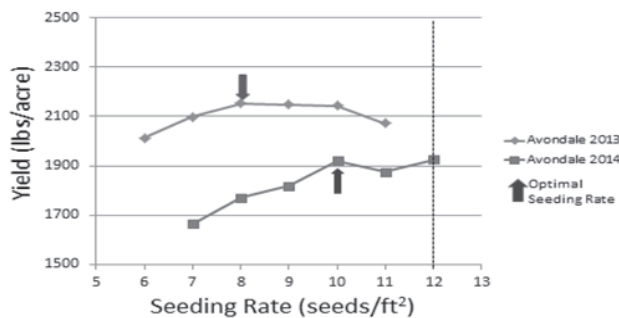


Figure 3. Avondale Lentil Seed Yield Response to Seeding Rate at Walla Walla and Pullman, WA. Vertical dashed line shows the typical seeding rate.

**Effect of Seeding Rate on Yield of Morena  
2013-2014**

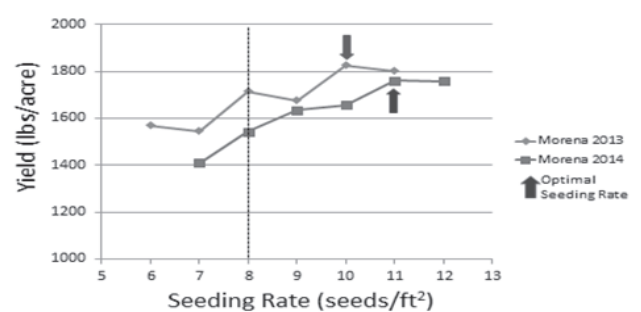


Figure 4. Morena Lentil Seed Yield Response to Seeding Rate at Walla Walla and Pullman, WA. Vertical dashed line shows the typical seeding rate.

These lentil seeding density experiments show adequate consistency across experiments to make useful seeding rate predictions for use by producers of 10 seeds  $\text{ft}^{-2}$ . Lentil seed costs less than chickpea and yield response is the primary factor to considered choosing seeding rates. However, the variability in chickpea response between 2013 and 2014 indicates more work is needed to refine potential responses to chickpea seeding rate and optimize production returns when factoring in costly seed. However, there are indications based on these results that additional profit could be realized in chickpea production systems by increasing seeding rates. Producers should be empowered to reach the full economic potential of their grain legume crops by planting each variety at optimal densities. Funding is provided by: The USA Dry Pea and Lentil Council, WSU Agricultural Research Center, and Washington State Crop Improvement Association.

## ARS Grain Legume Genetics, Pathology and Physiology Research

WEIDONG CHEN, REBECCA MCGEE, AND GEORGE VANDEMARK  
USDA-ARS

WSU is home to the USDA-ARS Grain Legume Genetics and Physiology Research Unit. In the USA, more than 1.6 million acres of dry peas, lentils, and chickpeas are planted annually. The pulse crops are an important component in cereal-based cropping systems in semi-arid environments. They help break weed and pathogen cycles, add organic matter to the soil and fix atmospheric nitrogen. The pulse crops are also important in human diets – they are high in protein and fiber, low in fat and have a low glycemic index.

Chickpea production in the USA is centered in the Palouse, where they were introduced in the 1980s. During the past decade chickpea production has increased by over 400%, to approximately 200,000 acres annually. The objectives of the chickpea breeding program are to develop new varieties that combine high yield with early maturity and desirable seed characteristics. Specific seed traits that are targets for enhancement through breeding include increased seed size, lighter seed coat color, and improved nutritional quality. Besides yield and agronomic traits, many advanced ARS chickpea breeding lines have been evaluated for the concentrations of several minerals and essential fatty acids. We have also determined the 'DNA fingerprint' of hundreds of breeding lines using various DNA marker technologies, which assists in our selection of parental lines. In collaboration with colleagues from Washington State University, the University of Idaho,

and local growers, the most promising chickpea breeding lines are evaluated at 10-15 locations each year. In 2013, the breeding program released the variety 'Nash', which consistently produces higher yields and larger seed than the most popular commercial variety, 'Sierra'. In 2013 the variety "Royal" was also released, which produces higher yields and larger seed than Sierra in the lower rainfall areas (14-18") of eastern Washington.

Dry peas have been produced in the Palouse region of Washington and Idaho since the early 1920's. In 2015, it is estimated that 150,000 acres of peas will be planted in WA and ID. The objectives of the spring pea breeding program are to develop adapted varieties of green and yellow field peas with increased yield and improved levels of resistance to diseases caused by soil borne fungal pathogens, foliar fungal pathogens and viruses. We utilize Fusarium wilt race 1 and Aphanomyces root rot nurseries at the Spillman Research Farm to screen breeding lines and segregating populations for resistance to these pathogens. We screen for resistance to Pea Seed-borne Mosaic Virus, Bean Leaf Roll Virus, Pea Enation Mosaic Virus and Powdery Mildew at the Oregon State University Vegetable Research Farm in Corvallis. 'Hampton' green pea was released by USDA-ARS in 2014. It is high yielding and has resistance to several virus diseases as well as soil-borne and foliar fungal pathogens.

Lentils have also been produced in eastern Washington since the early 1920-1930's. It is estimated that in 2015 approximately 100,000 acres of lentils will be planted in the Palouse. 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. Lentils are also screened for resistance to Aphanomyces root rot at Spillman and for resistance to Pea Enation Mosaic and Pea Seed-borne Mosaic Viruses at the OSU Research Farm. 'Avondale', a medium green (Richlea-type) lentil was released by USDA-ARS in 2014. It is high yielding and resistant to Stemphylium Blight.

The lentil and pea breeding programs also have strong components investigating tolerance to drought and heat stress. We have utilized high-throughput phenotyping in controlled conditions to screen lentil germplasm for heat tolerance during flowering and are currently mapping genes associated with that tolerance. In conjunction with our collaborators at the International Center for Agricultural Research in the Dry Areas (ICARDA), we are screening the USDA and ICARDA lentil core collections for tolerance to these abiotic stresses.

The autumn-sown pea and lentil breeding programs have become a strong, integral part of the cool season food legume breeding program. The objectives of these two programs are to develop high value, feed and 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. We also have an autumn-sown pea breeding program focused on developing varieties to be used as cover crops in organic and/or sustainable farming systems throughout North America. Recently released winter pea breeding lines and cultivars include PS03101269 and 'Lynx'.

## Metalaxyl Resistance and Pythium Damping-off of Chickpea

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Metalaxyl is a fungicide ingredient that has been used for decades to control plant diseases caused by Oomycetes, such as Pythium and Phytophthora diseases, and used in seed treatments to protect seeds from Pythium damping off. In 2014, severe seed rot and damping-off of chickpea were found in the Palouse region, and were associated with Pythium isolates with high levels of resistance to metalaxyl. High densities of metalaxyl-resistant Pythium populations were found in areas of severe chickpea seed rot and damping-off, and were observed in chickpea fields near Colton and Pullman, WA, and Kendrick and Juliaetta, ID. Under controlled conditions, metalaxyl treatments failed to protect chickpea seeds from damping-off inoculated with metalaxyl-resistant *Pythium* isolates. Scientists from USDA-ARS, Washington State

University and University of Idaho located at Pullman, Moscow and Prosser are working together to determine field prevalence of metalaxyl-resistance in chickpea production areas, identify alternative fungicides that can control or manage metalaxyl-resistant *Pythium*, and investigate mechanisms of metalaxyl resistance in *Pythium*.



Seed rot and damping-off of chickpea caused by *Pythium* sp. resistant to metalaxyl.

## Agronomy and Economics of Winter Triticale in Washington's Winter Wheat-Fallow Region

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Triticale, a cross of wheat and rye that is used as a feed grain, is not widely grown in the inland Pacific Northwest because feed grain prices have historically been low compared to wheat. However, with recent price increases, there has been renewed interest in this crop.

Beginning in the fall of 2010, winter triticale was incorporated after no-till fallow in the long-term cropping systems experiment on the Ron Jirava farm. Heavy region-wide rain events of more than 1 inch occurred during July or August in 2010, 2011, 2012, and 2013. This rainfall provided adequate seed-zone soil moisture for early planting in no-till fallow. We were therefore able to plant half of each triticale (variety 'Trimark 099') plot early (first week of September) and the other half late (mid-October). These two triticale plantings were compared to early-planted winter wheat (variety 'Xerpha'), planted into tilled summer fallow in the first week of September. Seeding rates for early-planted winter triticale and winter wheat were 40 pounds per acre, increasing to 60 pounds per acre for late-planted winter triticale. Experimental design is a randomized complete block with four replications with both the crop and fallow portions of all treatments present each year. Individual plots are 30 ft x 500 ft.

Late-planted winter triticale goes through the winter months in the one-to three-leaf stage, whereas early-planted winter triticale is much further developed. However, unlike late-planted winter wheat, late-planted winter triticale grows quickly in the spring and produces ample grain and straw biomass.

Over the four crop years, grain yields for late-planted winter triticale and early-planted winter wheat were statistically equal (averaging 3,798 pounds per acre for late-planted winter triticale compared to 4,020 pounds per acre, or 67 bushels per acre, for early-planted winter wheat) (Fig. 1). Yields for early-planted triticale were significantly greater, averaging 4,901 pounds per acre.

For the five-year period of 2010-2014, average local prices for soft white winter wheat and triticale feed grain were \$6.44 per bu and \$181 per ton, respectively (supplied by Howard Nelson, Central Washington Grain Growers). At the average yields found in this study, revenues would have been \$431 per acre for winter wheat, \$344 per acre for late-planted triticale, and \$444 per acre for the early-planted triticale.

As additional advantages, winter triticale can be grown in the same manner and with the same inputs and equipment used for winter wheat. In-crop grass weed herbicides such as Maverick™ and Olympus™ can be used on triticale. Winter triticale grows taller and produces more residue than winter wheat, and is thus a good choice for soils prone to wind erosion. Crop insurance for triticale will likely be available for the 2017 crop year (see related article on next page).

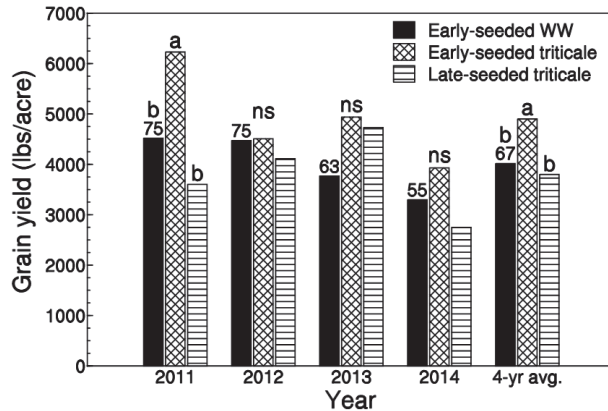


Figure 1. Grain yield of early- and late-planted 'TriMark 099' winter triticale planted into no-till summer fallow versus early-planted 'Xerpha' soft white winter wheat (WW) in the long-term cropping systems experiment at the Ron Jirava farm. Within-year grain yields followed by a different letter are significantly different at the 5% probability level. Numbers over the wheat yield bars indicate bushels per acre.

## Triticale Crop Insurance Likely Available for 2017 Crop Year

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AgriLogic Consulting, LLC based in College Station, TX is developing a Grain Triticale Crop Insurance Program for producers in Washington, Oregon, Idaho and California. The concept proposal was approved by the Federal Crop Insurance Corporation (FCIC) Board of Directors during their February 2015 Board meeting. The goal is to have an approved program available for producers to purchase prior to the 2016 fall-planting season (2017 harvest). The insurance program being developed is a multi-peril product providing a guarantee based on the producer's approved yield and protecting against yield losses similar to other federally subsidized small grain policies currently available.

AgriLogic has been developing crop insurance programs for the United States Department of Agriculture (USDA) Risk Management Agency (RMA) since 2001. AgriLogic will be working closely with Central Washington Grain Growers, Washington State University (WSU), and Pro-Genie Plant Research in addition to a number of local grain elevators and brokers in order to develop an actuarially sound and marketable insurance product.

Grain triticale, a cross of wheat and rye, has gained popularity in the United States over the last ten years due to its high lysine content, winter hardiness, and drought-stress tolerance. Grain triticale is used in a variety of both feed and food-grade products. Four years of research trials conducted near Ritzville, WA by WSU shows that late-planted winter triticale consistently produces equal yield to early-planted winter wheat. Additionally, early-planted winter triticale produces 18% greater grain yield than winter wheat planted on the same date. In addition to high grain yield, winter triticale can be grown in the same manner and with the same inputs and equipment used for winter wheat. Therefore, while the price of triticale is lower than that of winter wheat, the economics for winter triticale production are good (see related triticale story on previous page) given its superior grain yield. Price protection is not planned to be offered initially in the triticale crop insurance program, but may be considered in the future dependent upon data availability and producer demand. The initial insurance offering will be for triticale for grain but may be expanded into coverage for silage and/or forage in the future.



## Three New Winter Triticale Agronomy Experiments at Lind

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Winter triticale shows excellent potential as an alternative crop in Washington's low-precipitation (<12 inch annual) zone where winter wheat-summer fallow is the dominant crop rotation (see related winter triticale articles on previous two pages). Three new winter triticale agronomy experiments were initiated in late August 2014 at the WSU Dryland Research Station near Lind. These experiments are briefly described below. All experiments were planted into summer-fallowed ground.

1. Early versus late planting date experiment. The variety 'TriMark 099' was planted deep into carryover soil moisture at a seeding rate of 40 lbs/acre on 16-inch row spacing on August 26. The same variety was "dusted in" at a shallow depth at a seeding rate of 60 lbs/acre in paired rows on 12-inch spacing on October 21. The winter wheat variety 'Otto' was planted with the same seeding rates and drills on the same two dates. Each treatment is replicated six times in a randomized complete block arrangement. Early-planted stands of triticale and wheat are good. Appreciable fall rain did not begin until November, and late-planted triticale and wheat did not emerge until February; but stands are good.
2. Seeding rate for late-planting experiment. For the past five years, WSU researchers in the dry region have used a 60 lbs/acre seeding rate for late-planted winter triticale in cropping systems trials near Ritzville. Due to relatively low number of head-bearing tillers with late-planted winter triticale, we are curious to see if increasing seeding rate will affect grain yield. The variety 'TriMark 099' was planted at a shallow depth at a seeding rate of 30, 60, 90, and 120 lbs/acre on October 27 with a paired-row drill on 12-inch row spacing. The winter wheat variety 'Otto' was planted using the same four seeding rates and with the same drill on the same date. Neither triticale nor wheat emerged until February. This spring there are striking differences in plant stands among the treatments. Grain yield components (number of heads per unit area, kernels per head, and kernel weight) as well as grain yield will be determined. Beginning in the 2016 crop year, this experiment will also be conducted on the Mike Nichols farm in the western part of the Horse Heaven Hills in Benton County.
3. Winter triticale variety experiment. Work by Howard Nelson, Central Washington Grain Growers, in Douglas and northern-Lincoln Counties has shown that 'TriMark 099' is generally the highest-yielding winter triticale variety. No such testing of triticale varieties has taken place in the Adams, Franklin, or Benton Counties where precipitation is considerably lower. We are evaluating six winter triticale varieties planted both deep into stored moisture in late August as well as planted shallow in mid-October. We use a deep-furrow small-plot drill with 16-inch row spacing for early planting and a single-disc drill on 6-inch row spacing for late planting. The winter wheat variety 'Otto' is also included for both planting dates. There are four replicates of each treatment for both planting dates. In addition to the Lind site, this experiment will be conducted on the Mike Nichols farm in the western Horse Heaven Hills in the 2016 crop year.

## Stripper Header Stubble May Conserve Fallow Moisture

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The 2013-2014 growing season was very dry for both farmers and researchers, with the site of the Ralston Project receiving only 7.4" of rain, 1.4" of which fell from May 1 to October 15, 2014. Triticale and tall winter wheat ('Farnum') are being grown in the cereal phase of the rotation for their high residue production. These cereals are harvested with a stripper header to leave a tall standing stubble that is managed with chemical fallow and compared to a system where wheat is harvested with a cutter bar (shorter stubble) and managed under a reduced tillage fallow. Soil sheltered by tall

(36 in) triticale stubble experienced lower wind speeds than soil that had undergone reduced tillage operations that removed the standing stubble buffer. When measured 6 inches above the soil surface, the maximum recorded wind speed over reduced tillage soil was 12.17 mph, while its counterpart that was sheltered by stripper header triticale residue recorded a maximum speed of only 4.34 mph. These differences in wind speed likely contributed to the difference in seed zone soil moisture that was recorded at planting. Establishment of winter canola was better in the stripper header triticale residue than in the reduced tillage fallow as a result of these moisture differences, allowing us to meet our goal of being able to establish winter canola in no-till fallow in the low rainfall zone.

Video presentation available at REACCH PNA YouTube channel, <https://youtu.be/XTxAq-F3V10>.

### Part 3. Pathology

#### Identifying New Sources of Stripe Rust (*Puccinia striiformis* f. sp. *tritici*) Resistance in East African Bread Wheat Accessions

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Improving crop resistance to diseases of economic importance is a key element of increasing crop productivity. Stripe rust, caused by the fungus *Puccinia striiformis* f. sp. *tritici*, is a widespread and major threat to wheat production in the Pacific Northwest of the US and the world. Characterizing new sources of resistance and incorporating multiple genes into elite cultivars is required to develop cultivars with diversified resistance genes that can provide protection against the dynamics of pathogen virulence. The aim of this research was to identify quantitative trait loci (QTL) or genes conferring resistance to stripe rust in a germplasm panel composed of 190 east African bread wheat landraces. The accessions were characterized for stripe rust resistance under field conditions in six disease environments in Washington. Seedlings of the accessions were also tested for resistance to important races of the pathogen under greenhouse conditions. The germplasm were genotyped with 90,000 Single Nucleotide Polymorphism (SNP) markers that are distributed across the whole genome. Analyses of genotypic data and phenotypic trait values were carried out to identify regions conferring stripe rust resistance in this germplasm. Twenty five (25) accessions showed a high level all-stage resistance to stripe rust across all test locations, while 27 accessions exhibited good level of resistance at later stage wheat plant growth. Genotype-phenotype analyses detected 83 loci associated with stripe rust resistance in at least three tests. Eleven of these genomic regions showed strong and stable association for conferring stripe rust resistance. For seedling resistance, seven significant genomic regions were detected, two of which were among the eleven QTL detected at adult plant stage. The molecular markers of the genomic regions detected in this study for resistance to stripe rust should be useful in marker-assisted selection in wheat breeding after validation using proper germplasm and populations.

#### Searching for New Sources of Resistance to Stripe Rust in Diverse Accessions from the USDA-ARS Spring Wheat Core Collection

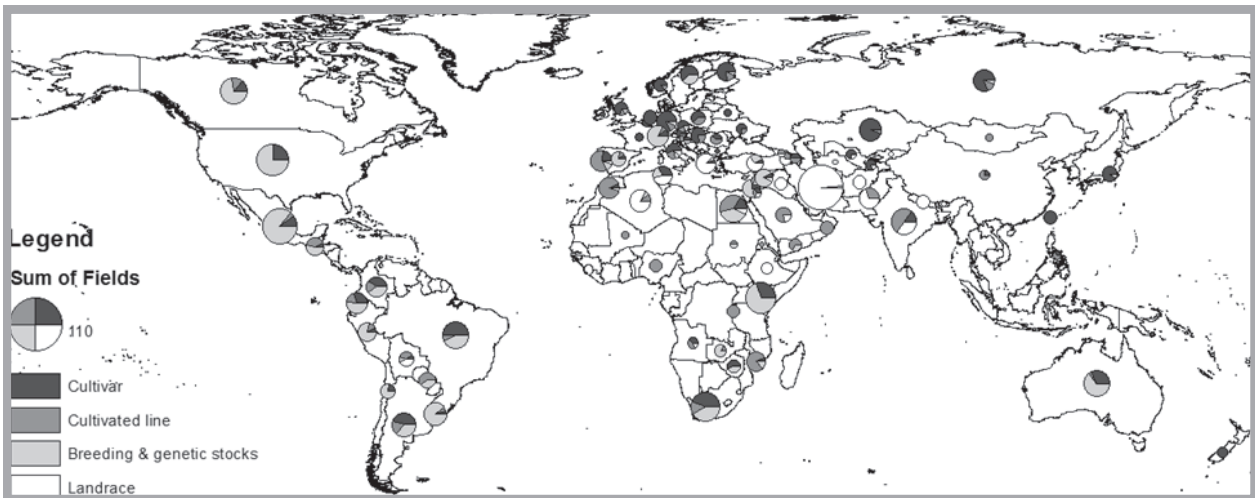
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Developing wheat cultivars adapted to the Pacific Northwest region is challenging due to stripe rust epidemics that are often triggered by emergence of new virulent races of the fungal pathogen, *Puccinia striiformis* f. sp. *tritici*. As part of the Triticeae Co-ordinated Agricultural Project (TCAP) funded by the USDA-NIFA, the wheat improvement program of WSU was tasked with the identification of new sources of resistance to stripe rust. To achieve this objective, 1,000 diverse accessions of spring wheat from the USDA-ARS wheat core collection were evaluated for resistance under natural disease

epidemics at field sites in Pullman and Mount Vernon. Using genetic and statistical approaches that combine the disease data collected from the field studies with molecular information generated through use of a dense set of DNA markers, we scanned over a thousand unique DNA segments across the entire genome of wheat for presence of resistance genes. We identified approximate 100 resistance genes that either correspond to previously identified genes or represent potential new genes. This study allowed us to identify the wheat accessions originating mainly from the Indian sub-continent region of Asia as potential sources of unique resistance genes that can be used for diversifying the stripe rust resistance gene pool in breeding programs. Our team is currently developing DNA markers that will accelerate and aid transferring some of these genes into the locally adapted cultivars. We are also in the process of completing a similar study on winter wheat accessions. Information generated from these studies is expected to have a significant and positive impact on wheat productivity in the State of Washington and beyond.



Country-specific distribution of the 1,000 accessions from the USDA-ARS spring wheat core collection.

## Seed Applied Insecticides for Wireworm Control in Cereal Grains

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Wireworm (*Limoniusspp.*) populations and crop damage increased in cereal grain (wheat: *Triticum aestivum* L. and barley: *Hordeum vulgare* L.) production across eastern Washington. Currently thiamethoxam, imidacloprid and clothianidin seed applied neonicotinoid insecticides are commonly used to control wireworms. At the inception of this project these seed applied insecticides were commonly used by farmers across the region at 0.07 g ai/100 kg. This rate, for multiple reasons, is inadequate for effective wireworm control in cereal grain production. In 2008 through 2013 a series of on-farm tests (OFT) were completed at two locations examining increased rates (0, 10, 20, 39 g ai/100 kg) of thiamethoxam seed applied insecticides on grain yield and wireworm populations. In 2014, a series of small research plots were initiated to study increasing rates of thiamethoxam, imidacloprid and clothianidin on both spring wheat and barley under moderate to heavy wireworm pressure. In the OFT near Davenport, yield and economic return over costs was increased 30 and 24 percent with increased insecticide rates. However, wireworm populations were not significantly different among treatments. At the OFT 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 *Limoniusspp.* (*Limoniusspp.*) is the predominate species and at Wilbur *Limoniusspp.* (*Limoniusspp.*) is the predominate species. In the small plot research, one year of data was inconclusive and further research is being completed.

## Genetic Tagging of Stripe Rust Resistance in Elite Durum Wheat

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Wheat stripe rust, caused by *Puccinia striiformis* f. sp. *tritici* (*Pst*), is one of the most damaging diseases for Pacific Northwest (PNW) wheat production. Growing resistant varieties is the most environmental-friendly and economical way to control wheat stripe rust. Previous studies indicated durum wheat (*Triticum turgidum* ssp. *durum*) has good potential for improving stripe rust resistance of wheat, but few new genes have been identified to date. In this study, 260 durum elite accessions mainly from Mediterranean countries and North America were used to identify seedling and adult plant resistance loci. The population was planted at three locations (Mount Vernon and two Pullman locations) to evaluate stripe rust response in 2014. Seven stripe rust races collected in United States and Italy were inoculated at seedling stage under greenhouse conditions. The panel was genotyped with 90,000 single nucleotide polymorphism (SNP) DNA markers. Preliminary analyses identified 13 genetic regions in 7 chromosomes (1A, 4A, 7A, 1B, 2B, 3B and 7B) that were associated with resistance to stripe rust. A total of 95 loci on all 14 chromosomes of durum wheat were linked with resistance at the adult stage. Now, we are in the process of taking additional data in the summer of 2015 at four locations (two Pullman locations, Central Ferry and Mount Vernon). After completion of this study, new resistance resources will help diversify the stripe rust resistance gene pool and SNP markers that are tightly linked to these resistance loci will facilitate breeding for resistance in common wheat.

## Stripe Rust Research in 2014

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In 2014, the low level of stripe rust was accurately forecasted using prediction models. Rust updates and advises were provided on time to growers for implementing appropriate disease management based on the forecasts and field surveys, which prevented unnecessary use of fungicides and saved growers millions of dollars. Wheat stripe rust occurred at the Pacific Northwest (PNW) at the lowest level in the past 15 years and also at low levels in other regions in the U.S. Barley stripe rust was also very low. Wheat leaf rust occurred in western Washington, but not found in eastern Washington. Barley leaf rust was severe in western Washington, but was not found in eastern Washington. Stem rust of wheat and barley was not observed in Washington. From 319 stripe rust samples collected from wheat (288), barley (24), triticale (1), rye (1), and grasses (5) in 13 states, we identified 33 races of the wheat stripe rust pathogen, 5 races of the barley stripe rust pathogen, and determined their distributions and frequencies in the country and various stripe rust epidemiological regions. Five of the wheat stripe rust pathogen races were new. Using virulence and molecular marker data, we determined that the stripe rust pathogen population in the western U.S. is more diverse than the population in the eastern U.S. We determined the bases for the fact that barberry plays essential role for stem rust, but not for stripe rust. Because the natural infection of the stripe rust pathogen was low, in 2014 we inoculated the experimental nurseries around Pullman with races which were predominant in the region in 2013, and created adequate disease levels for screening wheat and barley germplasm. We evaluated more than 30,000 wheat and barley entries for resistance to stripe rust. Using the stripe rust data, we collaborated with breeders in releasing five wheat varieties (WA 8162, WA 8165, WA 8166, WA 8169, and WA 8184) and one barley (2004NZ151) variety and registered seven wheat varieties and one barley variety. In 2014, we published the research results of mapping stripe rust resistance genes *Yr59*, *Yr62*, *Yr64*, and *Yr65* in wheat germplasm; mapped two genes for effective all-stage resistance in wheat genotype PI 195097 and two genes for high-temperature adult-plant resistance in wheat genotype PI 182126; and developed 15 mapping populations for identifying more resistance genes in wheat germplasm. We tested 30 fungicide treatments in fields for control of stripe rust; and 24 winter and 16 spring wheat varieties for their yield loss and fungicide response. The results of our fungicide tests and yield loss tests of currently grown PNW varieties are used for guiding rust management.

## Effect of Long-Term No-Till on Soil Fungal Communities in Dryland Wheat Cropping Systems

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Tillage has been shown to have major effects on soil bacterial and fungal communities in studies around the world. No-till is becoming more widespread in eastern Washington wheat cropping systems, as a way to control soil erosions. Previous work by our group has shown that tillage has no major effect on bacterial rhizosphere communities, and very few groups were favored by no-till in the bulk soil. We hypothesized that the increased residue in no-till may support a different fungal community, since fungi are more important in carbon cycling and breaking down cellulose and lignin in wheat straw. We sampled three locations with long-term no-till plots side by side with conventional tillage- the Palouse Conservation Farm (30 years +), Kambitsch Farm (15 years) and the Cook Agronomy Farm (17 years). DNA was extracted from bulk soil and pyrosequenced with ITS primers to determine the fungal communities. Based on the 2014 data, we identified 80 genera, mostly Ascomycetes. Some of the most dominant genera were in the families Chaetomiaceae and Lasiosphaeriaceae, which are cellulose decomposers. *Phomopsis* and *Trichocladium* were more dominant in no-till soils in all three locations. *Ulocladium* was more dominant in conventionally tilled soils. We will continue to analyze 2012 and 2013 samples to see if these trends are consistent across years. Graphs show 2014 data, with micrographs in same order as graphs.

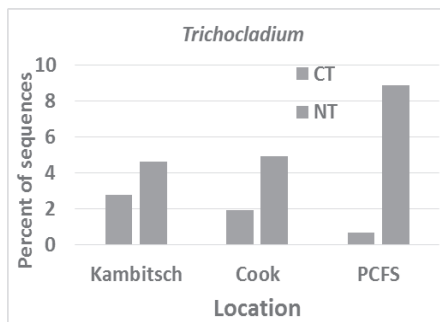


Figure 1. Effect of tillage on the frequency of sequences of *Trichocladium* at three different locations. CT= conventional tillage, NT -No-till.

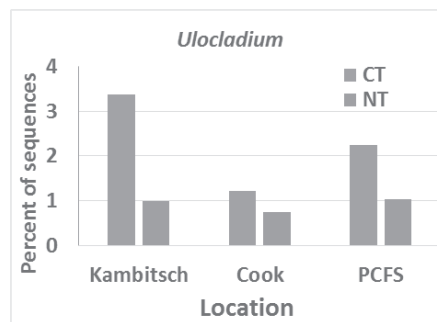


Figure 2. Effect of tillage on the frequency of sequences of *Ulocladium* at three different locations. CT= conventional tillage, NT-No-till.

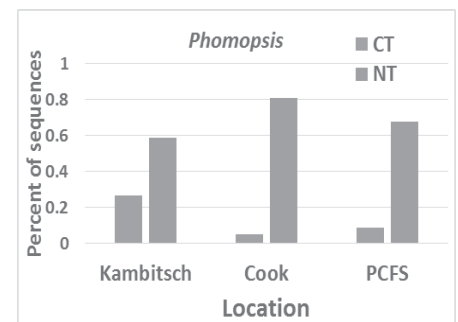


Figure 3. Effect of tillage on the frequency of sequences of *Phomopsis* at three different locations. CT= conventional tillage, NT-No-till.

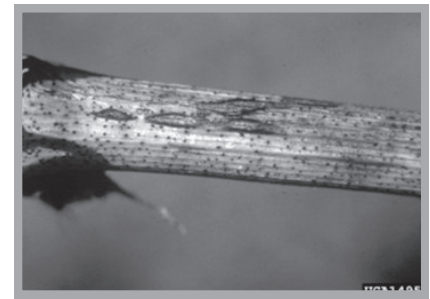
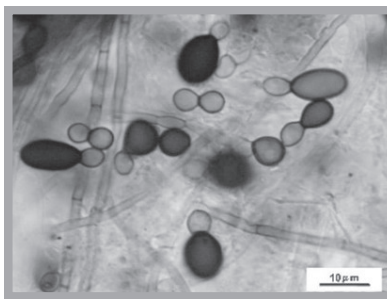


Figure 4 A. Conidia of *Trichocladium*. B. Conidia of *Ulocladium* C. Pycnidia of *Phomopsis*.

## Cataloging Stripe Rust Resistance Genes in Elite Pacific Northwest Spring Wheat through Genome-wide Association Mapping

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Cool and moist weather during the growing season is very conducive to stripe rust infestation. The Pacific Northwest (PNW) is one of the hot spots for stripe rust epidemics since our weather patterns are normally ideal for infection. Elite PNW spring wheat lines have been developed with resistance genes that have provided good resistance; however, many resistance genes remain largely uncharacterized, and given the high pressure of the disease, it is important to keep adding new and diverse resistance sources. Knowing the chromosome locations and markers closely located near resistance genes makes breeding for stripe resistance more efficient. We screened a panel of 409 elite PNW spring wheat lines at Spillman, Whitlow, and Mt. Vernon research farms for three years for stripe rust resistance and genotyped the panel with 9000 single nucleotide polymorphism (SNP) markers. We incorporated this information for a genome-wide mapping analysis, an approach which scans SNPs across the genome to detect genetic variations associated with stripe rust resistance. Multiple chromosome locations were identified as highly associated with resistance; however, the short arm of chromosome 1B was most frequently and consistently detected as significantly related with stripe rust resistance across different locations and years. Based on our findings, we can better strategize our breeding program by effectively choosing parents for new crosses, developing new markers which help selecting progenies with the resistance genes, and bringing new resistance sources which are missing from our current panel.

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

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Eyespot (strawbreaker foot rot) and Cephalosporium stripe are important diseases of winter wheat in the Pacific Northwest. These diseases are most common in the high-rainfall regions of Washington, but also occur in the low- and intermediate-rainfall wheat-producing areas and have potential to cause loss in grain yield up to 50% for eyespot and 80% or more for Cephalosporium stripe. Early-seeded winter wheat is at the greatest risk of being affected by these diseases, especially when planted following summer fallow.

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

True resistance to Cephalosporium stripe doesn't occur in wheat, but varieties differ in their susceptibility and some are tolerant including: Eltan, Bruehl, Coda, Masami, ORCF-102, Tubbs 06, WB 528, and Xerpha. Data for disease reaction, yield and test weight of winter wheat varieties and breeding lines in response to Cephalosporium stripe was evaluated at the Palouse Conservation Field Station, Pullman, WA, in 2014 and are available online (<http://smallgrains.wsu.edu/disease-resources/research-reports/>).

Four fungicides are registered for eyespot control; Tilt 3.6EC, Topsin-M 4.5FL, Priaxor 4.16SC, and Alto 100SL. The active ingredients in Tilt and Alto are related and belong to the triazole class of fungicides and application with Topsin-M is recommended for both. Priaxor contains two active ingredients, a carboxamide and a strobilurin, which are very effective in controlling eyespot. We test these and potential new fungicides for effectiveness in controlling eyespot and publish the data on the [Wheat and Small Grains website](#) (Table 1).

Table 1. Effect of foliar fungicides on eyespot disease, yield, and test weight of winter wheat, Plant Pathology Farm, Pullman, WA, 2013.

Treatment	Application rate/A	Disease incidence%	Disease severity 0 to 4	Disease index, 0 to 100	Yield, bu/A	Test weight, lb/bu
Non-treated	-	95.5	3.0	72.3	116.7	60.1
Priaxor 4.16SC	4.0 fl oz	68.3	2.7	45.8	130.1	60.2
Topsin 4.5FL + Tilt 3.6EC	10.0 fl oz + 4.0 fl oz	78.4	2.7	52.8	125.9	60.3
Priaxor 4.16SC + Tilt 3.6EC	2.0 fl oz + 4.0 fl oz	82.4	2.9	59.6	121.2	60.5
TwinLine 1.75EC	9.0 fl oz	74.3	3.2	60.7	123.3	60.2
Viathon 4.08L	32.0 fl oz	88.2	3.0	66.4	129.3	60.3
<b>LSD</b>		<b>NS</b>	<b>0.4</b>	<b>18.7</b>	<b>9.2</b>	<b>NS</b>

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

Soilborne wheat mosaic (SBWM) is a relatively new disease problem for Washington wheat growers that was first recognized in the Walla Walla area in 2008. 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. Variety ratings are available on the [WSU Wheat and Small Grains website](#).

Speckled snow mold and pink snow mold occur in the north-central wheat-producing area of eastern Washington where snow cover can persist for up to 150 days. These diseases can cause complete yield loss in years when they are severe, but disease-resistant varieties like Bruehl and Eltan are available to limit damage. Planting a resistant variety early is still the best control for the snow molds. In conjunction with the WSU Winter Wheat Breeding program and University of Idaho Extension Plant Pathology program in Idaho Falls, ID, we are testing current and new varieties for snow mold resistance in field plots near Mansfield and Waterville, WA, and Tetonia, ID. Snow mold developed at the Tetonia R&E Center in 2014, which allowed us to collect variety reaction data. In addition to field testing, we are also trying to improve methods of screening for resistance in the growth chamber based on inoculation under simulated winter conditions and by measuring accumulation and depletion of fructan polysaccharides.

## Screening for Resistance to Cereal Cyst Nematode in Locally Adapted Spring Wheat Cultivars of the Pacific Northwest

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Cereal cyst nematodes (*Heterodera spp.*) are an invasive root pathogen that causes significant economic damage to rainfed wheat fields worldwide. *Heterodera filipjevi* has been identified in wheat producing areas in the Pacific Northwest states of Oregon and Washington. Symptoms of pathogen include severe yield loss, whitehead formation, and stunted root systems. Crop rotations of wheat with broadleaf crops or a long fallow reduces cereal cyst abundance. However, the broadleaf crops and long fallow often are not profitable in the driest areas of the Pacific Northwest, and eggs within a female cysts can persist in the soil for many years in the absence of a host. Nematicides were a very effective alternative, but few are registered in North America due to the damaging effects they can have on human health. As a result, the use of genetic resistance is considered the most cost effective, environmentally friendly, and easily adopted method to suppress this pathogen. Field screenings were performed, to determine if there is resistance in locally adapted cultivars and experimental lines which could be introgressed into new Washington varieties. Cultivars were planted in two head rows, side by side with two rows of a susceptible check, "ALPOWA", and replicated in 5 blocks over the field. Samples (approximately .3 meters long) were collected 45-60 days after planting at Zadok 45-55 growth stage. Five plants from each sample were used as a pooled sample and the number of white female cysts visible on the roots were assessed using a 0-5 rating scale. In 2013, 83 adapted cultivars or experimental lines from the Western Spring Regional Nursery and Washington State Extension Trials were screened, and eight were identified as resistant. In 2014, thirteen cultivars or experimental lines with resistance were identified from a total of 112 in the Western Spring Regionals and Regional Variety Trials. "SY\_STEELHEAD" showed consistent resistance in both years, resistant cultivars and experimental lines from both years can be seen in Table 1. Screening will continue in 2015.

2013 Resistant Cultivars	2014 Resistant Cultivars
SY_STEELHEAD	SY_STEELHEAD
UC1711	SVEVO
AUBR31059W	IDO1202S
OUYEN	WB_HARTLINE
CHARA	GLEE-0W
WA_8163	SY605_CL
CHBR1481W	GLEE (WA 8074)
COI565W	UC1767
	WA8165
	UI_STONE (IDO599)
	05SB84
	CHARA



## Part 4. Breeding, Genetic Improvement, and Variety Evaluation

### Mold & Cold: The Solution is Sweet in Winter Wheat

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Wheat production is a billion dollar industry in Washington state. More than one hundred million bushels are produced each year, of which approximately 80% is winter wheat and is prone to damage from snow mold and freezing temperatures during the winter. Fortunately, efforts have been made to breed for resistance, which has been shown to be conferred by sugar accumulation in the crown region. Understanding the link between resistance and accumulation and maintenance of sugar stores will help breeders improve the winter hardiness of winter wheat. Fructans are a class of fructose polymers that have been shown to promote resistance to snow mold. Similarly, the simple sugars, glucose, fructose, and sucrose, have been demonstrated to serve as cryoprotectants. Because breeding for snow mold resistance occurs in cold environs, it is difficult to analyze resistance to mold and to cold, individually. A timecourse of sugar content, sugar-related gene expression, and degree of mold infection will help to distinguish between wheat's resistance to snow mold and to damage from freezing temperatures. Preliminary field data will enable identification of markers for associated QTLs to improve the efficiency of breeding for resistance.

### Winter Wheat Breeding and Genetics

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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. We are continuing to develop doubled haploid populations and evaluate roughly 3,500 annually. In 2014 we evaluated over 1,500 lines developed with marker selection for stripe rust resistance, foot rot resistance, grain protein content, and other various traits. We have developed Imazamox resistant breeding lines in both hard and soft backgrounds which are under advanced testing in field trials. 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. We are collaboratively developing high-throughput field phenotyping platforms to facilitate data collection which complement our phenotyping work under growth chamber conditions. The program continues to work effectively and efficiently to develop winter wheat cultivars with high yield potential and required agronomics, disease resistance, and end-use quality parameters for the state of Washington.

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

**Sprinter** was released in 2012 and certified seed is available. Sprinter has very high grain protein content, with an average of 14.4% protein in target environment. It is a tall variety with early heading date, has excellent end-use quality, and is targeted for late-planting situations in the state. If planted early (in August), spring heading dates may be early enough to be affected by frost damage.

**Puma** was released in 2013 and is on certified 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 three 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, and tolerance to low pH soils (aluminum tolerance), and excellent end-use quality.

**Jasper** was released in 2014 and is on foundation seed increase. This line is a soft white winter wheat, which appears to be broadly adapted to multiple rainfall regions of the state. In the 2014 Variety Testing trials, Jasper (WA8169) was in the top significance group for yield potential in all rainfall zones. This line seems to be very resilient to the drought conditions of 2014 and maintained a high yield potential even under these limited moisture conditions. It has very good adult plant resistance to stripe rust, and very good end-use quality.

## Improving Seedling Emergence of Winter Wheat from Deep Planting Depths

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In the low-precipitation (less than 12 inch annual) region of the Inland Pacific Northwest, winter wheat is sown as deep as seven inches below the soil surface to reach adequate soil moisture for germination. 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 deep depths under limited moisture conditions are needed. The present-day semi-dwarf cultivars in PNW contain either Rht1/Rht2 or both dwarfing genes. These genes have adverse effect on early seedling growth and hence effect emergence from deep planting compared to the taller varieties. With the objective to transfer the emergence trait from Buchanan (hard red) to Xerpha, 14,000 BC<sub>1</sub>F<sub>1</sub> seeds were produced. The BC<sub>1</sub>F<sub>1</sub> seeds were first phenotypically evaluated for coleoptile length and selected plants were then evaluated with DNA markers. The selected plants were further evaluated for deep emergence in field at the Lind Dryland Research Station. From the field emergence test, 15 lines were selected based on their better emergence and were further evaluated in 2013 growing season. Replicated plot trials were also planted in cropping season 2014. Based on emergence and quality, one selected soft white line is included in the WSU winter wheat variety-testing program at several sites.

## Two-Gene Clearfield Soft White Winter Wheat Varieties: Curiosity CL+ and Mela CL+

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Grassy weeds, especially jointed goatgrass, cause significant yield losses in the US Pacific Northwest (PNW). Clearfield technology provides an invaluable opportunity to control these annual grassy weeds. Imidazolinone (IMI) class of herbicides, available with a trade name 'Beyond,' can effectively control many grassy weeds including jointed goatgrass, but it cannot be applied to the commonly available wheat genotypes due to their sensitivity to this herbicide. Mutants in the acetolactate synthase (*ALS*) gene, namely *ahas1-1d*, *ahas1-1b* and *ahas1-1a* that confer tolerance to IMI herbicides, have been developed and exploited in wheat to achieve effective weed control. Currently, wheat varieties developed through Clearfield technology have become popular due to their ability to control noxious weeds and benefits for crop rotation with legume crops. Most of the Clearfield wheat varieties carry single gene Clearfield technology. Due to herbicide sensitivity, the wheat varieties carrying single gene Clearfield technology show significant yield penalty. In comparison, the two-gene Clearfield wheat varieties show improved tolerance to the herbicide and also allow use of

higher rates of herbicide and/or better surfactants such as methylated seed oil (MSO). 'Curiosity CL+' and 'Mela CL+' are the first soft white winter (SWW) wheat varieties that carry the two-gene Clearfield technology.

Curiosity CL+ was released as two-gene Clearfield SWW wheat variety in 2013 and it is in full commercial production. Curiosity CL+ was derived from a cross between CL0618 (an Australian SWS two-gene Clearfield line) and 'Eltan' using a molecular breeding method called marker-assisted background selection (MABS). It has high yield potential, excellent snow mold tolerance and better stripe rust resistance at seedling as well as adult-plant stage than any other Clearfield variety grown in the PNW. Curiosity CL+ has wide adaptation in the state as it performs well in high, medium, and low rainfall areas as well as in the typical Eltan growing areas with or without the herbicide application. The milling score of Curiosity CL+ was significantly better than 'ORCF102' and has significantly higher cake volume than that of 'Stephens'.

Mela CL+ was also released as two-gene Clearfield SWW wheat variety in 2013 and it is also in full commercial production. It was derived from a cross between CL0618 and Eltan using MABS. It exhibited high yield potential, excellent snow mold tolerance and better stripe rust resistance at seedling as well as adult-plant stage than any other Clearfield variety cultivated in the PNW. Mela CL+ has also shown wide adaptability like Curiosity CL+ in the Washington, but it is ideal for cultivation in the low rainfall regions or typical Eltan growing areas. Mela CL+ has very good milling and baking quality, and thus it was categorized in desirable class. Foundation seed for both of these varieties will be produced and maintained by the Washington State Crop Improvement Association (WSCIA).

## High-Throughput Field Phenomics Project

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Genomic technology has made rapid progress in recent years, yet the ability to quickly analyze the response of breeding populations in field environments has not kept pace. Interest in High-Throughput Field Phenomics (HTFP) is rapidly growing because it allows for the potential to quickly, efficiently and non-destructively collect data on crop characteristics such as vegetation indices, canopy temperature, crop height or disease pressure in field plot experiments.

Multi-spectral and thermal images were collected from winter and spring wheat experimental plots at Pullman, Lind, Othello and Central Ferry prior to harvest in June and early July, 2014. Cameras mounted on adjustable booms attached to a wheel tractor were operated using software on a laptop computer mounted near the driver's seat. Images were analyzed for their reflectance values. There were significant differences in reflectance values among entries within nearly all of the experiments ( $P < 0.05$ ). Future work will include scanning field trials at different developmental stages during the 2015 growing season, refining analysis of images, and utilizing GPS technology to georeference images with their corresponding field position.

## Late Maturity Alpha-Amylase (LMA): Reducing the Risk of Low Falling Numbers

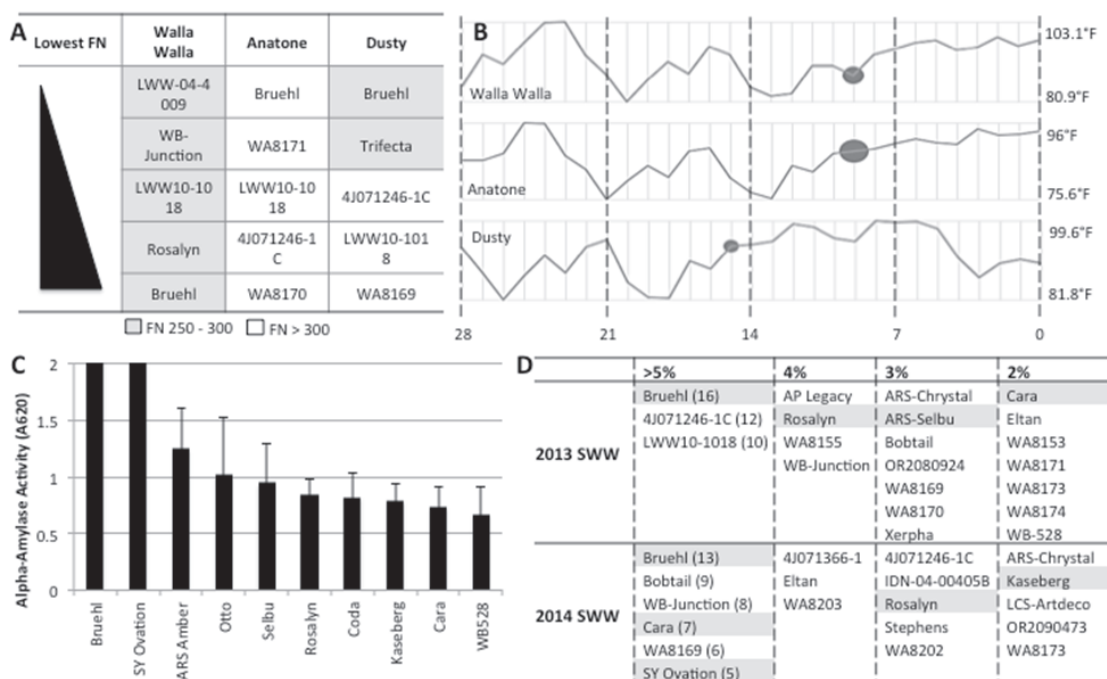
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Late maturity alpha-amylase (LMA) results in low Falling numbers (FN) when a hot or cold temperature shock occurs 26-30 days after pollen shedding. LMA results in low FN due to the presence of alpha-amylase, an enzyme that breaks down the starch into simple sugars. Since weather can be unpredictable, finding ways to assess genetic LMA susceptibility in PNW wheats is essential to preventing low FN and maintaining high Pacific Northwest (PNW) end-use quality. In 2013, FN were run on winter varieties from 20 different locations. The Steber lab FN website (<http://steberlab.project7599.php>) provides FN data along with average precipitation for each location, and actual weather data gathered (up to 28 days

prior to harvest) to show when and how much rain fell which can help determine whether low FN can be attributed to LMA or preharvest sprouting. **(A)** shows two locations, Walla Walla and Dusty, where we suspect FN below 300 sec (gray shading) was due to LMA. Anatone had no lines with FN under 300. Weather data are shown in **(B)**: the graph shows daily high temperatures and the circles symbolize rain events where the size of the circle represents how much it rained. It is likely that the temperatures were too warm and the precipitation too low to cause preharvest sprouting at these locations. Instead it appears that lower FN was associated with a large temperature fluctuation around 21 days before harvest. **(C)** In a greenhouse LMA experiment, those lines with an amylase value over 0.5 would likely give an FN below 300 sec. LMA susceptible winter cultivars are shown; Bruehl and SY Ovation are most LMA susceptible. **(D)** The greenhouse LMA susceptible lines also tended to show lower FN in the field. Cultivars were ranked for a tendency to be within the worst 5 for FN over 20 locations in 2013 and 2014; the >5% is the worst case. Cultivars shaded in gray showed LMA susceptibility in the greenhouse AND in the field.



## Breeding Barley to Meet Demands of the Washington Growers

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Under the auspice of the project WNP00251, entitled "Breeding Barley for Imidazolinone Resistance and High Grain Lysine Content" we are committed to develop nutritionally enhanced and ecologically adapted high yielding barley cultivars for the State of Washington. Spring barley, which is one of the preferred rotational crops after winter wheat, has lost acreage throughout the US. Specifically, in the State of Washington observed decline in acreage was quite significant, from 500,000 acres planted in 1999 to 115,000 acres in 2014. A combination of biological, edaphoclimatic and agronomical factors are responsible for this decline, in particular susceptibility of barley to commonly used herbicides and prevailing races of foliar as well as rhizopathogens contribute to it. No natural resistance to imidazolinone (IMI) herbicides and major rhizopathogens of dryland barley production exist in the extant germplasm. In addition, since feed barley is the preferentially cultivated class of barley in the State of Washington we focused our efforts both on enhancement of nutritional quality and sustainability of barley production by developing resistance to major rhizopathogens and tolerance to IMI herbicides. The progress made in this direction is described below:

i) Breeding for imidazolinone tolerance: The decline in barley acreage can be in part explained by the large-scale application of IMI herbicides and adaptation of IMI-resistant crops. Making transfer of IMI-resistance, characterized by us in the feed barley cultivar Bob to other relevant food, feed and malting barleys a primary breeding objective. In this connection the seed grant received from the Washington Grain Commission allowed us to transfer IMI resistance to six barley cultivars, two each belonging to three market classes of barley. The transfer of resistance was primarily confirmed by herbicide spray at a 2' (8oz/acre) field recommended dose (for winter wheat) followed by determination of plant vigor a month after herbicide spray. Based on the phenotypic screen 6-8 most vigorous F<sub>2</sub> plants per cross combination were tested for mutant allele at the *AHAS* (acetohydroxy acid synthase) locus by DNA sequencing, and the recovery of recipient parent genome by genotyping with the carrier chromosome 6H specific DNA markers. Results of this pilot study revealed a range of 20%–90% recovery of the recipient parent genome for the carrier chromosome in different cross combinations. Collectively, this study unambiguously showed that it is possible to identify plants with good recipient parent genome recovery without involving the laborious backcrossing steps. In view of these results we are now screening 192 F<sub>2</sub> individuals per cross combination for the recovery of the recipient parent genome using a three step marker-assisted selection approach. This approach involves a foreground selection step followed by two background selection steps, which include sequential screening with carrier chromosome specific and genome-wide DNA markers. The plants showing good recovery of the recipient parent genome will be evaluated for their performance in field on herbicide residue and under spray trials.

ii) Pre-breeding for the high grain lysine content. All cultivated barleys are lysine deficient, and require lysine fortification for feeding livestock. Thus, improving lysine content has always remained a primary breeding target. To cope with this problem the breeders have produced high-lysine barley mutants, but despite of several attempts, were unsuccessful in dissecting yield penalty associated with the only agronomically relevant high-lysine barley mutant Risø 1508 (*Lys3a*) with 44% more lysine than wild type. The possible reasons behind the unsuccessful attempts may be either the size of the primary mutation or its tight association with other undesirable background mutations. Moreover, the miss-localization of the *Lys3* locus on barley chromosome 5H made its cloning virtually impossible. With the help of our collaborators in Germany we determined that ~10Mb DNA stretch from Risø 1508 on the short arm of chromosome 1H carries *Lys3* gene. It is a big chromosome segment harboring several hundred genes. Thus, in order to narrow down the effect to a smaller chromosomal region with fewer genes, crosses were made between a near iso-genic line dubbed BW496 carrying the *Lys3* mutant allele in the Bowman background with Golden Promise, and >2000 F<sub>2</sub> grains were obtained. DNA markers flanking the region of interest will be used to evaluate these F<sub>2</sub> plants to identify genotypes carrying recombinations within this region. Identified recombinants will be genotypes with additional DNA markers mapping within the region. If required, more DNA markers will be developed and more crosses will be made, and the process will be repeated until a limited number of candidate genes will be identified whose effect on the lysine content will be confirmed by gene silencing.

iii) Breeding for root and crown rot resistance: The aim of this research is to address a gap in genetic resources available to barley breeders to combat the most devastating root pathogens of the dryland barley production. Direct seeding or conservation tillage are the preferred management practice in the low rainfall areas, where crop residue left on the soil surface provides an ideal environment for the proliferation of root and crown rot pathogens specifically *Rhizoctonia solani*, *R. oryzae*, *Fusarium culmorum* and *F. pseudograminearum*. Using biotechnology, an endochitinase (*ThEn42*) gene from a mycotrophic fungus *Trichoderma harzianum* was introduced in barley genomes, and expressed ectopically under the control of *35S* promoter. Production of enzyme in barley transformants was determined with the help of a fluorometric assay. The initial transformants identified in Golden Promise background were used to transfer transgene to barley cultivar Baronesse. Eight transformants in Baronesse background that showed high expression levels of *ThEn42* gene in roots were identified, and these genotypes are currently being challenged with root pathogenic fungi in greenhouse.

iv) Breeding for proanthocyanidin-free grains: In view of reducing the cost of the brewing process and to increase the industrial value of food barley a proanthocyanidin-deficient barley mutant *ant-499* in Apex background was deployed to develop a proanthocyanidin-free barley genotype adapted to the US Pacific Northwest (PNW). This characteristic provides barley with an added advantage of being free of proanthocyanidins (condensed tannins) in the seed coat that cause haze formation in beer after refrigeration (by binding to the protein), and give barley porridge a characteristic gray

color that makes it unsuitable as baby food and breakfast cereal. Since, feed barley is the preferentially cultivated class of barley in the US PNW a proanthocyanidin-free genotype, 2004NZ151 with high protein content was selected. Results of the multi-location yield trials in the western Washington showed that 2004NZ151 yields at least 1000 lb/a more than the large acreage varieties (i.e., Bob, Baronesse, and Champion), and exhibits resistance to lodging as well as prevalent races of stripe rust, leaf rust and powdery mildew. In view of its outstanding agronomical performance 2004NZ151 was approved for release under the name Richard for cultivation in the western Washington. Since, Richard breeds true for *ant-499* mutation it will serve as an excellent material to breed for the proanthocyanidin-free malting and food barley cultivars adapted to the US PNW or elsewhere.

## Finding the Genetic Causes of Freezing-Tolerance in Washington Winter Wheat

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Damage caused by freezing is an inconsistent, but costly problem for wheat farmers in Washington. In severely cold temperatures, where snow-cover is insufficient, freezing stress is often lethal to the plants. A large amount of variation exists in the genes that provide the plants with cold tolerance. This poses a challenge for breeders who are trying to improve the trait because freezing tolerance is difficult to measure consistently on a large scale, and the genetic markers for the trait are not yet accurate enough to predict tolerance consistently. A recombinant inbred line population was made from two cultivars (Finch and Eltan) that differ in freezing tolerance. The genetics from the progeny of that cross were examined, and a genetic map was made of the population. That map was compared with freezing tolerance data on those progeny in order to find the genetic sources of variation for freezing tolerance between those lines. Understanding the causes of differential freezing tolerance in Finch and Eltan are important because these cultivars have been used extensively in the development of Washington wheat breeding material. We found that FR-2 (a locus that is close to the vernalization locus) and two other loci were important in controlling freezing tolerance in these lines. We are further investigating these loci in order to develop better markers for freezing tolerance so that we can improve the efficiency of breeding for the trait.

## The USDA-ARS Western Wheat Quality Laboratory

CRAIG F. MORRIS, DIRECTOR; 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, arabinoxylans, puroindolines, soft durum wheat, polyphenol oxidase (PPO), waxy wheat, and quinoa. Our recent publications include a study on the grain consumption preferences of the house mouse, published in the Journal of Food Science. Research on tracking arabinoxylans through the preparation of pancakes was published in Cereal Chemistry. A study modeling end-quality in United States soft wheat germplasm was published in Cereal Chemistry. Research on the evaluation of texture differences among thirteen varieties of cooked quinoa was published in the Journal of Food Science. A study on polyphenol oxidase as a biochemical seed defense mechanism was published in Frontiers in Plant Science. Other research includes extrusion characteristics, thermal and rheological properties of waxy soft white wheat flour; the internal structure of carbonized wheat grains and the relationship to kernel texture and ploidy; and the repeatability of mice consumption discrimination of wheat varieties across field experiments and mouse cohorts. Currently the lab is working on grant-funded research

aimed at removing the culinary constraints of soft kernel durum wheat, a genetically rich cereal species. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Babe, Cara, Diva, Farnum, JD, Kelse, ORCF-103, Skiles, Tubbs 06, Whit, Xerpha, Crescent, Chrystal, Amber, Gene, Goetz, Eden, Finch, and Otto.

## Approaching the Target of Developing Celiac-Safe Wheat Genotypes

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Wheat and derived products are elicitors of a number of frequent diet-induced health issues including gluten intolerance, sensitivity and allergy, collectively known as the 'gluten syndrome'. These disorders cumulatively affect more than 7.5% of the U.S. population. In particular, the gluten intolerance or celiac disease, alone affects more than 71 million individuals around the globe (i.e., ~1% of the world population), which makes it one of the most devastating disorders of the gastrointestinal tract. The seed storage proteins of wheat in particular prolamins (i.e., gliadins and glutenins) are known to trigger this autoimmune condition. So far 190 celiac causing epitopes were identified from wheat prolamins where origin of the 180 epitopes were tracked back to  $\alpha$ / $\beta$ -,  $\gamma$ - and  $\omega$ -gliadins and remaining 10 to low and high molecular weight glutenin subunits. Interestingly, out of these 10 epitopes from glutenins, high molecular weight glutenins (HMWGs) contribute to only two epitopes, which have shown to elicit immune responses in relative fewer cases. This explains that patients with immunogenic HMWGs are less frequent, which in addition to their vital role in the bread making process make it a very important characteristic. In addition, the low molecular weight glutenins (LMWGs) and gliadins have imbalanced amino acid profiles with 15% proline and 35% glutamine, and reduced content of essential amino acids lysine, threonine, methionine and histidine. Parallel research has also demonstrated that gliadins and LMWGs are superfluous for baking, as the flours derived from wheat deletion lines and transformants lacking one or more families of the gluten proteins baked into normal bread loaf with characteristic organoleptic properties. Similarly, the *in vitro* experiments with washed out wheat flour residues mixed with recombinant HMWg subunits (HMWDx5 and HMWDy10) baked into normal looking bread loafs, which further supported the observations made with the wheat transformants and deletion lines. Moreover, the reduced-gluten transgenic lines exhibited improved nutritional properties since their lysine content was significantly higher than that of normal flour due to the compensatory increase in the amount of lysine-rich proteins.

Since HMW glutenin subunits largely contribute to the baking properties of wheat, and are primarily non-immunogenic, we undertook a strategy to specifically eliminate LMW glutenin subunits and gliadins from grains by endosperm-specific silencing of wheat *DEMETER* (*DME*) homoeologues. *DME* enzymes regulate transcriptional activation of the prolamins genes (except HMW glutenin genes) during endosperm development by demethylation of their promoters. Under the auspice of the NIH (National Institutes of Health) and LSDF (Life Sciences Discovery Fund) funded research projects we undertook cloning of wheat *DME* homoeologues, established connections between temporal expression of *DME* homoeologues and accumulation of specific prolamins, and transformed wheat variety Brundage 96 to express *DME*-targeting hairpin (hp) and artificial micro (ami) RNAs in endosperm. Using this RNA interference based approach 401 candidate transformants were obtained. Of these 401 transformants 333 were obtained through particle bombardment and 68 via microspore electroporation. Using protein gel electrophoresis and liquid chromatography 19 viable wheat transformants showing elimination of 45.2-76.4% immunogenic prolamins were identified. Protein profiling of these transformants exhibited elimination of specific prolamins and/or prolamins groups. Differential silencing of three *DME* homoeologues in individual transformants due to variations in number and site of transgene integration(s), the *DME* site targeted by hp- and amiRNAs and the level of conservation among *DME* homoeologues at the small interfering RNA targeted sites, explains the observed incomplete elimination of gluten proteins. This partial elimination of prolamins has motivated us to pyramid the effects of different transformants to a single plant, to obtain genotypes completely devoid of celiac causing prolamins. To achieve the desired objective crossing of selected transformants after doubled haploidization is currently underway.

Moreover, in order to get the preliminary idea about the end-use quality of the selected transformants T<sub>4</sub> grains of these genotypes were used for the detailed mixing and baking experiments at the Western Wheat Quality Laboratory in Pullman. In view of the importance of the physical properties of grain in determining end-use quality a number of single kernel parameters like grain hardness, grain weight and grain size were studied using the Perten Single-Kernel Characterization System (SKCS). However, no major difference in the physical properties of the selected transformants and the untransformed control was observed. In order to get a deeper insight into the end-use quality of grains other physical parameters like flour yield, break flour yield, flour ash content and milling score were recorded on the selected transformants. For these parameters the transformants exhibited subtle differences among themselves and with the control. Since, most of the above mentioned parameters are reflective of kernel hardness and the literature suggests that it is not a decisive characteristic for bread making, various parameters that represent flour protein content and gluten strength were studied. Specifically the SDS (sodium dodecyl sulfate)-sedimentation test and mixograph analyses, which are considered as good indicators of bread-making quality, were studied in the selected transformants. The analyses suggested significant gluten strength in transformants namely P42G4, P32F2, P31D12, P48F6, P78E7 and P48F5 in comparison with the wild type control, Brundage 96. Interestingly, different transformants exhibited higher scores for different mixograph parameters. Specifically, wheat transformant P31D12 that exhibited 76.4% reduction in amount of immunogenic gluten proteins also showed highest gluten strength. In addition to the mixing assay baking experiment was also performed with these transformants. In this experiment loaf volume of breads baked from the selected wheat transformants ranged from 775 cubic centimeter (CC) for P22H3 and P48F6 to 930 CC for P42G4, whereas the loaf volume of the untransformed control was 765 CC. Four transform, namely P42G5, P42G4, P32F2 and P31D12 exhibited significantly high loaf volumes in comparison with the control. Collectively these biochemical and baking experiments unambiguously suggested that these transformants however exhibit physical properties similar to soft wheat genotypes they possess potential to be baked into breads somewhat similar to hard wheat genotypes.

## Pre-Breeding for Root Rot Resistance Using Root Morphology Traits

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Reduced tillage or minimal tillage has been very beneficial for increasing soil moisture and organic material in soils, while also reducing wind and water erosion. However, reduced tillage and increased plant residue intensifies the levels of some soilborne pathogens that use the residue to grow and propagate. Pathogens such as *Rhizoctonia solani*, can become a major yield-limiting issue for growers who use direct seeding or who plant into live or dying green material (volunteer plants, weeds, and potential cover crops) after spraying with herbicides. As of today, no wheat or barely varieties are resistant to *R. solani* or other pathogens favored by these conditions. Our research goals are to develop wheat varieties that are tolerant to these conditions by transferring natural resistances from wild wheat relatives into commercial varieties of wheat. Initially, resistance was identified in five 'Synthetic' derived wheat lines from a screen of approximately 400 accessions. Genes from all five sources have been backcrossed into the cultivar Louise to make lines carrying approximately 85% of their genes from the Louise parent (BC2 lines). Large families from two of the lines have been developed as mapping populations to characterize the number and locations of the resistance loci. The genomes of the two mapping populations were genotyped using next generation sequencing to cover their genomes with thousands of markers. These are being used to mark DNA fragments carrying the genes for resistance to more efficiently track them as they are moved into selected cultivars. BC2 lines in the Louise background are currently being selected and increased for further testing. We had many undesirable traits from the wild wheat that will need to be removed. By backcrossing into the Louise background, this will remove many of these undesirable traits, while also maintaining the resistance. Field assays this spring include direct-seeding into cool, wet, green bridge soils where plots were sprayed with glyphosate 2-3 days prior to planting. Individual lines are being compared to those grown in soils which were sprayed four weeks prior to planting (no green bridge, low disease pressure). After we have selected BC2 lines with these favorable resistance alleles from each resistant source and have increased these lines, we will begin conducting yield trials in 2016. We plan on testing the resistance and yields under a variety of direct seeding conditions in different rainfall zones. We are also testing a new field phenotyping assay in collaboration with bio-systems engineer Dr. Sindhuja



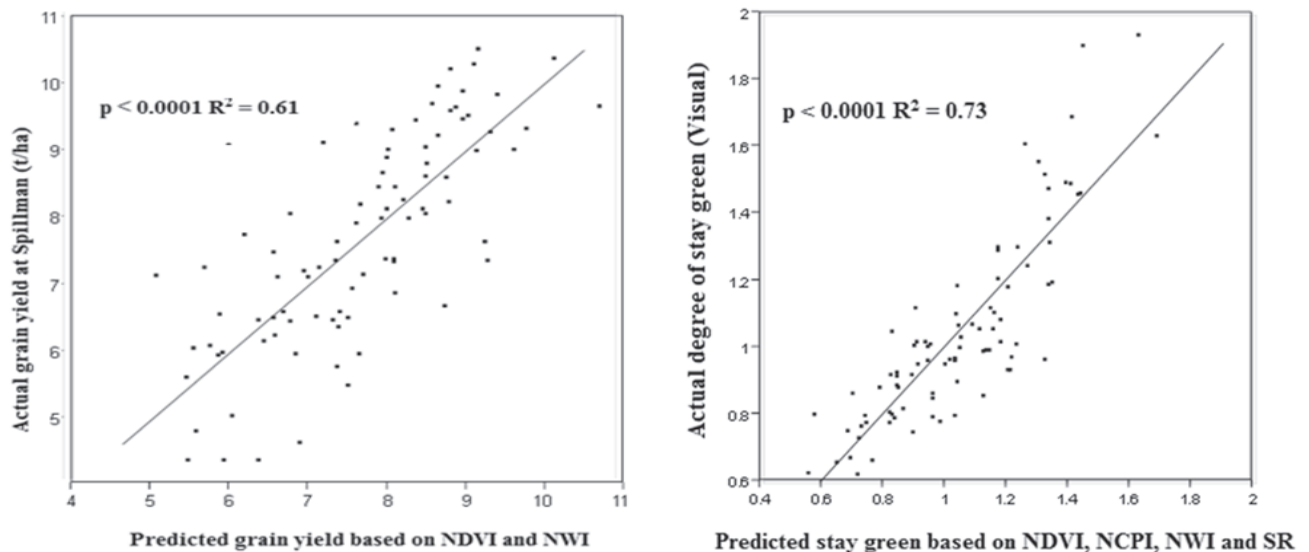
Sankaran which will use aerial imaging and differences in plant color as a rapid assay for disease tolerance. We hope this allows for faster, above-ground screening to determine resistant lines, and expedite the transfer of resistance into more wheat varieties. Our cooperators include Drs. Tim Paulitz and Deven See.

## Characterization of Pacific Northwest Winter Wheat for Drought Adaption and Yield Potential Using Agronomic Traits and Spectral Reflectance Indices

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This study was conducted to evaluate drought responses, phenotypic associations, and genetic variability of yield and developmental traits in Pacific Northwest (PNW) winter wheat. Phenotypic evaluation was done for flag leaf senescence, spectral reflectance indices (SRIs), phenology and grain yield on a total of 402 winter wheat genotypes (87 hard and 315 soft) grown under water deficit, irrigated, and moist-cool conditions in 2012 and 2013. Genotype and environment had significant effect on the studied traits ( $p < 0.001$ ). Variation in soil moisture and thermal time cumulatively explained 86% of total yield variation across the trials. Stay green character was consistently yield positive whereas phenology and plant height had variable effect on yield under different environments. Normalized difference vegetation index (NDVI), anthocyanin reflectance index (ARI), normalized chlorophyll pigment ratio index (NCPI), photochemical reflectance index (PRI), normalized water index (NWI), green normalized vegetation index (GNDVI) and simple ratio (SR) showed moderate to high heritability ( $H^2 \geq 0.56$ ) and strong phenotypic correlation with yield ( $p < 0.001$ ). Linear regression models using these indices showed moderate to high predictive power for grain yield ( $R^2 = 0.3 - 0.90$ ) and stay green character ( $R^2 = 0.24 - 0.77$ ). Genome-wide association study identified a total of 89 SNP markers that were significantly associated with one or more SRIs, yield, and stay green ( $p < 0.01$ ). The results of this study highlighted the possibility of using these traits and associated molecular markers to facilitate adaptation breeding for the Mediterranean-like climate in PNW.



Prediction of grain yield (left) and stay green character (right) using spectral reflectance indices.

## Washington Extension Cereal Variety Testing Program

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The WSU Extension Cereal Variety Testing Program provides growers, the agribusiness industry, university researchers, and other interested clientele with comprehensive, objective information on the adaptation and performance of wheat and barley cultivars across the various climatic regions of eastern Washington. The Cereal Variety Testing Program conducts comparisons using scientifically sound methodology, produces independent results, disseminates all data to clientele, and uses uniform testing procedures across common locations. The evaluation trials are conducted at many locations: 21 for soft white and 12 for hard winter wheat; 16 for soft white and hard spring wheat; and 11 for spring barley. Trial results are available in printed form in *Wheat Life* and the Cereal Variety Testing Annual Report. Comprehensive results for last year and many previous years can be found on the Variety Testing Website (<http://variety.wsu.edu>). Variety performance data is provided within days after harvest via the program website and an email list-serve. Oral presentations, field days, and industry and extension meetings are other means used for delivering research results. Growers and interested parties are welcome to visit the testing sites whenever they would like. Plot maps are available on the program website and can also be found attached to the large Variety Testing signs at each trial location.

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

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

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One of the major exports of the Pacific Northwest (PNW) is soft white winter wheat. Foreign markets use soft white wheat in diverse end products which require specific end-use quality profiles. Hence, it is important for wheat breeders in the PNW to develop cultivars with superior end-use quality, so that the PNW can maintain or expand its market share in foreign markets. Determining which breeding lines exhibit superior end-use quality by laboratory milling and baking tests can be expensive and time consuming. As such, it is advantageous for wheat breeders to develop molecular markers to effectively identify cultivars with superior end-use quality. Molecular markers may be used to detect quantitative trait loci (QTL), which are regions of the wheat genome that contain genes associated with important end-use quality traits. An association mapping panel comprised of 480 PNW cultivars and breeding lines has been genotyped for single nucleotide polymorphisms (SNP) markers. Using the genotyping data and historical end-use quality data from the Western Wheat Quality Lab, associations are made between SNP markers and desirable end-use quality traits. Concurrently, marker-trait associations are being assessed in a bi-parental mapping population between club and common parents to supplement the markers identified in the association mapping panel. Discovery of QTL associated with favorable end-use quality allows wheat breeders to use marker assisted selection for these quantitative traits. Cultivar development may be expedited because breeding lines with favorable alleles may be selected in earlier generations.

## Residue Decomposition Potential of a Finch x Eltan Breeding Population

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Managing crop residue is essential to conservation farming systems that enhance soil quality. There is a need to quickly assess the residue decomposition potential of large numbers of experimental cultivars to identify those that decompose rapidly for ease of seeding in conservation systems. Previous analysis has shown that Eltan soft white winter wheat residue consistently decomposes rapidly in the field, whereas residue from Finch soft white winter wheat decomposes slowly. Preliminary results from a population of 160 Finch x Eltan recombinant inbred lines showed that entries differed significantly from each other and from the Finch and Eltan parents in residue fiber (neutral detergent fiber, acid detergent fiber, acid detergent lignin), carbon (C), nitrogen (N) and C/N ( $P < 0.05$ ), and that many crosses could be categorized as having characteristics for either "rapid" or "slow" residue decomposition. Near infrared spectroscopy (NIRS) shows promise as a method to rapidly predict residue fiber and nutrient characteristics; however, further work is needed to develop adequate calibrations for this method to be used in variety development.

A Finch x Eltan population was planted at Pullman, Mansfield and Waterville, WA in the Fall of 2014. Residue will be collected at harvest, analyzed for fiber components, C and N, and scanned using NIRS with the objective of developing a method for rapid screening of residue from breeding populations. In addition, a collection of 480 diverse germplasm grown at Pullman will be characterized for the above mentioned traits in order to further calibrate and refine the NIRS methodology. The product of this work will be winter wheat varieties with excellent potential for yield and quality, and the ability to be produced in conservation farming systems that maintain and build soil quality and productivity.

## Association Mapping for Agronomic Traits Under Drought and Irrigated Conditions

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Drought is a major abiotic stress that affects the overall agronomic performance of wheat (*Triticum aestivum* L.). In March 2015, drought was declared in three Washington state regions that included major wheat production areas. Prolonged drought conditions and abnormally high temperatures significantly reduce wheat yields now and perhaps more often in the future. Development of drought tolerant varieties will ensure sustained wheat production amid unpredictable adverse environmental conditions. A genome-wide association mapping study was conducted to examine regions in the wheat genome that are linked to different agronomic traits (heading date, plant height, peduncle length, spike length, above-ground biomass, harvest index, grain yield, test-weight and whole grain protein) in drought and irrigated conditions. An elite spring wheat panel of 250 breeding lines and cultivars from different wheat breeding institutions in North America and Mexico were screened for two years under drought and irrigated conditions in Othello, WA. The panel was also genotyped using single nucleotide polymorphisms (SNP) markers to tag specific segments on wheat chromosomes. After analyzing both field and molecular marker data, a total for 371 marker-trait associations (MTA's) were detected. Among these, 142 and 170 MTA's were unique for drought and irrigated conditions, respectively. Another 59 MTA's were significant across conditions and years, indicating there are many beneficial genes that will help improve productivity in diverse environments. The location of many of these loci coincided with known major genes and published QTL. However, new loci identified in this study can provide opportunities to improve wheat performance especially under yield limiting conditions in Washington.

## Preharvest Sprouting Tolerance and Susceptibility in PNW Winter Wheat

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Preharvest sprouting (PHS) is the germination of mature grain on the mother plant when rainy and cool conditions occur before harvest. Sprouting susceptibility is associated with lack of seed dormancy at maturity. Mild rain can cause damage before sprouting is visible when the enzyme alpha-amylase is induced, resulting in starch degradation and lower Falling Number (FN). Wheat flour with high alpha-amylase/low FN produces poor quality bread and cakes. Breeding for higher FN and PHS tolerance can prevent economic losses due to discounts for FN below 300 sec. Genetic tolerance and susceptibility to PHS is shown for winter wheat grown in Pullman 2014 based on spike wetting tests. Intact wheat spikes were misted for 6 sec every minute. Figure 1 shows the sprouting score after four days of misting. Sprouting scores are on a 1-10 scale where 1 has no visible germination and 5+ has 100% germination. Cultivars such as Boundary, Salute, Otto, and Coda show promising results for sources of PHS tolerance, whereas Trifecta, Bruneau, and Sprinter were highly susceptible under cool and wet conditions. You can compare these lines with the tolerant control Brevor (light grey bar) and the susceptible control Greer (black bar). These experiments have identified good sources of PHS tolerance and will be used for association mapping (AM) of the Quality AM Panel to identify genetic loci contributing to PHS tolerance. This will improve our ability to select PHS tolerance in early generation breeding lines. The FN data 2013 and 2014 Cereal Variety Trials can be found at: [steberlab.org/project7599.php](http://steberlab.org/project7599.php).

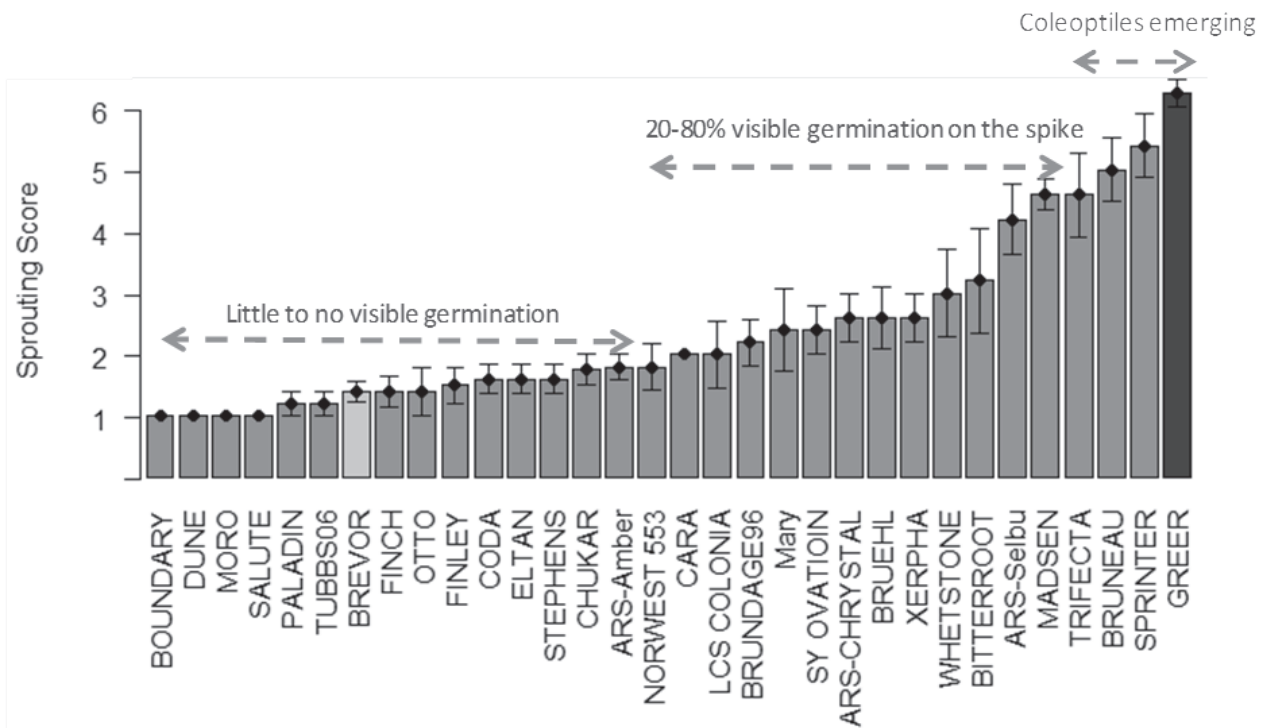


Figure 1. Known winter wheat varieties tested for preharvest sprouting using the spike wetting test. Sprouting scores are on a 1-10 scale with 1 having no visible sprouting and 10 having 100% sprouting. The tolerant control is Brevor (light grey) the susceptible control is Greer (black). Raw means are presented and the error bars represent standard error.

## Understanding Genetic Control of Coleoptile Length and Emergence from Deep Planting Depths

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Winter wheat seedling emergence is a complex and important trait in the low-precipitation zone. Coleoptile length is significantly correlated with seedling emergence. For dryland farming with less than 12 inches of annual rainfall, winter wheat is planted as deep as eight inches below the soil surface to reach soil moisture required for germination, and successful stand establishment is the main determinant of grain yield. With the objective to understand genetic mechanisms controlling seedling emergence and its relationship with commonly used dwarfing genes, a double haploid (DH) population consisting of 384 individual lines from a cross between Perigee (extremely dwarf; 13 inches) and Indian (pre-green revolution tall line; up to six feet) was generated. The population showed tremendous variation both for coleoptile length and seedling emergence. In comparison to the coleoptile length of 30 mm for Perigee and 95 mm for Indian, the range for the DH population was 30 to 157 mm. The population was evaluated for seedling emergence in the field for two years at the WSU Dryland Research Station at Lind. Indian emerged 7 days after planting, whereas Perigee showed no emergence even after 21 days. Among the population, 55 lines emerged on day 7, 58 on day 10 and a total of 113 lines by 21 days after planting. The remaining lines had no emergence. Average coleoptile length of the 113 lines that emerged was 85 mm compared to 60 mm for the lines that did not emerge. The shortest coleoptile among the 113 lines was 40 mm and the longest coleoptile among the lines that did not emerge was 90 mm. One line showed significantly better emergence than Indian. The population is currently being genotyped with SSR and other DNA markers, as well as for the Rht genes.

## Identification and Characterization of Resistance to Hessian Fly in Pacific Northwest Spring Wheat Germplasm

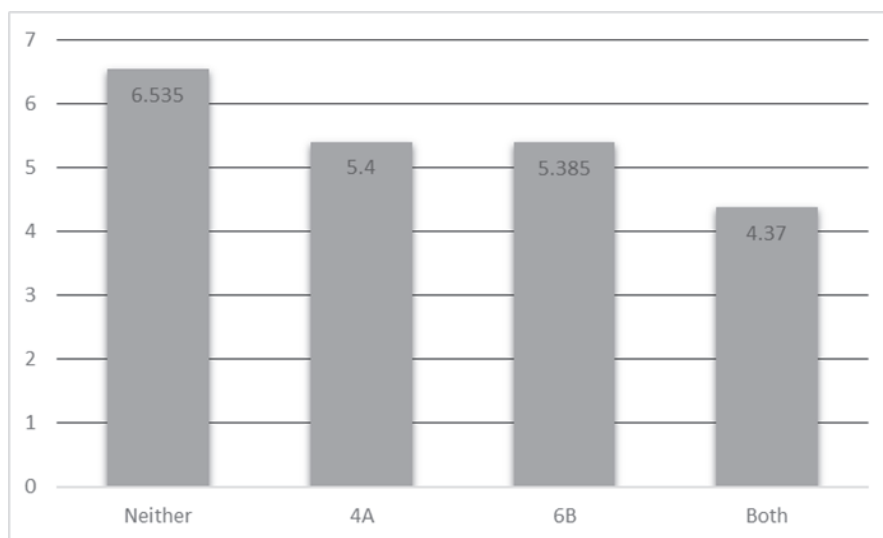
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Hessian fly, *Mayetiola destructor* (Say) is an important pest of spring wheat in the Pacific Northwest (PNW). Breeding for resistance is the most effective and economical control strategy to reduce yield losses. The objective of this research is to identify DNA markers for selection of the Hessian fly resistance gene in Washington breeding line WA8076, which may be used for routine breeding efforts. A doubled haploid population was developed with WA8076 as the resistant parent, with 300 progeny produced. Hessian fly phenotyping of the population indicates single gene Hessian fly resistance from WA8076, where 50% of the progeny were resistant or susceptible. A genetic map with 3218 codominant markers was constructed. Twenty-five linkage groups were obtained representing all the 21 chromosomes. The A and B chromosomes received higher marker densities than D chromosomes. Additional markers will be integrated into the genetic map in an attempt to obtain higher markers coverage and maximize the likelihood of identifying the resistance gene. Further, the diagnostic molecular markers will facilitate marker-assisted selection and assist identifying Hessian fly resistance genes in the PNW spring wheat cultivars.

## 6B and 4A QTLs for Stripe Rust (*Puccinia striiformis* f. sp. *tritici*) Resistance in Soft White Winter Wheat (*Triticum aestivum* L.) Varieties 'Finch' and 'Eltan'

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Stripe rust (*Puccinia striiformis* Westend f. sp. *tritici*) of wheat (*Triticum aestivum* L.) is a devastating disease in temperate regions where environmental conditions lead to high disease pressures and the introduction of new virulent races. With the sporadic yet severe occurrence of outbreaks, disease resistance is a key tool for controlling the severity of stripe rust on wheat. The goal of this research was to identify the genes or quantitative trait loci (QTLs) involved in stripe rust resistance from two important PNW soft white winter wheat cultivars 'Finch' and 'Eltan'. An  $F_{2.5}$  recombinant inbred line (RIL) Finch by Eltan mapping population of 151 individuals was constructed through single seed descent. The RILs were analyzed with a total of 8,631 SNPs and 156 SSR markers distributed across the wheat genome. A total of 1154 SNPs and 88 SSRs were found polymorphic. Of those, 683 unique SNP loci and 70 SSR markers were used to develop 22 linkage groups consisting of 16 out of 21 chromosomes (2D, 3D, 4D, 5D and 6D chromosomes were not represented). Data was collected on stripe rust infection type and disease severity in Pullman and Central Ferry, WA during the summers of 2012, 2013, and 2014. QTL analysis identified two genomic regions on chromosomes 4A (*QYr.wak-4A*) and 6B (*QYr.wak-6B*) associated with the stripe rust resistance from Eltan and Finch, respectively. The results of the QTL analysis show that *QYr.wak-4A* and *QYr.wak-6B* reduce infection type and disease severity of stripe rust. The two QTLs were compared to those QTL previously identified in similar genomic regions. Based upon both molecular and phenotypic differences, *QYr.wak-4A* is potentially a novel QTL for HTAP resistance to stripe rust and will be submitted for formal designation as *Yr68*. The QTLs for stripe rust resistance identified in this study can be incorporated into susceptible wheat germplasm using the significant markers associated with *QYr.wak-4A* and *QYr.wak-6B*.



Infection type ratings for 2012 across all environments for Finch x Eltan recombinant inbred line population for those containing both stripe rust QTLs, only 4A QTL, only 6B QTL, and neither.



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