2014
Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS

WASHINGTON STATE UNIVERSITY EXTENSION

WSU Dryland Research Station Field Day—Lind, June 12, 2014
WSU Wilke Farm Public Field Day—Davenport, June 24, 2014

Department of Crop and Soil Sciences
Technical Report 14-1

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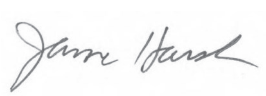
Welcome to our 2014 Field Days!

As Chairman of the Department of Crop and Soil Sciences, I am proud to present the ***2014 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! We have made new hires in Agricultural Education (Dr. Joey Blackburn), Soil Microbiology (Dr. Tara Sullivan-Guest), Barley and Alternative Crop Breeding (Dr. Kevin Murphy), Crop Physiology (Dr. Karen Sanguinet), and Quantitative Genetics (Dr. Zhiwu Zhang). We are just beginning a search for someone to fill a research and extension position in soil fertility management. We are excited to have these new faculty members join us in our efforts to solve the problems facing the agricultural industry.

We are engaged in many research activities of local, regional, and national importance. Our 2014 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.

Sincerely,



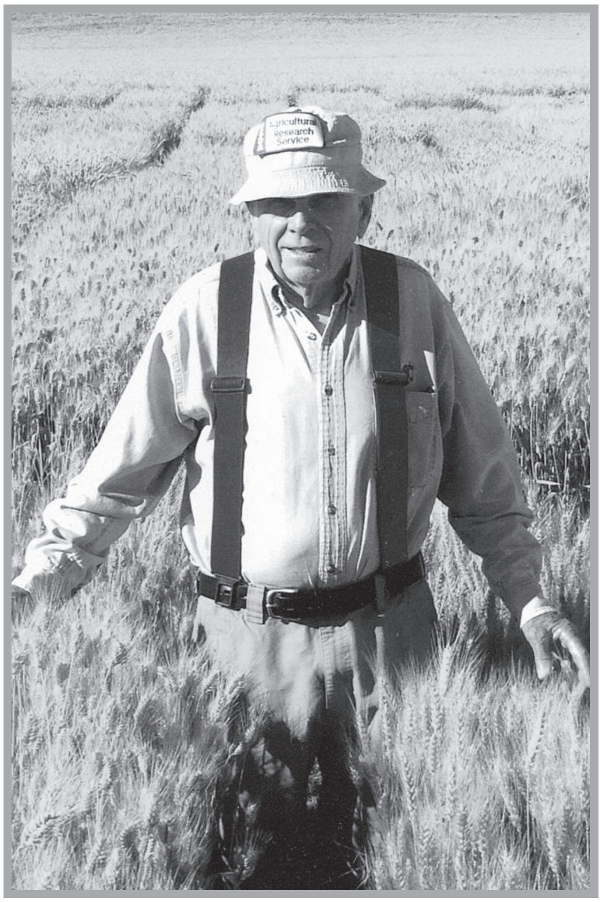
Dr. James B. Harsh, Professor and Chair
Department of Crop and Soil Sciences

Washington State University
Department of Crop and Soil Sciences
Technical Report 14-1
Samantha Crow and William Schillinger, Editors

Dedication to Dr. Robert E. Allan

I am honored to have the 2014 Field Day Abstracts dedicated to me. It certainly was a pleasant surprise.

I began working with Orville Vogel in September of 1957, right after finishing my PhD in Agronomy at Kansas State College. I never interviewed for the job. I got it because Orville's first choice took another job! Looking back, it was an exciting time. Orville was in the final process of evaluating his famous semidwarf, Gaines. Control of the devastating disease common bunt, was almost accomplished due to identifying a highly effective seed treatment and wheat varieties with multiple gene resistance.



Orville suggested I study the inheritance of semidwarf plant height. I worked with Norin10-Brevor, Selection 14 which Orville had used extensively in his breeding program. Offspring of a cross between Selection 14 and Chinese spring wheat clearly segregated in a 9:6:1 ratio for tall, intermediate and short plants indicating Selection 14 had two independent genes for semidwarf plant height. Nearly all of Orville's semidwarf selections, including Gaines, had intermediate plant height. It seemed likely they only had one of the Selection 14 genes for plant height. Test crosses proved that they did only have a single semidwarf gene. I crossed several of these single gene semidwarfs to each other. Some of them had the same semidwarf gene in common, while others had a different gene. I named these two semidwarf genes Sd1 and Sd2, also called Rht1 and Rht2. Stephens, Madsen and Eltan have Rht1, while Nugaines, Daws and Tres have Rht2. Selection 14 was a sister of the line Orville gave Norman Borlaug, which he used to launch his Green Revolution. Over one-half of the wheat grown in the world has these genes. By doing some pretty simple genetics, my career got off to a good start.

Orville also assigned me to investigate poor emergence of semidwarf wheat. A report out of New Mexico indicated that wheat varieties with long coleoptiles emerged better than those with short coleoptiles. I set about screening Orville's semidwarf selections for coleoptile length. They all had coleoptiles that were shorter than standard height varieties. I hoped that short coleoptile length and short plant height were controlled by different genes that were closely linked to each other. I tried to break the linkage by repeated backcrossing. Even after numerous backcrosses to tall parents, all of the semidwarf plants had short coleoptiles. I was forced to conclude that the Rht1 and Rht2 semidwarf genes reduce plant height and coleoptile length. The two traits cannot be separated and are controlled by the same genes. Additional work showed that other genes can modify the effect of Rht1 and Rht2 on coleoptile length. However, no genes have been found that completely overcome the negative effect these genes have on coleoptile length. No doubt, favorable modifier genes explain why semidwarf varieties Eltan and Bruehl emerge better than Madsen and Cara. Currently several research groups are trying to come up with different semidwarf genes that do not negatively effect emergence but still have the same favorable attributes of Rht1 and Rht2. Good luck!

With co-workers, I developed seven club wheat varieties. They have been grown on nearly six million acres. Several were short-lived because they succumbed to stripe rust. There are two types of resistance to stripe rust. One is race specific all stage (RSAS) resistance and the other is called high temperature adult plant (HTAP) resistance. Often new races overcome RSAS resistance. HTAP resistance is more durable but may allow for significant damage in bad rust years.

(Continued from page 2)

Combining both RSAS and HTAP resistances is the best strategy. This may not be easy. RSAS resistance can mask HTAP resistance which makes it hard to know for sure if a variety has both types of resistance. I was fooled in the case of Tyee and Tres and I thought they had both types of resistance when they only had RSAS resistance. I used a new strategy to develop Crew and Rely. They are multiline varieties and are made up of blends of several lines, each of which differ genetically for RSAS resistance. A new virulent stripe rust race may attack plants of one of the lines of the multiline variety, but not those of its other lines. The build-up of the virulent race is isolated and diluted. Rust development on the crop is much slower. The multiline strategy worked. Rely was especially successful. It has been grown on over one million total acres and was the leading club wheat during 1996-2001. Seldom did Crew or Rely sustain significant damage caused by stripe rust. Most research on multilines having lines with different RSAS genes for resistance is theoretical. Crew and Rely gave tangible proof that this approach works.

Among my varieties, Madsen had the greatest impact. Since its release in 1988, it has been grown on over twelve million total acres. I had a lot of help in its development. I was indebted to French wheat geneticists who shared their germplasm with me that had highly effective strawbreaker foot rot resistance of a weedy relative. Dr. Bill Bruehl and his group taught us the procedures for growing inoculum, inoculating plants in the field and rating disease symptoms on them. These allowed us to make steady selection progress. My technician, John Pritchett, became an expert at growing foot rot inoculum, applying it to the plots and scoring plant stubble for disease severity. In addition to foot rot resistance, Madsen has resistance or tolerance to six other diseases. It continues to be grown 26 years after its release.

My career has given me a good deal of satisfaction. I especially have valued my involvement with wheat growers and their organizations. I advised a number of outstanding graduate students. My friendship with fellow scientists has been especially gratifying. Some of my research had significant impact. Admittedly I was lucky. Dr. Elmer Heyne, my mentor at Kansas State, told us that most plant breeding successes were mainly due to luck-Doing what it takes to be lucky would be up to us.

I worked my entire 39 year career at Pullman as a USDA/ARS plant geneticist. I continue as an adjunct scientist with WSU Crop and Soil Sciences. I have spent the last three years writing a book on club wheat and it is about to be published.
I am pretty much "a one trick dog". I am still making crosses and conducting wheat genetic studies on my farm. It keeps me going.

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Part 2. Agronomy and Soils

Part 3. Biofuels and Other Alternative Crops

Part 4. Pathology

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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.

William J. Spillman, breeding plots at Pullman, 1900

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

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

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

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

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

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

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

Wheat Variety History at WSU

Variety	Year Released	Market Class	Background / Named After
SPILLMAN			
Hybrid 60	1905	HWW Club	Lost
Hybrid 63	1907	SWS Club	Turkey/ Little Club; still grown at Spillman Farm
Hybrid 108	1907	SRS Club	Jones Fife/Little Club; lost
Hybrid 123	1907	SWS Club	Jones Fife/Little Club; still grown at Spillman Farm
Hybrid 128	1907	SWW Club	Jones Winter Fife/Little Club; still grown at Spillman Farm
Hybrid 143	1907	SWS Club	White Track/Little Club; still grown at Spillman Farm
GAINES			
Mayview	1915	SRS	Selected from field of Fortyfold near Mayview
Triplet	1918	SRW	Jones Fife/Little Club//Jones Fife/Turkey
Ridit	1923	HRW	Turkey/Florence; first cultivar in USA released with smut resistance
Albit	1926	SWW Club	Hybrid 128/White Odessa
Flomar	1933	HWS	Florence/Marquis
Hymar	1935	SWW Club	Hybrid 128/Martin
VOGEL			
Orfed	1943	SWS	Oro/Federation
Marfed	1946	SWS	Martin/Federation
Brevor	1947	SWW	Brevon/ Oro
Orin	1949	SWW	Orfed/Elgin
Omar	1955	SWW Club	Oro and Elmar in pedigree
Burt	1956	HWW	Burton Bayles, principal field crop agronomist for ARS
Gaines	1961	SWW	EF Gaines (Vogel's professor) WSU Cerealist, 1913-1944
Nugaines	1965	SWW	Sister line of Gaines (new Gaines)
NELSON			
McCall	1965	HRW	M.A. McCall, first superintendent of Lind Station
Wanser	1965	HRW	HM Wanser, early dryland agronomist
ALLAN			
Paha	1970	SWW Club	Rail point (town) in Adams Co. between Lind and Ritzville
Coulee	1971	HWW	Town in Grant Co.
Tyee	1979	SWW Club	Rail point (town) in Clallam Co. between Beavor and Forks
Crew	1982	SWW Club	Multiline with 10 components (crew of 10)
Tres	1984	SWW Club	Spanish for three. Resistant to stripe rust, leaf rust & powdry mildew
Madsen	1988	SWW Club	Louis Madsen, Dean of College of Agriculture at WSU, 1965-1973
Hyak	1988	SWW Club	Rail point in Kittitas Co. east of Snoqualimie pass
Rely	1991	SWW Club	Multiline with reliable resistance to stripe rust
Rulo	1994	SWW Club	Rail point in Walla Walla Co.
Coda	2000	SWW Club	The finale (of a symphony). R.E. Allan's last cultivar
BRUEHL			
Sprague	1972	SWW	Rod Sprague, WSU plant pathologist. First snowmold resistant variety for WA
John	1985	SWW	John Thompson and John Goldmark, both supporters of snow mold research
PETERSON			
Luke	1970	SWW	Name of Nez Perce Indian that saved Rev. H.H. Spalding's life near Lapwai, ID
Norco	1974	SWW	Released as cultivar-recalled in 1975 due to susceptibility to new stripe rust race
Barbee	1976	Club	Earl Barbee, WSU agronomist
Raeder	1976	SWW	Plant pathologist JM Raeder, U. of ID professor of CJ Peterson

Daws	1976	SWW	Dawson Moodie, chair, Dept. of Agronomy, WSU
Lewjain	1982	SWW	Lew Jain, farmer friend of Peterson
Dusty	1985	SWW	Town in Whitman Co.
Eltan	1990	SWW	Elmo Tanneberg, Coulee City, WA wheat farmer/supporter
Kmor	1990	SWW	Ken Morrison, WSU Ext. State Agronomist
Rod	1992	SWW	Rod Betramson, chair, Dept of Agronomy, WSU
Hiller	1998	SWW Club	Farmer/cooperator in Garfield Co.

KONZAK

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

DONALDSON

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

KIDWELL

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

JONES

Edwin	1999	SWW Club	Edwin Donaldson, WSU Wheat Breeder
Bruehl	2001	SWW Club	George (Bill) Bruehl, WSU Plant Pathologist
Masami	2004	SWW Club	Masami (Dick) Nagamitsu, WSU wheat researcher

Bauermeister	2005	HRW	Dale and Dan Bauermeister, Connell, WA wheat farmers/cooperators
MDM	2005	HWW	Michael Dale Moore, Kahlotus area farmer/cooperator
Xerpha	2008	SWW	WSU botanist and wife of Edward Gaines

CAMPBELL

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

CARTER

Otto	2011	SWW	Otto Amen, long-time Washington legislator and wheat farmer
Sprinter	2012	HRW	Dual agronomic characteristics of both Spring and Winter wheat
Puma	2013	SWW	Named after the animal

GILL

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

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, hulless	Ullrich	selection from Scout/WA8893-78
Washford	1997	spring, 6-row, hay	Ullrich	selection from Columbia/Belford
Farmington	2001	spring, 2-row, feed	Ullrich	WA10698-76/Piroline SD Mutant/Valticky SD Mutant /3/ Maresi
Bob	2002	spring, 2-row, feed	Ullrich	selection from A308 (Lewis somaclonal line)/Baronesse
Radiant	2003	spring, 2-row, feed	Wettstein	selection from Baronesse/Harrington proant mutant 29-667
Muir	2013	spring, 2-row, feed	Murphy	selection from Baronesse/Spaulding (named after Carl Muir)
Lyon	2013	spring, 2-row, feed	Murphy	selection from Baronesse/Bob (named after Steve Lyon)

Dry Pea, Lentil and Chickpea Varieties History at WSU

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

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

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

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.

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 Lentils

Turkish 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 tye chickpea released in 1997. Evans is earlier flowering and earlier to mature when compared with Sanford and Dwelley.

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

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

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

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

Desi Type

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

Part 1. Breeding, Genetic Improvement, and Variety Evaluation

Winter Wheat Breeding and Genetics

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DEPT. OF CROP AND SOIL SCIENCES, WSU

The Winter Wheat Breeding and Genetics Program at Washington State University remains committed to developing high yielding, disease resistant, and good end-use quality cultivars for release to maintain sustainability of production. We are using the newest tools available to accomplish this task and are excited about the breeding lines under evaluation and their release potential. In 2013, we evaluated over 2,000 doubled haploid lines under field conditions and planted another 1,500 for 2014 evaluation. We are continuing to develop doubled haploid populations and are increasing the number of lines produced annually. In 2013, we evaluated over 1,000 lines developed with marker selection for stripe rust and foot rot resistance. We have developed Imazamox resistant breeding lines in both hard and soft backgrounds, which are under advanced testing in field trials, one of which came through our DH breeding strategy and is variety testing this year. Additional breeding populations developed include those for stripe rust, nematode resistance, stem rust resistance, soil borne mosaic virus resistance, aluminum tolerance, snow mold, and various other biotic stresses.

We continue our work and collaboration with the spring wheat breeding program on the USDA funded TCAP grant working on drought tolerance and stripe rust resistance. Additionally, we have work progressing under field and greenhouse conditions for heat tolerance in conjunction with the spring wheat breeding program.

We are collaboratively developing high-throughput field phenotyping platforms to facilitate data collection, which complement our phenotyping work under growth chamber conditions. We have increased our field screening locations to include aluminum tolerance along with those for snow mold, stripe rust, and foot rot resistance. We have completed some work on molecular mapping of stripe rust resistance genes, and have begun to incorporate that germplasm and marker selection into our breeding program. Our program has redirected efforts to develop hard white winter wheat for the domestic market, and have lines on increase for potential release in 2014.

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. In the fall of 2013, it emerged very well under unfavorable conditions, and survived 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 is resistant to eyespot foot rot. This line is targeted to the <15" rainfall zones as a replacement for Eltan.

Sprinter was released in 2012 and is on foundation seed increase. Limited seed will be available this fall. This line has had difficulty going through the grain grading system as it grades as a hard red spring. We have sent multiple samples to the grain graders and they are working on accurately determining grain class. 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.

Puma was released in 2013 and is on foundation seed increase. This line is a soft white wheat targeted to the high rainfall zones of the state and particularly eastern Whitman county. It has been the #1 yielding variety averaged over two years in the >20" rainfall zone and the #2 yielding variety in the 16-20" zone. It has high test weight, adult plant resistance to stripe rust, resistance to eyespot foot rot, good tolerance to Cephalosporium stripe, and tolerance to low pH soils (aluminum tolerance), and excellent end-use quality. Foundation seed will be available this fall.

'Curiosity CL+' and 'Mela CL+': Two New 2-Gene IMI Soft White Winter Wheat Varieties

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Soft white winter (SWW) is a major market class of wheat in the Pacific Northwest (PNW). Annual grassy weeds such as jointed goatgrass are major problem and cause serious economic losses. Imidazolinone group of herbicides (trade name 'Beyond') can effectively control many grassy weeds, including goatgrass, but cannot be applied on normal wheat due to its sensitivity to the herbicide. Mutants in the *ALS* genes (*ahasl-1d, ahasl-1b and ahas1-1a*) provide tolerance to 'Beyond'. Commonly known as 'Clearfield technology', wheat varieties mostly carrying single-gene mutations have been in cultivation for some time. Because of sensitivity to the herbicide, the wheat cultivars carrying single-gene technology show significant yield penalty. In comparison, the two-gene Clearfield wheat varieties show significantly better tolerance to the herbicide and also allow use of higher rates or/and better surfactants such as methylated seed oil (MSO). 'Curiosity CL+' and 'Mela CL+' are the first WSU wheat varieties carrying the 'Clearfield technology'. Both carry the two-genes for herbicide tolerance. A new fast breeding method, marker-assisted background selection (MABS), was used to develop the varieties from a cross between a SWW variety Eltan and CL0618, a hard red spring line from Australia.

Mela CL+ is ideal for low rainfall and typical Eltan growing areas. It yields significantly better than ORCF103, has snow mold tolerance even better than Eltan, stripe rust resistance both at the seedling as well as adult plant stage, good milling and baking quality, and moderate level of Cephalosporium stripe resistance and eye spot resistance. Curiosity CL+ has wide adaptation in the state as it does well in high, high medium, and low rainfall areas, as well as in the typical Eltan growing areas, even without the herbicide spray. Curiosity CL+ yields better than Eltan and ORCF102, has excellent snow mold tolerance and stripe rust resistance both at seeding as well as adult-plant resistance better than any Clearfield variety grown in the PNW. It has winter hardiness similar to Eltan. Overall, it has consistently performed better than ORCF102 especially in the high rainfall areas of the state. The milling score of Curiosity CL+ was significantly better than ORCF102 and has significantly higher cake volume than that of Stephens. Foundation seed for these varieties will be produced and maintained by the Washington State Crop Improvement Association (WSCIA). Curiosity CL+ has been planted in > 500 acres, whereas Mela CL+ planted in > 300 acres for foundation seed production.

Return of Barley as a Major Rotational Crop in the U.S. Pacific Northwest

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Extensive application of imidazolinone (IMI) herbicides had a significant impact on the barley productivity leading to a continuous decline in its acreage over the last two decades. A plausible solution to this problem is to transfer IMI-resistance from a recently characterized mutation in the barley *AHAS* (acetohydroxy acid synthase) gene to other relevant food, feed and malting barley cultivars. Since, the Pacific Northwest (PNW) shares 22.87% (335,000 ha) of land under barley cultivation in the United States, and is home to the high-yielding barley cultivars with an average grain yield of >4200 kg/ha; we focused our efforts on transferring IMI-resistance to barley varieties adapted to this region. To effectively breed for IMI-resistance, we studied genetic diversity among the 13 two-rowed spring barley cultivars/ breeding-lines from the US PNW using 61 microsatellite markers, and selected the six barley genotypes that showed medium to high genetic dissimilarity (with dissimilarity coefficient values ranging from 0.435 to 0.726) with the 'Bob' *AHAS* mutant. The six selected genotypes were used to make 29-53 crosses with the *AHAS* mutant and a range of 358-471 F_1 grains were obtained (Figure 1). To perform informed selection for the recovery of the recipient parent genome, genetic location of the *AHAS* gene was determined and its genetic nature was assessed. Moreover, to improve phenotypic screening of IMI-resistance, an effort was made to determine a discriminatory dose of herbicide that can distinguish between heterozygotes and homozygotes for the mutant allele. However, the results of *in vitro* enzyme activity assay suggested that the mutant can survive up to the 10x field recommended dose of herbicide used on the IMI-resistant wheat. Thus, it is practically impossible to find such a critical herbicide dose.

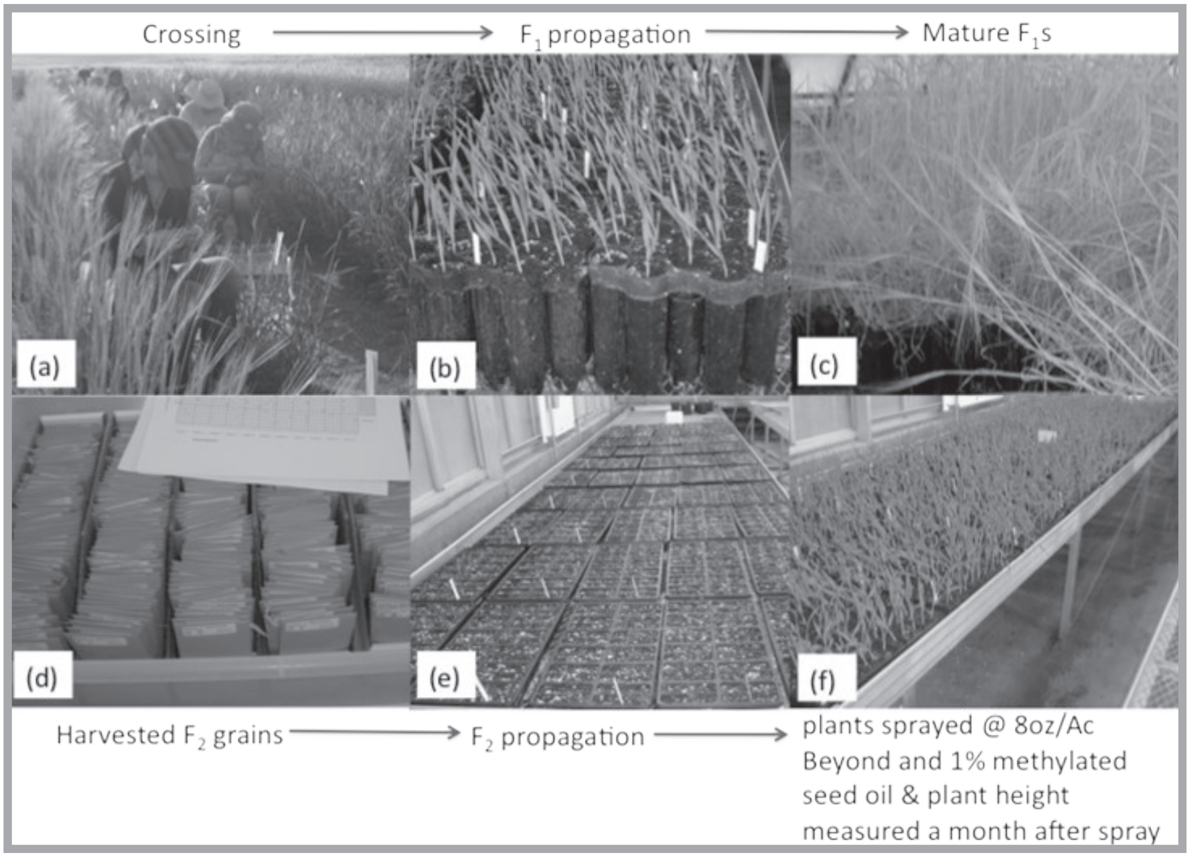

Figure 1. The workflow of events from field to glasshouse: (a) A large number of crosses were made to transfer IMI-resistance to 2 genotypes each of the three market classes of two-rowed spring barley at the Spillman Agronomy Farm, WSU Pullman; (b) The F_1 grains obtained from field were propagated in glasshouse to obtain F_2 grains; (c & d). The F_2 plants from each cross combination were analyzed for herbicide resistance, and the survivors were evaluated for seedling vigor a month after herbicide spray (e & f).

As a remedy, large F_2 populations ranging in size from 2158-2846 individuals were evaluated for herbicide-resistance and seedling (determined a month after herbicide spray). Based on these results F_3 lines from the six most vigorous F_2 genotypes per cross combination were evaluated for their backgrounds using 10 evenly spaced chromosome 6H specific DNA markers. A range of 20%-90% recovery of the recipient parent genome for the carrier chromosome was observed. Collectively, this pilot screen has clearly demonstrated the feasibility of transferring IMI-resistance to the desired genotypes in a single generation with a possibility of finding genotypes showing good recovery of the recipient parent genome.

Efforts are currently being made to take these IMI-resistant barley genotypes from laboratory to field by committing to the following steps: i) screening of F_3 families, representing 250 F_2s selected per cross combination, based on their vigor a month after herbicide spray, for their genetic backgrounds using DNA markers; ii) fixing hybrid vigor (that confounds the phenotypic evaluations) of selected lines by doubled haploid (DH) production; and iii) field evaluation of DH lines for their performance on herbicide residue in the field and under spray trials.

Cold-induced LMA in Spring Wheat: A Potential Cause of Low Falling Numbers

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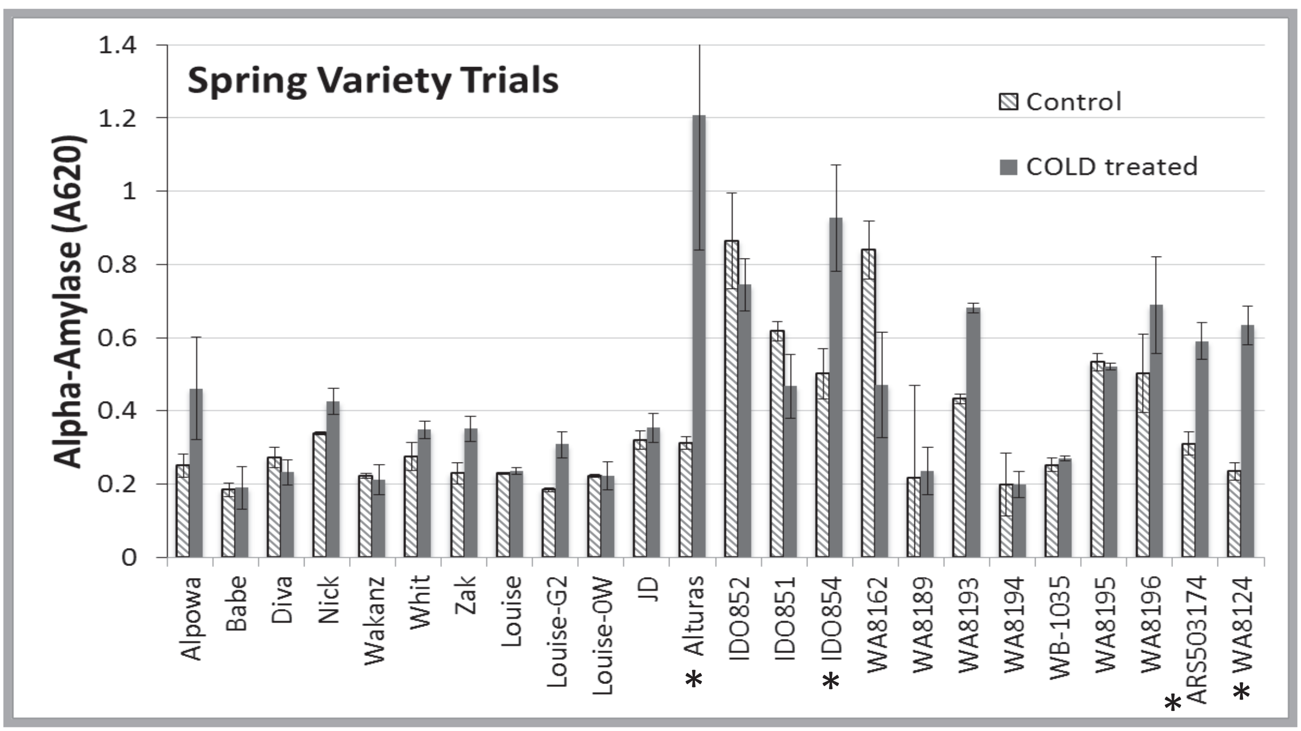
Sometimes farmers have problems with low Falling Numbers (FN) when there has been no sprout-inducing rain. Such problems can be caused by a cold temperature shock (not freezing, just cold) during the late maturation phase of grain development. This problem, called Late maturity alpha-amylase (LMA), is a condition when the enzyme alpha-amylase is produced in maturing grain due to a cold temperature shock. The enzyme alpha-amylase degrades starch, resulting in flour that gives poor-quality breads or cakes. This starch break-down is measured by the Hagberg-Perten Falling Numbers (FN) test. Higher alpha-amylase enzyme levels lead to lower Falling Numbers. This decrease in FN is an economic problem because grain with an FN below 300 seconds is discounted. This study looked at the susceptibility of the spring variety trials to LMA inducing treatments. Grain from the spring wheat variety trials were grown in the greenhouse. These plants underwent a cold temperature treatment lasting one week at 25-30 days after pollen shedding. Hand threshed spikes were ground and analyzed for their alpha-amylase activity using the Phadebas enzyme assay. The data below compares alpha-amylase levels in control plants that received no cold treatment and plants that were given an LMA-inducing cold treatment. There were four spring wheat lines that appear to be susceptible to LMA based on the fact that there was a statistically significant increase in alpha-amylase with cold treatment (Lines marked with *). Based on previous data, we estimate that an alpha-amylase reading (A620) of 0.4 and higher corresponds to an FN of 250 sec or lower. Interestingly, older named cultivars tend to have an A260 below 0.4 (which is good). However, quite a few Washington and Idaho breeding lines show values over 0.4, suggesting that there is a new susceptibility to higher alpha-amylase levels in spring breeding lines. It will be important to select against this to reduce risk of financial loss and of decreasing quality as a result of low FN and high alpha-amylase levels in Washington wheat.



Performance of Variety Blends Versus Blend Components of Soft White Winter Wheat

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Winter wheat in Washington State is seeded with blended (multiple) varieties on about 20% of the area. Blending supposedly stabilizes grain yield, mitigates disease, and improves grain test weight and protein content. This study investigates benefits of blended varieties using data from the Washington State University Variety Testing Program soft white winter wheat trials from 21 locations during 2006-2012. Grain yield, test weight, and protein content of blended varieties and individual blend components were compared (Figure 1). Grain yield of blends significantly exceeded the average yield of blend components in only 27 of 454 observations (6%), while blends yielded below components in 19 observations (4%). Blends out yielded the best blend component only 5 times (1%) and performed significantly below in 85 observations (19%). Test weight of blends was significantly higher than the average of components in 28 of 450 total observations (6%) and significantly below the average in 20 cases (4%). Blends significantly exceeded test weight of the best component in only 9 observations (2%), and performed below the best component 129 times (29%). Protein content of blends was significantly higher than component average only 18 of 454 observations (4%) and significantly lower in 26 observations (6%). Blends' protein content exceeded the best component in 6 cases (1%) and was significantly lower in 86 cases (19%). Grouping data by precipitation zones did not change performance. This study shows that under a high number of comparisons across locations and yields, growing blended soft white winter wheat varieties in Washington does not result in significantly improved grain yield performance, test weight, or protein.

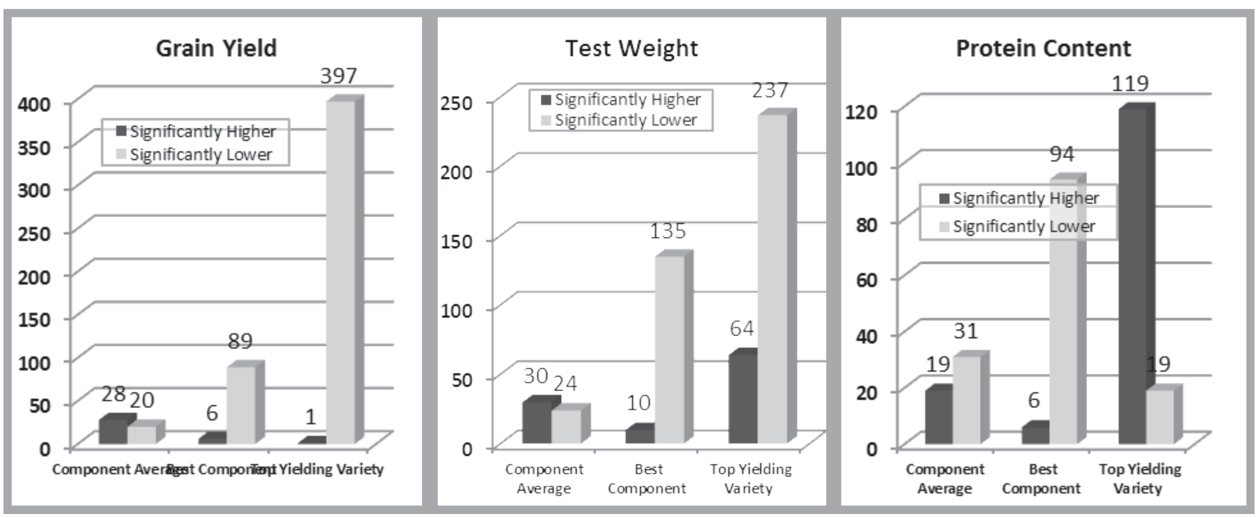

Figure 1. Number of observations with significant differences in Grain Yield, Test Weight and Protein Content between Variety Blends, Blend Components and Top Yielding Variety.

Breeding Celiac-Safe Wheat Cultivars: A Future Market Class of Wheat

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The gluten-induced disorders dubbed, as 'gluten syndrome' collectively affect >7.5% of the U.S. population. So far the only known therapy for the gluten syndrome is life-long adherence to an abstinence diet, which is difficult to follow, and shown to have an adverse influence on the diversity of gut microbiota in consumers making them vulnerable to a number of disorders including colon cancer. It has been demonstrated repeatedly that strict adherence to 'gluten-free' diet result in an upward shift in the body mass index (BMI) of the consumers, predisposing them to various disorders. In addition, none of the alternative food choices (including cereals and pseudocereals) available to celiac patients are perfect for their consumption due to different reasons. Further more, the daily intake of wholegrain wheat products was demonstrated to reduce the risk of many prevailing disorders. Collectively, these piling evidences suggest that it is imperative to develop potential alternatives of 'gluten-free' diet by modifying the composition of wheat grains to make them less prone to inducing the most common of dietary disorders. It is also evident from the above description that none of the natural products make a perfect dietary solution for celiac patients. Thus, this trait is an obvious candidate for genetic engineering.

In this connection, our research showed that it is possible to obtain wheat genotypes completely devoid of immunogenic prolamins while retaining their baking properties by silencing the wheat *DEMETER* (*DME*) homoeologues. The *DME* genes are responsible for transcriptional activation of genes encoding gliadins and the low molecular weight glutenins (LMWgs) in the developing wheat endosperm. But, so far, after screening ~400 transformants expressing hairpin or artificial microRNAs targeting wheat *DME* homoeologues, a genotype showing 85.6% suppression in *DME* transcript abundance and up to 76.4% reduction in the amount of immunogenic prolamins could be identified. The observed low frequency of the desired transformants can be attributed to the unpredictability of both the number and site of transgene integration(s) using the current transformation procedures, which has a consequential effect on the transcription level of the transgene. In view of the technical difficulties associated with current transformation procedures, we undertook the TILLING (Targeting Induced Local Lesions In Genomes) procedure for identification of knockout or knockdown mutants in the wheat *DME* homoeologues. Screening of a hexaploid 'Express' and a tetraploid 'Kronos' wheat TILLING populations for mutations in *DME* homoeologues resulted in identification of a total of 191 mutants in the Express and 77 mutants in the Kronos background. These single mutants identified in *DME* homoeologues showed specific eliminations and/or reductions in the amount of prolamins. However, developing 'celiac-safe' wheat genotypes require pyramiding of single mutations to obtain double mutations in Kronos and triple mutations in Express background. The nonsense mutations and splice-site variants in individual *DME* homoeologues with quantifiable effects on prolamin composition/content showed adverse effects on pollen viability and germination, imposing difficulties in pyramiding the effects of individual mutants in a single genotype. In view of these difficulties an alternative approach employing a 'chimeric-hairpin' construct capable of producing multiple interfering RNAs corresponding with the transcripts of the prolamin super-family genes was undertaken. This approach required aligning the sequences of the wheat gliadins (a/b-, g- and w-types) and low molecular weight glutenins (LMWgs) available in the public domain. The alignment results allowed identification of the five consensus sequences each representing a prolamin gene family, which were fused together to obtain the arms of the chimeric-hairpin. The chimeric-hairpin construct was used for wheat transformation. The transformants showed sizable amount of reductions in the content of immunogenic prolamins very similar to the transformants expressing *DME* hairpin or amiRNA constructs, which showed reductions and specific-eliminations to variable degrees in the grain prolamin content. A compensatory increased in the amount of high molecular weight glutenins (HMWgs) was also observed in some cases, which is a desirable characteristic for maintaining the end-use quality of the genotypes. As none of the wheat transformants showed complete elimination of immunogenic prolamins these genotypes with reduced gluten content are currently being crossed with an aim of pyramiding their effects on prolamin content or composition into a single wheat genotype.

Moreover, to avoid the negative consequences of introducing point mutations in *DME* genes, and to obtain wheat genotypes showing complete elimination of immunogenic prolamins, we are currently using a site-directed procedure to achieve complete silencing of *DME* genes in the developing wheat endosperm. To achieve this objective we are attaching an engineered DNA binding domain of the *Xanthomons* transcription activator-like effector (TALE) to a universal *Arabidopsis* EAR-repression domain (SRDX) that allows transcriptional suppression of the targeted gene(s). This *DME*-specific TALE repressor will be introgressed into the wheat genome via homologous recombination. Since, in this procedure the selected wheat transformants will be used as explant donors for retransformation a complete silencing of *DME* homoeologues is expected.

As a small number of celiac patients were also reported to show sensitivity against the HMW glutenins, we undertook another approach, which involves detoxification of gluten proteins by ectopic expression of gluten detoxifying enzymes (glutenases). For this purpose a combination of a glutamine-specific barley endoprotease B2 (EP-B2) and a post-proline cleaving prolyl endopeptidase from *Flavobacterium meningosepticum* (Fm-PEP) were selected and expressed in wheat endosperm. Wheat transformants showing sizable amount of reduction in Pro/Gln-rich peptides under simulated gastro-intestinal conditions were obtained. Since we intend to use wheat grains expressing 'glutenases' as an ingredient of the daily bakery products it is ideal to have thermostable enzymes that retain activity at and over 90°C. In order to achieve this objective a site saturation mutagenesis approach was followed. The amino acid substitutions at residues 412, 413, 414 and 415 increased thermostability of Fm-PEP from 60°C to 90°C, while maintaining its catalytic properties under simulated gastro-intestinal conditions. Similarly, in view of increasing thermostability of EP-B2 a structure-based site directed mutagenesis approach was adapted and an increase in thermostability by 10°C was witnessed. The observed increase in the thermostability of EP-B2 is not substantial, but this pilot study demonstrated a possibility of obtaining thermostable variant of both Fm-PEP and EP-B2.

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

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Most soft white wheat grown in the Pacific Northwest (PNW) is exported to foreign markets. Therefore, developing cultivars with superior end-use quality is essential in order for the PNW to maintain or even expand its market share in diverse foreign nations. Soft white wheat is utilized in various products that require specific end-use quality profiles. Since milling and baking laboratory tests can be time consuming and expensive, it is beneficial for wheat breeders to understand the genetics behind end-use quality traits and develop molecular markers to efficiently identify cultivars with superior end-use quality. Molecular markers are used to detect quantitative trait loci (QTL), which are regions in the wheat genome that contain genes associated with end-use quality traits of interest to breeders. Using an association mapping panel of 480 PNW lines that are genotyped for single nucleotide polymorphisms (SNP) markers and end-use quality data from the Western Wheat Quality Lab, associations can be made between SNP markers and enhanced end-use quality traits. Simultaneously, marker-trait associations are being made in a bi-parental mapping population between club and common parents in order to complement the markers found in the association mapping panel. Another bi-parental mapping population is being used to identify marker-trait associations specifically for arabinoxylan content, an important component of end-use quality because of its impact on water absorption properties in dough. Identification of QTL associated with superior end-use quality enables wheat breeders to increase response to selection by using marker assisted selection for these quantitative traits. Marker assisted selection expedites cultivar development because breeding lines with the proper alleles may be selected in earlier generations. Further research into the genetics of end-use quality traits will assist wheat breeders in developing superior cultivars for use in the PNW.

Pre-Breeding for Root Rot Resistance Using Root Morphology Traits

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[1]MOLECULAR PLANT SCIENCES PROGRAM AND DEPT. OF PLANT PATHOLOGY, WSU; [2]USDA-ARS, ROOT DISEASE AND BIOLOGICAL CONTROL

Root rot caused by the fungal pathogen *Rhizoctonia solani* can be a major yield-limiting disease in minimal tillage or direct-seeded cereal production systems. Reduced tillage greatly influences the plant residue retained on the soil surfaces. This retained residue (green bridge) provides increased disease pressure from *R. solani*, but chemical fungicides are not cost-effective. Currently, no resistance in the *Triticum* germplasm has been identified to this soil-borne pathogen. By identifying and transferring natural resistance using the genetic diversity of 'synthetic hexaploid' and natural landraces of wheat into commercial varieties, we will greatly improve this problem. The objectives of our study are to (i) identify root rot resistance in synthetic and landrace accessions of wheat; (ii) transfer this resistance into the Pacific Northwest (PNW) commercial spring wheat cultivar, Louise; and (iii) identify the phenotypic and genetic markers associated with this resistance. To identify resistance, approximately 400 accessions of wheat were evaluated in greenhouse and field assays with high levels of disease pressure. Six accessions were identified having reduced stunting under heavy disease pressure. These six accessions consisted of four synthetic (SYN 30, SYN 172, SYN 182, and SYN 201), one synthetic-derived (SPCB 3104), and one landrace (AUS28451); all have all been crossed at least once to the cv. Louise. In the past year, two large BC_1 (two crosses into Louise) derived populations (SPCB 3104 and SYN 172) were evaluated for the second time in our field assays in spring of 2013. These evaluations consisted of planting the individuals into a “green” and “clean” field assay. The green planting consisted of direct-seeding into cool, wet, soils whose plots were chemically sprayed 2-3 days prior to planting (green bridge with high disease pressure). These individuals were compared to those grown in clean soil which was sprayed four weeks prior to planting (no green bridge, low disease pressure). Individual seedlings were evaluated for stunting four weeks after planting. From these evaluations BC_2-derived lines were made in the field and have been advanced in the greenhouse. This spring, we will be screening BC_1F_6 individuals of SYN30 in a green and clean field assay, and backcrosses will be conducted in the field. We have begun evaluating a new mapping population, (AUS28451 by Louise) in a green and clean field assay. AUS28451 is a soil nematode resistant landrace of wheat that we have evaluated in greenhouse and field trials and showed real promise for *R. solani* resistance. We have continued advancing the best lines from the remaining 2 synthetic populations and have made BC_2-derived lines. We will begin screening BC_2 lines (three crosses to Louise) for SYN182, SYN 201, 3104, and SYN 172 individuals in greenhouse assays. Finally, using genetic markers from these populations we will identify quantitative trait loci that can be used to transfer this resistance and identify root morphology traits in the best advanced backcrossed lines. Our cooperators are Tim Paulitz and Deven See.

Identification of QTL for Stripe Rust Resistance in the PNW Cultivars Finch and Eltan

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DEPT. OF CROP AND SOIL SCIENCES, WSU

Stripe rust (*Puccinia striiformis* Westend f. sp. tritici) resistance is an important economic trait in the Pacific Northwest where environmental conditions lead to high disease pressures and the introduction of new virulent races. Disease resistance is a key tool for controlling the severity of stripe rust on wheat (*Triticum aestivum* L.). The goal of this research is 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’. We constructed a $F_{2:5}$ recombinant inbred line (RIL) Finch by Eltan mapping population of 151 individuals through single seed descent. The RIL were analyzed with a total of 8,631 SNP and 853 SSR markers distributed across the wheat genome. A total of 606 SNP and 49 SSR markers were found polymorphic, which were used to develop 24 linkage groups consisting of 17 out of 21 chromosomes (D3, D4, D5 and D6 chromosomes were not represented). Data was collected on stripe rust infection type and percent leaf cover in Pullman and Central Ferry, WA during the summers of 2012 and 2013. Preliminary QTL analysis identified two genomic regions on chromosomes 4A and 6B associated with the stripe rust resistance from Eltan and Finch, respectively. We are in the process of collecting additional data in the summer of 2014 and plan to conduct a seedling resistance screen to identify any all-stage resistance genes possibly present in Finch. Furthermore, we are investigating the distribution of these genes in other winter wheat varieties, as well as identify which races the genes show resistance to. After validation of the results, SNP markers will be useful to incorporate these resistance genes into other breeding lines via marker-assisted breeding, thereby enhancing the level of resistance in lines as well as diversifying the gene combinations used in soft white winter wheat.

The Western Wheat Quality Laboratory

CRAIG F. MORRIS, DIRECTOR; AND DOUG ENGLE

The mission of the USDA-ARS Western Wheat Quality Lab is two fold: conduct milling, baking, and end-use quality evaluations on wheat breeding lines, and conduct research on wheat grain quality and utilization. Our web site: http://www.wsu.edu/~wwql/php/index.php provides great access to our research. Our research publications are readily available on our web site.

Our current research projects include grain hardness, puroindolines, waxy wheat, soft durum wheat, polyphenol oxidase (PPO), arabinoxylans, fiber, and SDS sedimentation test and instrumentation. Our recent publications include two studies on molecular characterization and diversity of *puroindoline b-B2* variants in cultivated and wild wheat, and allelic variation and distribution of *puroindoline b-B2* variants and their association with wheat grain texture in wheat. A review of the occurrence of *Grain softness protein*-1 genes in wheat was published in Plant Molecular Biology. A comprehensive survey of soft wheat grain quality in United States germplasm was published in Cereal Chemistry. Research on how the house mouse (*Mus musculus* L.) shaped the evolutionary trajectory of wheat was published in Ecology & Evolution. Optimizing experimental design using the house mouse as a model for determining grain feeding preferences was published in the Journal of Food Science. A study on wheat arabinoxylan structure providing insight into function was published in Cereal Chemistry. Other research includes segregation analysis indicating that *Puroindoline b-2* variants 2 and 3 are allelic in *Triticum aestivum* L. and that a revision to *Puroindoline b-2* gene symbolization is needed. 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; and better understanding the fate of fiber and phytonutrients in whole wheat products during processing. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Babe, Cara, Diva, Farnum, JD, Kelse, ORCF-103, Skiles, Tubbs 06, Whit, Xerpha, Crescent, Chrystal, Amber, Gene, Goetz, Eden, and Otto.

Washington Extension Variety Trials 2013: New Ways to Bring Variety Performance Information to Growers

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

The WSU Extension Variety Testing program provides growers, the agribusiness industry, university researchers, and other interested clientele with comprehensive, objective information on the adaptation and performance of small grain and grain legume cultivars across the climatic regions of eastern Washington. The Variety Testing program conducts comparisons using scientifically sound methodology, produces independent results, disseminates all data to clientele, and uses uniform testing procedures across common locations. The replicated Variety Testing program evaluation trials in the dryland and irrigated production areas of eastern Washington are conducted at many locations: 21 for soft white and 11 for hard winter wheat; 16 for soft white and hard spring wheat; and 10 for spring barley. In addition, the WSU Variety Testing program has, since 2011, been conducting field evaluations of dry pea, lentil, and chickpea varieties in eastern Washington at four locations. Trial results are available in printed form in: Wheat Life, the Cereal Variety Evaluation Annual Report, summarized in the WSCIA Certified Seed Buying Guides, and comprehensive results for last year and many previous years can be found on the Variety Testing Web site (http://variety.wsu.edu).

In early 2014, our Extension team launched a new, more comprehensive small grains website (http://smallgrains.wsu.edu). An overall goal of the website is to provide a one-stop place to find current information about small grain production in the region. One feature of the website is a variety selection tool based on two years of results of variety performance data from the variety trials and other variety characteristic ratings from other sources. The ratings or performance data is in columns for the varieties listed and are sortable by rank, can be value limited, and moveable to group to compare characteristics most important to the user. The variety selection tool is updated as new data and ratings are available to keep it current.


Spring wheat, pre-harvest at Walla Walla

Oral presentations, field days, and industry and extension meetings are other traditional means used for delivering research results. Results from the Extension Variety Testing Program provide independent assessment of variety performance to support variety selection decisions by growers and for other decisions by other clientele. Growers can realize a timely economic payback using information from yield and variety performance data that is provided within days after harvest via an email list-serve. This project is made possible by contributions of land and time from farmer cooperators where trials are located, and cooperators at the WSU research units at Pullman and Lind. Partnerships with research scientists from public and private sectors are vital to make this program successful. Funding is provided by: Washington Grain Commission, Dry Pea and Lentil Council, WSU Agricultural Research Center, and Washington State Crop Improvement Association.

Determining Preharvest Sprouting Tolerance and Falling Numbers in Soft White Wheat

Shantel A. Martinez[1], Tracy J. Harris[2], Rehana S. Parveen[3], Kimberly Garland-Campbell[2, 3], Arron H. Carter[3], Michael O. Pumphrey[3], Stephen O. Guy[3], and Camille M. Steber[2, 3]
[1]Molecular Plant Sciences Program; [2]USDA-ARS; [3]Dept. of Crop and Soil Sciences, WSU

Preharvest Sprouting (PHS) is the germination of grain on the mother plant under rainy conditions. Sprouting is associated with lack of seed dormancy. A seed is considered dormant if it is unable to germinate under favorable conditions. Even when you cannot see visible sprouting, mild rain events can cause alpha-amylase expression, resulting in starch degradation and lower Falling Numbers (FN). Breeding for higher FN and PHS tolerance can help to prevent problem economic losses due to discounts for FN below 300 sec. Here we present preliminary characterization of soft white winter wheat for PHS tolerance/susceptibility and for Falling Number after the rain event of 2013 in Pullman WA. Spike wetting tests (artificial rain) performed showed that there is considerable variation for PHS tolerance in terms of visible sprouting (grey circles). Cultivars such as Ovation and Coda show promising results for sources of PHS tolerance in SW springs, whereas Bruneau was highly susceptible. Xerpha, Bruehl, Bruneau, and Legacy had very low FN. FN over 300 sec was seen in sixteen lines such as Cara, Ladd, Mary, Masami, SY-Ovation, Puma, and WB-Junction (Note: FN below the line are over 300 sec). These experiments have identified good sources of PHS tolerance.

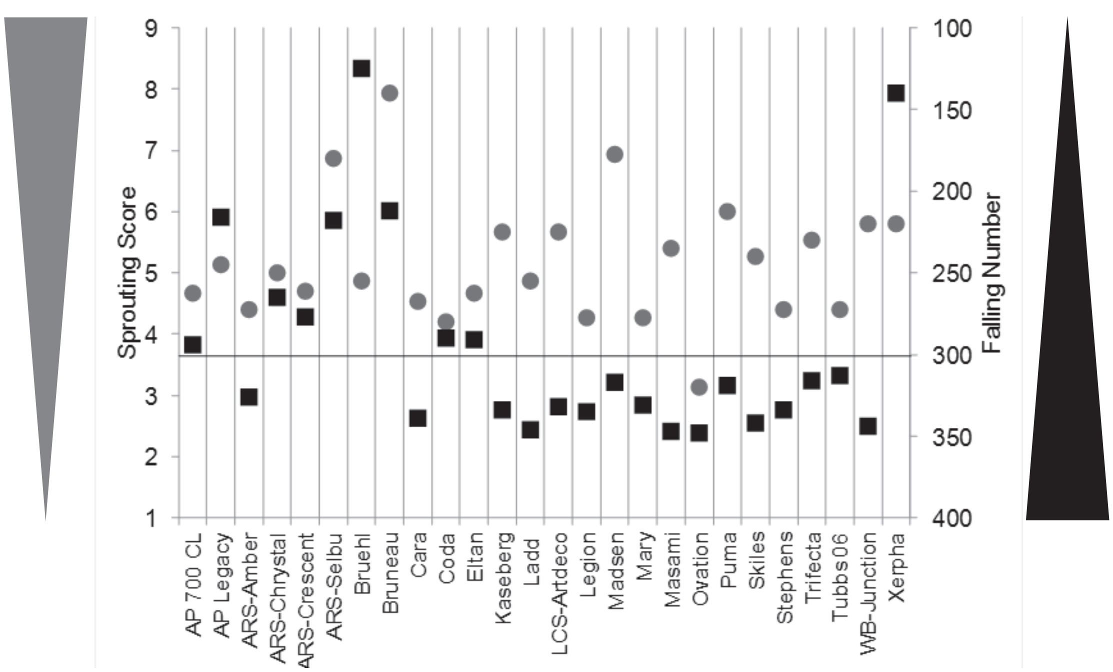

Figure 1. Known spring white winter varieties tested for preharvest sprouting (●) and Falling Numbers (■). Sprouting scores are on a 1-10 scale with 1 having no sprouting and 10 having 100% sprouting. Cultivars/squares above the black bar have a Falling Number of less than 300.

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

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

The Neff lab has identified a group of plant-specific genes that, when mutated in a particular way, uncouple seedling elongation from adult size. These genes encode AHL (AT-Hook Containing, Nuclear Localized) proteins have two domains. One domain, the AT-Hook, binds AT-rich regions of DNA. The second domain is involved in protein/protein interactions. This project includes three main objectives: 1) to identify AHL family members in wheat, 2) to identify those genes that are expressed at high levels in the coleoptile, and 3) to examine the role of both wild type and mutant genes on coleoptile elongation. To date we have identified twelve full-length wheat *AHL* sequences: *Taq1* through *Taq12*. We have shown that *Taq3* is expressed at high levels in the wheat coleoptile and that some of these Taq proteins behave biochemically similar to the ones we have been characterizing extensively in the model brassica *Arabidopsis.*

The third objective is critical for being able to elucidate the role of wild-type and mutant AHL genes in wheat seedling emergence. As such, we have been focused on establishing a successful wheat transformation protocol. Dr. Jiwen Qiu (the post doc working on this project) has established a protocol for transforming wheat. Wheat Taq3 is the most similar AHL to Arabidopsis AHL29/SOB3 that we have cloned. We know that expressing AHL29/SOB3 at high levels in Arabidopsis leads to dwarf plants with pale leaves (Street *et al.* 2008; Zhao *et al.* 2013). We have transformed Arabidopsis with wild-type Taq3 and have observed numerous plants with the same dwarfing phenotype (plant on right) as AHL29/SOB3 when compared to the wild type (plant on the left). These results also imply that the cellular/protein mechanism is conserved between these two plant species.

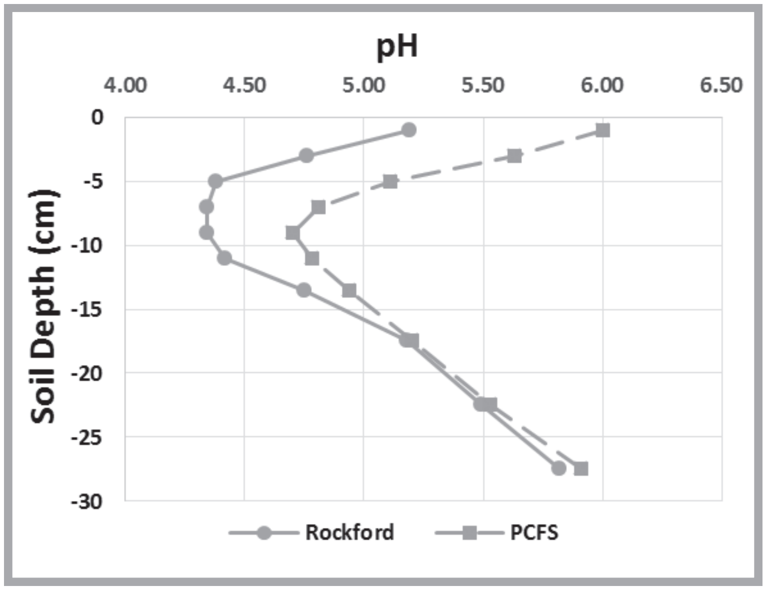
We know that expressing Arabidopsis AHL29/SOB3 with a deleted AT-hook leads to a dominant-negative long-hypocotyl phenotype (Zhao *et al.* 2013). We have performed the same experiment using Taq3 with a deleted AT-hook. We have observed at least 20 primary T1 transformants with hypocotyls ranging from 7 to 9 mm (average = 7.625) whereas the wild type control plants have a hypocotyl length averaging 4 mm. These exciting results also imply that the cellular/protein mechanism is conserved between these two plant species. We have recently been awarded a USDA/NIFA grant ($498,000/three years) to continue this project. Half of this award is for working with wheat, the other half for *Camelina*.

Part 2. Agronomy and Soils

Remediation of Stratified Soil Acidity Through Surface Application of Lime in No-Till Cropping Systems

CAROL MCFARLAND, DAVE HUGGINS, TABITHA BROWN, KURT SCHROEDER, RICH KOENIG, JOEY BLACKBURN, LYNNE CARPENTER-BOGGS, AND TIM PAULITZ

Yield reduction and reduced crop vigor, resulting from soil acidification, are of increasing concern in eastern Washington and northern Idaho. In this region, soil pH has been decreasing at an accelerated rate, primarily due to the long-term use of ammonium based fertilizers. In no-till systems, the acidification is stratified and a zone of much lower soil pH is often measured at the depth where fertilizer is applied.



It is well known that liming raises soil pH. At the same time, the properties of soils in the Palouse region, which include cut-over timber soils as well as those which were natively prairie, are unique and not typical of "acid" soils. The unique properties of Palouse soils means that they will have different requirements and responses to liming than characteristically acid soils.

The research focus is on understanding the response of crops and soils in the Palouse to liming. At two sites under no-till management, one at Freeman, WA and representative of cut-over timber soil, and the other at the Palouse Conservation Field Station (PCFS) which was natively prairie, soil pH stratification has been measured. Fluid lime and sugar lime were surface-applied at the two sites and soil and crop response to the treatments will be compared. The fluid lime is a product which has recently become commercially available, and is a highly-reactive, ultra-fine particle size calcium carbonate.

The depth and magnitude of surficial lime treatment effects on soil are being measured to assess their effectiveness in remediating acidic zones in no-tilled soils. Parallel studies are underway to update soil pH buffer tests and corresponding lime requirement recommendations for the region and to assess how different liming materials react in the soil over time.

WSU Lind Shovel Drill Prototype Thoroughly Tested: Now Who Will Build It Commercially?

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We have completed three years of field testing to evaluate several deep-furrow drill prototypes for successful planting into tilled summer fallow with high levels of surface residue. By far the most successful prototype for residue clearance is a shovel-type drill that resembles an International Harvester (IH) 150 drill, but on a grander scale. The WSU shovel type drill has 17-inch row spacing with staggered shovel-type openers on two ranks (Photo 1). The prototype is equipped with 36-inch-tall split-packer wheels behind each opener. We have had no plugging problems with this drill due to a much greater ground clearance of the frame, as well as greater distance between the ranks of openers compared to the IH 150 drill currently used by many farmers.

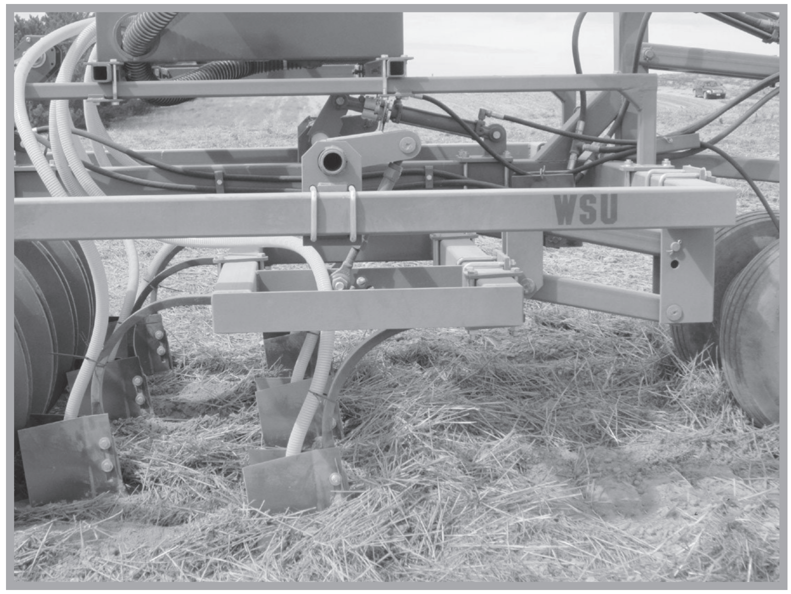

Photo 1: WSU shovel-type deep-furrow drill prototype. High ground clearance and ample spacing between the two ranks of openers allows this drill to pass through high quantities of surface residue without plugging.

The frame of the WSU shovel drill is made of 4x4 inch steel. Clearance from the frame to the tip of the opener is 27 inches compared to 16 inches for the IH 150. In addition, the distance between opener ranks is 26 inches (Photo 1) compared to 19 inches for the IH 150. The drill works well in damp residue. We have never had plugging issues with the shovel-type prototype and plant stand establishment has been excellent (Photo 2).

Photo 2: Excellent stands of winter wheat have been achieved with the shovel-type prototype during three years of testing. Note the extremely high amount of residue that remains on the surface after planting.

The WSU shovel-type prototype is simple, durable, and effective. We feel that this drill is ready for commercial manufacture in 40-to 60 -foot units. Most farmers want a deep-furrow drill that either folds up or folds backward for road transport. How this will be best accomplished has yet to be determined. Farmers have expressed interest in purchasing this drill. The next step is to identify a manufacturer interested in building this drill commercially.

Final Results: Wide Row Spacing for Deep-Furrow Planting of Winter Wheat

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Introduction. Deep-furrow drills used in the winter wheat-summer fallow region have row spacing of 16 to 18 inches. Since 2009, we have worked to design and test improved deep-furrow drill prototypes for successful planting into tilled summer fallow with high quantities of surface residue (**see related article on page 35**). As part of this effort, we conducted a 3-year experiment at three sites (total = 8 site years) to determine if row spacing can be widened from that currently used to facilitate residue clearance without detrimental effects on grain yield. Row spacing treatments in the study were 16, 18, 20, 22, 24, and 32 inches. Experimental design was a randomized complete block with four replications and individual plot size was 100 x 16 ft.

During the first two years, all row-spacing treatments had the same number of seeds per row; thus, the 50 lb/acre planting rate for the 16-inch spacing treatment was diluted to 25 lb/acre planting rate for the 32-inch spacing. In the third year, we procured a specialized seed metering devise to plant an additional study with the same number of seeds per acre for all treatments.

Same number of seeds per row. With the same number of seeds per row, there were never any within-year grain yield differences between the 16 and 18-inch row spacing and a decline in yield with 20-inch spacing only occurred in one of the eight years (data not shown). Grain yield slowly and progressively declined during most years with 22, 24, and 32-inch row spacing. When averaged over the eight site years, the 16 and 18-inch treatments had the highest yields, with small but statistically significant ($P<0.05$) declines in yield as row spacing widened. The average grain yield from narrowest to widest row spacing over the eight sites years was 60-to 50-bu/acre. Gradual grain yield decline with widening row spacing was due to fewer spikes per unit area, despite a tendency for more kernels per spike with wider rows. Kernel weight was never a factor. Straw production declined with wider rows, especially with the 32-inch row spacing.

Same number of seeds per acre. With more seeds per unit length of row with the wider spacing treatments (i.e., same number of seeds per acre), there were no grain yield differences among treatments at Lind or Pendleton and, at Ritzville, there were no differences in yield until row spacing reached 24 inches (Table 1). When averaged across the three sites, there was no difference in grain yield among the 16, 18, 20, and 22-inch spacing treatments, and with a narrow range of only 49 to 45 bu/acre from the 16-inch to 32-inch treatments, respectively (Table 1).

Conclusions. Wheat growers in the dry wheat-fallow region of the Pacific Northwest are reluctant to retain high quantities of surface residue in fallow fields due to concerns about plugging their deep-furrow drills during planting. Drills with wider row spacing will enhance residue clearance. Data from our study suggest that row spacing can be widened to 20 and possibly 22 inches with little to no decline in grain yield compared to the 16 and 18-inch row spacing of drills currently used by growers.

Table 1. Winter wheat grain yield at three locations (3 site years) as affected by 16, 18, 20, 22, 24, and 32-inch row spacing with the same number of seeds per acre (i.e., number of seeds per unit length of row increased as row spacing widened). Within-row grain yields followed by the same letter are not statistically different at the 5% probability level.

	Spacing (inches)					
	16	18	20	22	24	32
	Grain yield (bu/acre)					
Lind, WA	41	41	39	40	39	38
Ritzville, WA	78 a	75 ab	77 a	74 ab	71 bc	68 c
Pendleton, OR	29	30	30	29	29	29
3-site avg.	49 a	49 a	49 a	47 abc	46 bc	45 c

Russian-Thistle Control with Spartan® Herbicide in Spring Wheat

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DEPT. OF CROP AND SOIL SCIENCES, WSU

A field study was conducted at the Lind Dryland Research Station near Lind, WA to determine the efficacy of Spartan (sulfentrazone) herbicide for Russian-thistle control in spring wheat. 'Louise' spring wheat was planted on March 13, 2013 at a rate of 100 lbs/acre using a Kyle drill with 12-inch row spacing and set to seed at a depth of 1 inch. N-P-S fertilizer was applied as a liquid solution at the time of seeding at the rate of 40, 8, and 6.5 lbs/acre, respectively. The soil was a silt loam with 1.3% organic matter and a pH of 6.3. The experimental design was a randomized complete block with four replications. Herbicide treatments were applied PRE immediately after planting with a CO_2 backpack sprayer calibrated to apply 10 gpa at 35 psi and 3 mph. The trial was harvested on July 29, 2013.

Rainfall following Spartan application was light, with 0.16 of an inch received 7 days after application and 0.22 of an inch received more than two weeks after that. The lack of rainfall after application likely influenced crop injury and weed control. Observed crop injury was necrotic leaf spotting, most likely from soil splashing during rainfall events. The level of crop injury observed was low, with no significant treatment differences. Russian-thistle densities in the nontreated checks were moderate to heavy. Spartan applied at 4 or 5 ounces of product per acre provided fair control of Russian-thistle, which was significantly better than the control provided by 1 or 2 ounces/acre of Spartan. With the exception of the 3 ounces/acre treatment, none of the Spartan treatments had a grain yield significantly different than the nontreated check.

Spartan herbicide demonstrated some potential as a commercially viable control for Russian-thistle in spring wheat (See Table 1). However, the lack of rainfall following application limited the conclusions that could be drawn from this study. March rainfall in 2013 was just 0.39 of an inch compared to the long-term average of 1.01 inch. Only 0.16 of an inch was received in March after herbicide application. April rainfall totaled just 0.5 of an inch compared to the long-term average of 0.81 of an inch. This study, or a similar study, should be repeated in 2014 to better assess the efficacy of Spartan herbicide for Russian-thistle control in spring wheat.

Table 1. Russian-thistle control with Spartan® herbicide in spring wheat.

		23-Apr-13		20-May-13	29-Jul-13
Treatment	Rate	Injury	Russian-thistle control	Russian-thistle control	Yield
		----------------	----------------%----------------	----------------	
	oz/a		----------		bu/a
Spartan 4F	1	4	25	13	24.1
Spartan 4F	2	4	40	31	25.8
Spartan 4F	3	6	50	45	23.3
Spartan 4F	4	9	71	65	28.9
Spartan 4F	5	9	60	69	26.3
Nontreated check		0	0	0	28.4
LSD (5%)*		7	39	26	4.8

*Treatment differences less than the LSD value are not considered significant because we do not feel confident that the difference is due to the treatment rather than to experimental error or random variation associated with the experiment.

Post-Harvest Control of Russian-Thistle Following Spring Wheat

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DEPT. OF CROP AND SOIL SCIENCES, WSU

A field study was conducted at the Lind Dryland Research Station in Lind, WA to evaluate the effect of herbicide application timing on Russian-thistle control. Spring wheat was harvested on July 29, 2013. Post-harvest herbicide applications were made on August 9. The experimental design was a randomized complete block with four replications. The first application time was at dawn, when Russian-thistle plants should have recovered from the previous day's drought stress to the maximum extent possible. The air temperature was 61 F, the soil surface temperature was 53 F and the relative humidity was 60%. The second application time was at mid-afternoon, when day time temperatures were near their maximum and plants would have been shutting down as a result of drought stress. The air temperature was 91 F, the soil surface temperature was 84 F, and the relative humidity was 17%. All treatments were applied with a CO_2 backpack sprayer set to deliver 15 gpa at 3 mph and 35 psi. Russian-thistle plants were 6-12" tall.

The time of day at which herbicide applications were made did not appear to affect the level of control achieved by any particular treatment. The greatest difference in control between early morning and mid-afternoon application occurred for the treatment of Roundup (glyphosate) at 64 oz/acre, although the difference was not statistically different (See Table 1). These data do not support the recommendations by some to apply herbicides at night for better control, although this is just one site and one year. The results will need to be verified with further research. The treatments containing Gramoxone Inteon (paraquat) provided the best control of Russian-thistle, particularly two weeks after application. The Buctril (bromoxynil) + dicamba treatment was a very close second. As can be seen in the table below, Roundup at 64 ounces per acre provided good to very good control of Russian-thistle four weeks after application, but a reduced rate of Roundup, with or without Sharpen (saflufenacil), provided only fair control of Russian-thistle four weeks after application. The Roundup + Sharpen treatment did provide better control than Roundup at 64 oz/acre at two weeks after application, but not at four weeks after application.

Table 1. Post-harvest Russian-thistle four weeks after herbicide application.

Treatment	Rate	Russia-thistle control	
		AM application	PM application
	oz/a	---------------------- %	----------------------
Gramoxone Inteon*	48	93	95
Gramoxone Inteon*	32	90	93
Karmex DF	5		
Buctril	24	89	83
Dicamba	8		
Roundup PowerMax**	32	56	55
Roundup PowerMax**	64	89	80
Roundup PowerMax**	32	71	73
Sharpen***	1		
Untreated Check		0	0
LSD (5%)[1]		--------------------- 10	---------------------

*NIS added at 0.5% v/v, **AMS added at 17 lb/100 gal, ***MSO added at 1.0% v/v

[1]Treatment differences less than the LSD value are not considered significant because we do not feel confident that the difference is due to the treatment rather than to experimental error or random variation associated with the experiment.

Re-Integrating Perennial Pasture and Livestock into Palouse Cropping Systems

JONATHAN WACHTER[1], ERIC ZAKARISON[2], LYNNE CARPENTER-BOGGS[1], DAVID HUGGINS[3], KATE PAINTER[4], AND JOHN REGANOLD[1]
[1]DEPT. CROP AND SOIL SCIENCES, WSU; [2]ZAKARISON PARTNERSHIP; [3]USDA-ARS; [4]U OF I

This research on mixed crop-livestock cropping systems is designed to address two important needs on the Palouse: first that, despite improvements in tillage practices, erosion and loss of soil organic matter continue to be a major problem; and second that there has been relatively little research to support growers who wish to decrease their dependence on synthetic inputs and fertilizers on the Palouse. Green manures and perennial pastures in crop rotations can increase soil organic matter; break weed, pest, and disease cycles; and biologically fix up to 100 lb N per acre if legumes are used. The integration of livestock into crop rotations at strategic times can diversify revenue, manage weeds, and utilize resources such as straw and green manure biomass while returning nutrients to the soil. The overall goal of this project is to examine the economic, agronomic, and environmental performance of three cropping systems: a conventionally managed winter wheat – spring wheat – field pea rotation; a sheep-integrated winter wheat – spring wheat – grazed winter pea green manure; and a sheep-integrated organic alfalfa – field pea – winter wheat rotation. These three systems are assessed by: analysis of financial performance based on enterprise budgets and breakeven points; crop productivity, including crop yield and quality; animal productivity; soil erosion potential, soil quality, nitrogen budgets, and nitrous oxides losses. This project is entering its third growing season, so only limited comparisons between cropping systems can be made at this time. Most significantly, after year 1, soil carbon in the surface 12 inches increased under pasture in the organic rotation, while soil carbon declined slightly in both the conventional (field pea crop) and integrated (pea green manure) rotations. More results will be discussed at a field day during this growing season.

Soil Quality Assessment in Long-Term Direct Seed

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[1]DEPT. OF CROP & SOIL SCIENCES, WSU; [2]LAND MGMT. & WATER CONSERVATION RESEARCH UNIT, USDA-ARS; [3]SCHOOL OF ECONOMIC SCIENCES, WSU

Producers in the Pacific Northwest are adopting direct seed farming to reduce soil erosion, improve soil quality and increase water infiltration. Some direct seed producers are concerned with reaching the yield and profit potential expected with long-term direct seed, and this may be due to soil stratification with lack of soil disturbance that makes nutrients unavailable for plant uptake due to pH, electrical conductivity (EC), or banding of nutrients at potentially toxic or deficient levels. We are investigating the soils of thirteen long-term direct seed sites and three sites farmed with conventional or conservation tillage to identify characteristics that play a part in limiting yield potential. Sites represent low, intermediate and high rainfall zones of eastern Washington and northern Idaho. Biannual soil sampling began in spring, 2013 and will continue through fall, 2014. Three landscape positions (top, mid-slope and bottom) were sampled at each location, and samples were separated into six depth increments from 0-8 in. A comparison of soil characteristics between direct seed and tilled systems from the first sampling in Spring, 2013 is shown in Table 1.

Rainfall zone/ System	pH	EC	CEC	P	K	S	Al	Cd
	1:1 water:soil	μs cm^{-3}	meq $100g^{-1}$	mg kg^{-1}				
High								
Direct Seed	5.0 b	237.9 a	18.6 b	34.1 a	319.5 a	39.4 a	65.1 a	1.44a
Tilled	5.5 a	138.4 b	24.7 a	33.6 a	258.7 a	24.9 b	17.1 b	0.05 b
Intermediate								
Direct Seed	6.7 b	144.0 b	11.9 b	25.7 a	668.2 a	13.7 a	10.4 a	0.06 a
Tilled	7.4 a	182.4 a	14.1 a	15.2 b	448.1 b	4.1 b	3.9 a	0.02 b
Low								
Direct Seed	6.3 b	106.1 b	8.9 b	22.5 a	548.2 a	10.4 a	2.1 a	0.04 a
Tilled	7.3 a	161.0 a	13.0 a	13.7 b	407.8 b	5.4 b	0.3 b	0.02 b

Table 1. Comparison of soil characteristics between direct seed and conventional or conservation tillage averaged across landscape positions and depth increments in Spring, 2013. Different letters in the same section in the same column represent significant differences at $P \leq 0.05$.

Remedial management by farmers to improve, maintain or restore soil quality will depend upon their efficiency in managing variable and fixed costs when carrying out field operations. With these factors identified, management options can be investigated and strategies developed to obtain sustainable systems. The 2013 annual report of preliminary results for this study can be viewed at: http://mysare.sare.org/mySARE/ProjectReport.aspx?do=viewRept&pn=SW12-122&y=2013&t=0.

Best Management Practices for Summer Fallow in the World's Driest Rainfed Wheat Region

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The Horse Heaven Hills (HHH) located in south-central Washington contains the world's driest rainfed wheat production region where farms receive as little as six inches of average annual precipitation. Late summer establishment of winter wheat into carryover seed-zone moisture after a year of fallow is essential to achieve the highest grain yield potential. Tillage of fallow land during the spring is considered necessary to retain adequate seed-zone water during the dry summer months, but blowing dust from excessively-tilled fallow is a major safety, environmental, and soil-quality concern. We conducted a 5-year study to compare three fallow management systems on two farms in western and eastern portions of the HHH where long-term annual precipitation averages 6.02 and 8.31 inches, respectively (Figure 1). Fallow management treatments were: (i) traditional tillage (TTF), undercutter conservation tillage (UTF), and no-tillage (NTF). Late-summer planting of winter wheat in TTF and UTF was possible in only one year of five at the Western site due to lack of adequate seed-zone moisture whereas late-summer planting was possible every year at the Eastern site. There were no significant differences in profit/acre among fallow management treatments at the Western site whereas profit/acre averaged a positive $41 for TTF and UFT versus a negative -$37 for NTF at the Eastern site. Although seed-zone water in late summer was consistently lowest with NTF at both sites, NTF is the best option for farmers in the Western HHH because achieving adequate seed-zone moisture for early wheat establishment is generally not possible with any fallow management practice. On the other hand, in the Eastern HHH, where adequate seed-zone moisture for early planting can be achieved with tillage essentially every year, farmers should practice UTF. This study documented that NTF in the Western HHH and UTF in the Eastern HHH are best management practice for farmers and the environment in a region where wind erosion from excessively tilled soils is a huge problem. See related article on page 41.

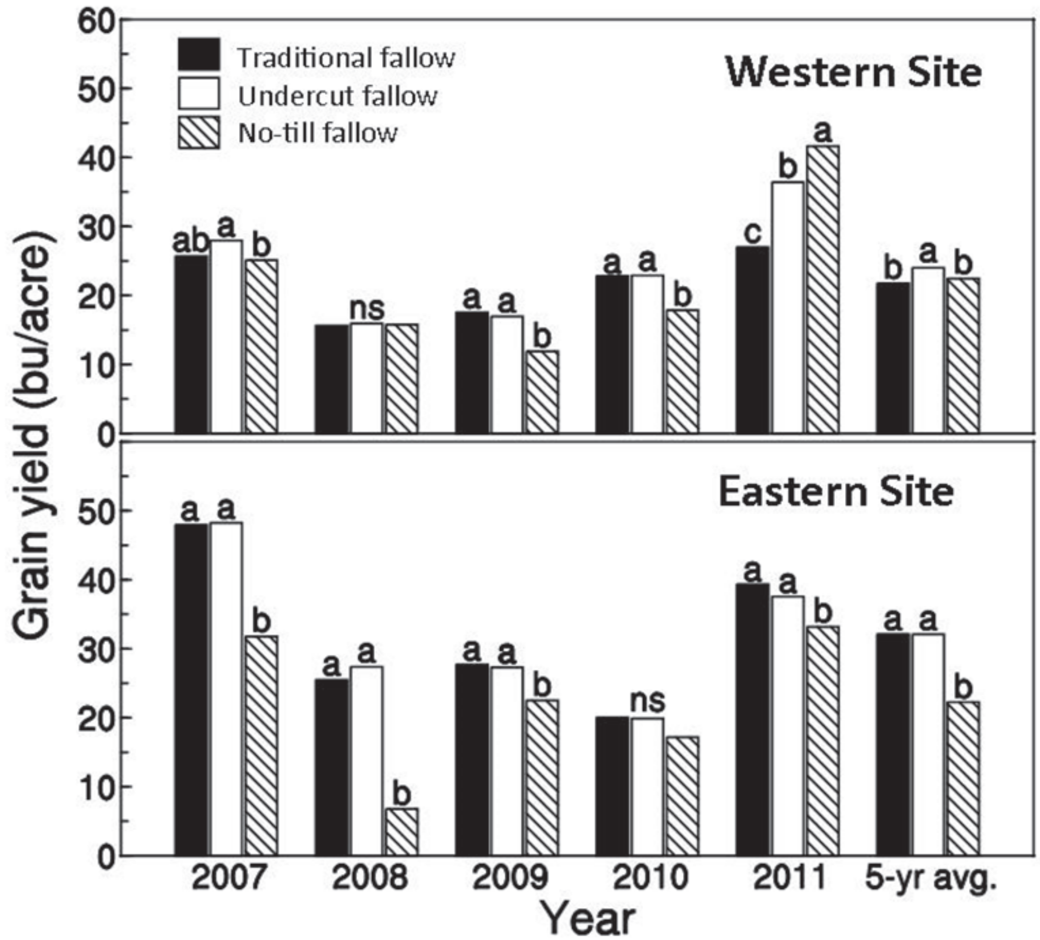

Figure 1. Grain yield of hard red winter wheat for three fallow management systems for five years as well as the 5-year average at two locations in the Horse Heaven Hills, WA. Grain yield within a site and year with the same letter are statistically equal at the 5% probability level.

Economics of Three Fallow Systems in the Horse Heaven Hills, Washington

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We assessed the profitability (net returns over total costs) of hard red winter wheat (HRW) following traditional (TTF), undercutter (UTF), and no-till fallow (NTF) in the Western and Eastern portions of the Horse Heaven Hills (HHH) from 2007-2011. The 5-year average yield of HRW following TTF was 22 bu/acre at the Western site versus 32 bu/acre at the

Eastern site. All systems and sites sold HRW at the same 2009-2013 average price of $7.09/bu. Returns also included government annual direct and countercyclical payments. Costs are based on the annual operations and machinery utilized by host farmers for each system on the two sites. Average crop-year (Sept. 1-Aug. 31) precipitation was 6.46 and 8.54 inches at the Western and Eastern sites, respectively. Current prices were charged for all inputs including diesel, fertilizer, herbicides, seed, and labor. Total economic costs include a market return for the farmer's land, machinery, and labor. Profit is presented per rotational acre of one half acre of HRW and one half acre of fallow.

Profits/acre are discussed separately for each site because the objective was to compare fallow systems in markedly different agro-climatic environments. On the Western site, all three fallow systems earned statistically equal average profit ranging from $31.04/ac for TTF to $41.02/ac for UTF (Table 1). The point estimate of relatively high UTF profit is encouraging because this system substantially reduces wind erosion. These results also underscore the favorable potential for NTF in the western HHH where adequate seed-zone soil moisture is rarely available for early planting even with tillage-based fallow. For the Eastern site, Table 1 shows statistically equal average profit of about $41/ac for the TTF and UTF systems. On this site, NTF profit lagged sharply due to low yields and high herbicide costs. Lower average profit for TTF in the West versus the East is due to lower yields. High yearly profit variation is caused by fluctuations in precipitation and yields. See related article with more detail on yields and soil water on page 40.

Table 1. Profit ($/ac) by year, fallow system and site, Horse Heaven Hills, Washington

	……………………………….Western………………………………					
Fallow System	**2007**	**2008**	**2009**	**2010**	**2011**	**Mean**
Traditional	49.65	13.46	10.17	31.82	50.11	31.04 a
Undercutter	58.75	11.98	9.37	33.84	91.16	41.01 a
No-Till	35.59	8.92	-17.10	7.79	117.02	30.44 a
	……………………………….Eastern………………………………					
Traditional	123.72	10.10	27.87	-30.71	72.72	40.75 a
Undercutter	125.64	20.20	27.09	-30.07	61.09	40.79
No-Till	0.13	-92.39	-27.95	-53.01	-12.53	-37.15 b

Note: Same lower case letter denotes statistically equal profit at ≤ 0.05 level by Tukey's test.

Economic Impact of Planting Date by Crop, Cook Agronomy Farm, 2001-2009

KATHLEEN PAINTER[1], DAVID HUGGINS[2], AND SHELLEY JONES[3]
[1]U OF I; [2]USDA-ARS; [3]WSU

Impacts of planting date on yield were compared for direct-seeded spring barley, spring canola, spring peas, and spring and winter wheat at the Cook Agronomy Farm (CAF) over a nine-year period. Planting dates for each year were compared to the subsequent yield by year. Regressing over these data produced an averaged change in yield per day's delay in planting relative to the earliest planting date during this period (Table 1). Average farmgate prices over this time period were used to calculate an average cost per day's delay in planting.

Table 1. Cost of delayed planting in terms of yield (lb/ac/day) and economic impact ($/ac/day), 2001-2009, Cook Agronomy Farm

		2001 - 2009					
		Per Acre Cost of Delayed Planting				Planting Dates	
Crop	Unit	Price	Price/lb	lb/day	cost/day	Earliest	Latest
HRSW	bu	$6.09	$0.10	-32.68	-$3.32	24-Mar	5-May
HRWW	bu	$5.25	$0.09	-30.90	-$2.70	30-Sep	25-Oct
SB	ton	$119.21	$0.06	-34.31	-$2.04	26-Mar	12-May
SP	cwt	$9.09	$0.09	-18.27	-$1.66	24-Apr	2-Jun
SC	cwt	$12.80	$0.13	-22.21	-$2.84	26-Mar	12-May

Notes: HRSW = hard red spring wheat, HRWW = hard red winter wheat, SB =spring barley, SP = spring peas, SC = spring canola. Crop prices represent average farmgate prices in the Pullman, WA, area, for the period 2001-2009.

Spring barley had the largest daily yield decline at 34.31 lb, followed by spring and winter wheat at 31 lb and 33 lb respectively. However, the price per pound for hard red spring and hard red winter was higher than for barley, resulting in a more costly impact for hard red spring wheat at $3.32/day and for hard red winter wheat at $2.70/day. The cost of delaying planting for spring canola was actually second highest, at $2.84/day, given a price of $0.13/lb and a 22.21 lb/day penalty for delaying planting.

Spring barley and spring canola planting dates ranged from March 26 to May 12, over the 9-year study, a span of 47 days (Table 1). The earliest planting date for hard red spring wheat was March 24, while the latest planting date was May 5, a 42-day span. Spring peas were planted over a span of 39 days over the study period, from an earliest planting date of April 24 to a latest date of June 2. Winter wheat planting dates ranged from September 30 to October 25, a range of 25 days.

Nitrogen Balance Approach to Assess Rotational Nitrogen Cycling Within Dryland Cropping Systems

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In annual cropping systems, nitrogen use efficiency is typically estimated on a single crop basis. However, this approach ignores the dynamic nature of N cycling within multi-year crop rotations featuring a diverse set of crops. In addition to the UNR, we have developed a multiple-year N budget approach to track N dynamics over a three year spring canola-spring pea-winter wheat cropping sequence in the annual cropping wet-cool and fallow-transition zones. Our research follows the N fertility described above at the same two locations, in order to determine canola-based rotational N use efficiencies. Our N budgets indicate that canola, like winter wheat, is effective at scavenging N from the soil profile. In 2011 and 2012, residual nitrate is less than 45 lb N/ac in the top 4 feet of soil, after winter wheat and canola, which can exceed 55 lb N/ac following spring peas. Although the N supply is typically greater than the total amount of N exported in grain for the entire rotation, crop residues can retain 8 to 40% of the total N inputs which are not subject to immediate loss. Furthermore, residual inorganic N remaining after canola and winter wheat represents less than 10% to 33% of the total N supplied to the crops. N use indices indicate that winter wheat is a more efficient N user than peas and canola, but has a relatively greater dependence on fertilizer N. Residual inorganic N is able to satisfy a greater proportion of canola's N requirement at yield-optimizing fertilizer rates, while peas reduce the need for fertilizer N through biological N fixation. In this rotation, the cropping sequence and N fertilization rate of canola resulted in apparent increases in net N mineralization, or the accumulation of inorganic N, of 18 lb N/ac or less measured in spring wheat check-plots (unfertilized) and in soil cores (0-6 inch) collected from the field. These findings will help support new soil test and yield potential-based N fertilizer recommendations for canola based on estimates of N uptake, N utilization efficiencies and N mineralization of residues within a rotation.

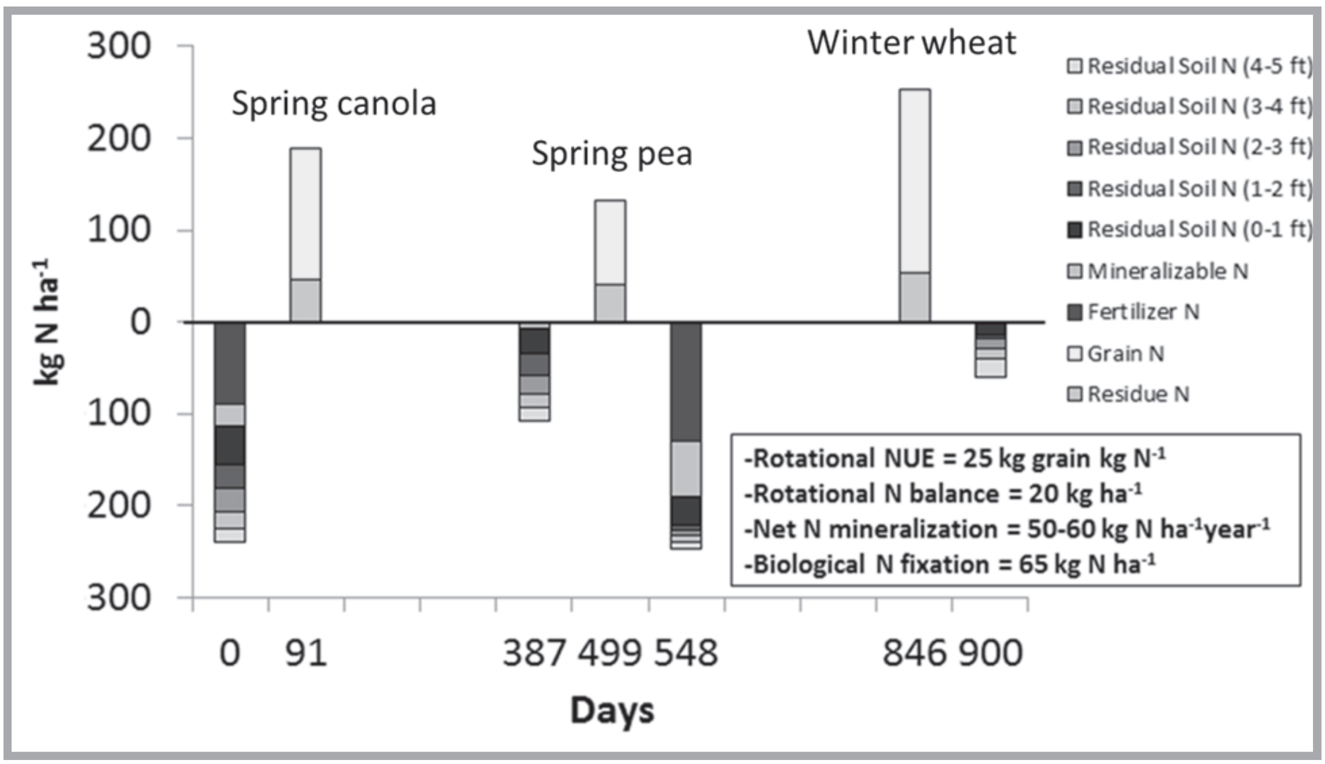

Figure 1. Changes in grain, crop residue, and plant-available soil N during a 3 year rotation of spring canola-spring pea-winter wheat in the high precipitation zone. Estimates are provided for crop sequence nitrogen use efficiency (NUE) = total yields/total N supplied; rotational N balances = (N fertilizer + N mineralization + biological N fixation)-(total grain N exports + residual soil inorganic N); BNF = biological N fixation = (plant N - change in soil N relative to an unfertilized spring wheat reference crop).

Soil Quality Stratification – Sampling, Education and Demonstration Project

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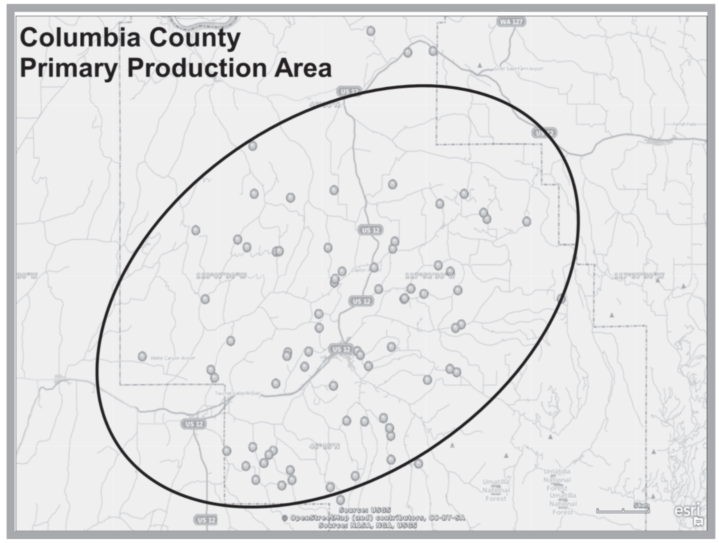
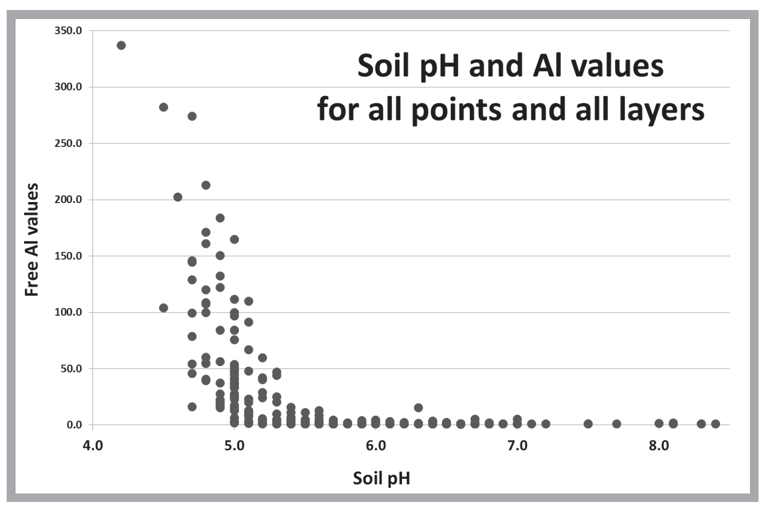
Columbia County, Washington is in the Palouse wheat country. The soils of the farming region are mostly a rich silt loams having an annual rainfall ranging from 12 inches in the north near the Snake River to 25 inches in the south with most of the production area having about 14-18 inches annually. Elevations range from 1000 to 3500 feet.



Intense soil sampling indicates that applications of nitrogen over the years have created a stratified soil nutrient problem through continued injection of ammonium based fertilizers. In April 2006, intense soil sampling (1 cm increments) on a plot provided evidence of seed zone depth (1 to 3 inch depth) soil pH levels ranging from 4.14 to 4.56 over 4 replications. These data combined with recent soil acidity and free aluminum concerns in some regions of the state have encouraged further intense soil sampling.

To determine the extent of the concern, a demonstration and education project (2 years) was developed through the assistance of the local Columbia Conservation District and the Washington Conservation Commission. The project offered farmers an opportunity to apply for participation where they identified locations for soil sampling and nutrient testing. Locations were distributed across the landscape so that all rainfall zones (12-16", 16-20", and >20") were represented throughout the county. The results establish a baseline for further work and are being utilized to develop methods to address the reduced soil pH problem and to produce educational materials and plan events.



In 2013 a sampling project collected data on 76 farmer fields. Two sites were used to represent native soil conditions. Samples were collected in stratified increments of 0-3, 3-6, 6-12, and 12 -24 inches. A complete lab analysis was conducted to provide a baseline of data. Some (10%) of the samples were divided and sent to an additional lab for validation of results.

Analysis of the lab results revealed 2 sites with soil pH values over 8.0, native soil pH values ranging from 6.1 to 6.9 and production sites mostly below pH 6.0. With the exception of the 2 sites above pH 8.0, all other sites had a pH below 5.4 in the 3-6 inch layer regardless of the rainfall zone, tillage system, or cropping rotations. Available aluminum ranged from 1 to 336 ppm (see graph). The results identified that there is a growing problem with soil pH in the intense wheat production areas. We are now looking at research sites for application of pH amending products to stabilize soil pH levels and reverse the trend.

Nitrogen Fertilization and Crop Rotation Effects on Soil Crusting

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DEPT. OF CROP AND SOIL SCIENCES, WSU

Soil crusting is a common occurrence in many cultivated soils in arid and semi-arid regions. The severity of crusting is strongly affected by climatic events, such as rainfall and soil type. Additional factors that affect soil crusting include accumulation of silicon (Si) and soil pH. Plants greatly differ in their ability to accumulate Si. Therefore, crop residue and fertilizer management may have an important impact on Si solubility and movement. In order to determine the effects of the decomposition of Si from wheat (*Triticum aestivum* L.) and canola (*Brassica napus* L.) on soil crusting, a residue incubation and field survey was initiated. The residue incubation utilized samples containing 100 g of Ritzville silt loam and 0.8 grams of wheat or canola residues. Half of the samples received 200 mg N/kg soil as ammonium phosphate in order to create ammonium induced acidification during nitrification. Samples were maintained for 20 weeks, while destructive sampling occurred every two weeks. The field survey was conducted in Ralston, WA on a Ritzville silt loam in order to further determine the long-term effects of rotations in a field setting. Three fields were sampled with the following rotations: WW/BAR/SW, WW/SF/C/SF, and C/SF/WW/SF. Multiple penetrometer readings and soil cores were taken from each field. For analysis, cores were separated into 0-10 cm, 10-20 cm, and 20-30 cm depths. Samples from both studies were analyzed for moisture, surface resistance, pH, water-soluble silica (Si_{ws}), amorphous silica (Si_{am}), and crust thickness. The residue incubation results showed that pH rather than crop residue type had a significant effect on the measured parameters. Samples with a pH value of 4.5 compared to the 5.5 treatment had significantly less soil Si_{am}, Si_{ws}, surface resistance, and crust thickness. These results along with previously determined correlations between Si levels and crusting suggest that in an acidic environment, Si may become mobile and leach farther down the soil profile. The field survey results indicated that the moisture levels significantly differed between fields. The WW/BAR/SW had the highest moisture followed by the WW/SF/C/SF and C/SF/WW/SF fields. The penetrometer values showed an inverse relationship to the moisture values; therefore, surface resistance was significantly higher in drier fields. Soil Si_{am} values were only significantly affected by depth rather than crop type. Therefore, moisture rather than soil Si levels was the most significant factor contributing to surface resistance. Although these results did not provide many conclusions as to whether crop rotations have an effect on soil crusting, some important relationships have been observed between pH and moisture, and future studies will need to measure crusting at uniform soil water contents.

Kentucky Bluegrass Germplasm for Turf and Seed Production

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The objective of the study was to develop bluegrasses that have sustainable seed yield without post-harvest field burning and still maintain acceptable turfgrass quality. This long-term study consisted of 10 Kentucky bluegrass entries; eight are USDA/ARS Plant Introduction (PI) accessions and two are commercial cultivars ('Kenblue' and 'Midnight'). All entries in previous research had expressed high seed yield without burning of post-harvest residue and good turfgrass quality. 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. The turfgrass trials were evaluated according to NTEP (National Turfgrass Evaluation Program) protocol. Seed production plots were harvested (2008-2011) and seed increase plots established in 2011 were harvested in 2012 and 2013.

Results indicate that PI 368241, selection heads/area, showed the most promise of being able to provide long-term turfgrass seed yield without field burning in both non-irrigated and irrigated seed production (Table 1). Kenblue, selection seed/head, had good seed yield and fair turfgrass quality. PI 371775 selection seed/head had good turfgrass quality, while maintaining good seed yield with irrigation. These three selections are currently in seed increase plots at

Pullman. In the PNW, bluegrass seed yields in 2013 were considerably below average. It will be interesting to see if the yields in the dryland seed increase plots were following the regional trend in 2013, or will rebound in seed yield in 2014.

Table 1. Kentucky bluegrass germplasm turfgrass quality and seed yield.

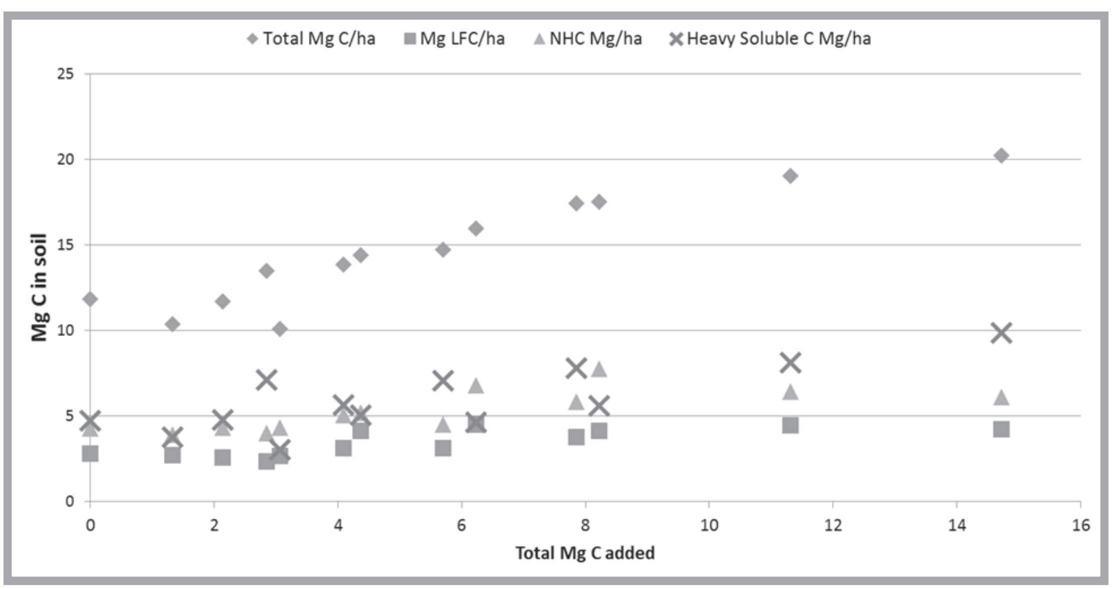
Turfgrass quality[1]			Seed Yield (lbs/A)		Seed Increase Plots Seed yield (lbs/A)	
Cultivar or PI#	Selection Parameter	5-yr Mean Pullman	4-yr Mean Dryland	4-yr Mean Irrigated	2012	2013
Midnight	Elite-type check	7.1 a[2]	136 c	243 d		
Kenblue	Common-type check	5.3 c	398 b	608 c		
Kenblue	Seeds/head	5.4 c	795 a	995 ab	1207[3]	911[3]
371775	Seeds/head	6.1 b	404 b	800 bc	729[4]	913[4]
368241	Heads/area	5.1 d	893 a	1102 a	934[3]	673[3]

[1]Turfgrass quality rated 1 to 9; 9 = Excellent
[2]Means within columns followed by the same letter are not significantly different. LSD $P = 0.05$
[3]Dryland
[4]Irrigated

Carbon Fractionation of Biosolids Amended Soils

LAUREN YOUNG, YAOYI XIAO, CRAIG COGGER, AND WILLIAM PAN

Anaerobically digested and dewatered biosolids can be an effective source of nutrients in a cropping system. The GP-17 project, located near Waterville, WA, has been employing biosolids as a nitrogen source for winter wheat crops since 1994. Every four years, biosolids are applied and incorporated into the soil following wheat harvest in a WW-Fallow system. Carbon fraction analysis techniques have recently been applied to historical soil samples from this site, and show that acid resistant, light fraction, and heavy soluble carbon pools in the soil increase with applications of biosolids. The trend is for soil C levels to increase as C is added; about 20% of the added carbon is stored in the acid resistant fraction, 14% in light fraction, and 36% in the intermediate heavy soluble fraction. Due to augmentation of these three C fractions, total soil C increases by around 70% of what is applied. This research demonstrates biosolids applied to wheat producing soils increases C sequestration above and beyond what wheat straw returns.

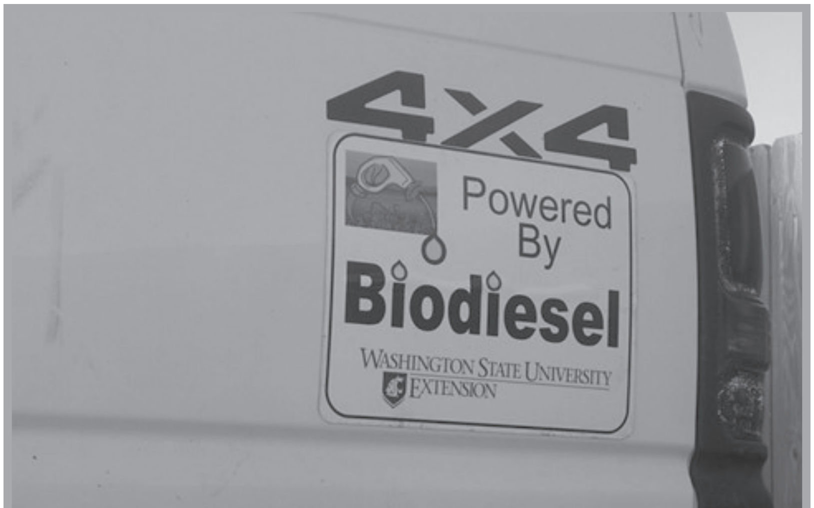


Part 3. Biofuels and Other Alternative Crops

The Rise of the Canola Industry in Washington State

KAREN SOWERS[1], MARY BETH LANG[2] AND BILL PAN[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]WASHINGTON STATE DEPT. OF AGRICULTURE

Canola has been produced on limited acreage in Washington State since the 1980's, yet in recent years the sight of a bright yellow field of flowering canola has become more commonplace, particularly in eastern Washington. State canola acreage more than doubled from 15,000 acres in 2012 to 37,000 acres in 2013, and recent Prospective Plantings data released by USDA-NASS indicate a continued increase for 2014 to 45,000 acres. Why the increased interest in canola production in the predominantly cereal-based cropping systems of WA? The answer may be different depending on who is asked. To a grower, the benefits of canola in many situations result in an improved bottom line in the entire rotation, regardless of rainfall zone. Increased yield of following cereal crops, improved weed control, breaking disease and insect pest cycles, and a crop that can be used with deficit irrigation are commonly cited as benefits. To state legislators, it's the opportunity to produce renewable energy and create a new industry in Washington that benefits farmers and our rural communities. In 2007, the WA legislature allocated monies to WSU to initiate the Washington State Biofuels Cropping Systems Research & Extension Project (WBCS) to evaluate alternative crops that may have the potential to meet some of the increasing demand for biofuel production. In addition, state funding was applied to support an in-state industry of crushers and biodiesel plants to process the crop, and policies were put in place to promote in-state use of biodiesel. Fast forward to 2014 and, thanks to continued funding from the state, the WBCS team of researchers, grad students and technicians continue to make great strides in finding best management practices for winter and spring canola in various crop rotations and rainfall zones across the state; education and outreach opportunities abound; there are local processors with an insatiable demand for canola; and the state is purchasing more than 1 million gallons of biodiesel annually to fuel the state ferries system and state vehicles. A vision is being realized for WA-produced oilseeds, crushed and processed in-state, and utilized for biodiesel, animal feed and food-grade canola oil, resulting in environmental and economic benefits for Washington State.



Spreading the Word About Oilseed Production – WSU Extension and Outreach

KAREN SOWERS[1], DENNIS ROE[1], BILL PAN[1], FRANK YOUNG[2], AARON ESSER[1], AND BILL SCHILLINGER[1]
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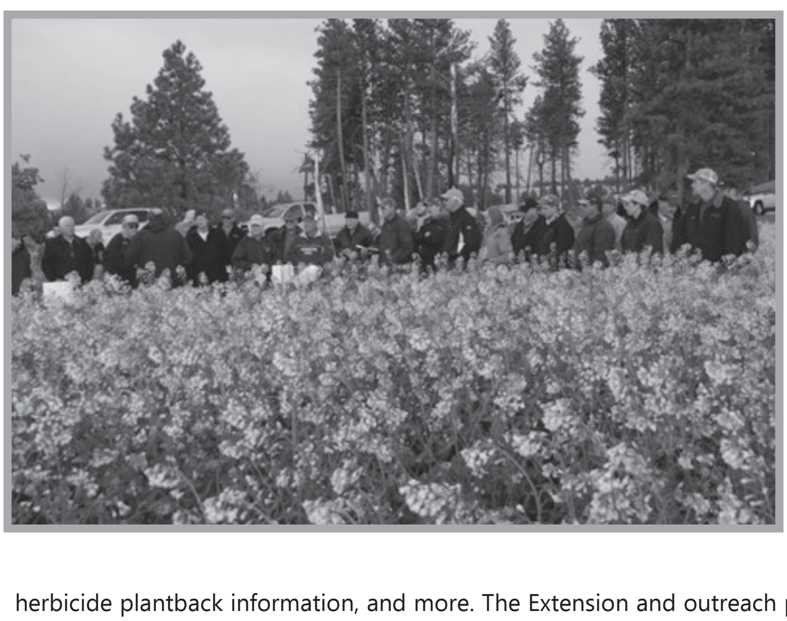
After nearly seven years of research and data produced from the Washington State Biofuels Cropping Systems Research and Extension Project (WBCS) team, it remains imperative that the information generated be readily available to WA and PNW oilseed growers, processors, ag industry reps, and state and local agencies. This is accomplished via canola field tours, presentations at industry and grower events, publications, a WBCS-dedicated website (www.css.wsu.edu/biofuels), on-farm visits, and an annual oilseed conference. Field tours during 2013 included winter canola variety trials located in a wide range of rainfall and elevation; residue management research plots in irrigated winter canola; WSU research farm field days that featured canola and camelina; and canola informational stops during WSU cereal variety trial tours. In the off season, the majority of the Direct Seed breakfasts in Colfax and Lewiston, co-organized by Dennis Roe (funded by WBCS), include presentations about canola and were attended by 345 people in 2013 and 2014. A major component of the Extension portion of the WBCS project is the annual oilseed production conference. In 2014, the Pacific Northwest Direct Seed Association joined the conference and the event attracted nearly 500 attendees. Along with conference attendees there were 45 vendors, over 40 research posters, and nearly 50 speakers representing Australia, Canada, and 16 U.S. states to provide a wide variety of perspectives and discussion about oilseed production and direct seed cropping systems. Tentative plans are in the works for another joint conference in 2015 with WSU and the PNDSA. Access of the WBCS website continue to increase, with more than 8,835 page views from 48 countries (up 128%), 43 states (up 39%) and 69 cities in WA (up 53%) from April 2013 to April 2014. The annual compilation of PNW oilseed supply and delivery locations is a popular resource, and the content of the website will expand further in 2014 to meet the needs of growers and ag industry learning about oilseed production, including local market prices, insect and disease photos and identification, herbicide plantback information, and more. The Extension and outreach portion of the WBCS project tailors information to accommodate all knowledge levels of producers and crop consultants, and efforts now span a much broader geographic range as oilseed acreage continues to increase annually in Washington state.



High Residue No-Till for Soil Moisture Conservation and Canola Establishment

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

Current research at the Ralston Project (11 inch rainfall zone) is evaluating the use of tall cereal varieties for maximum biomass production, and harvest with a stripper header to create tall standing stubble, which is maintained during chemical fallow. When compared to cereal crops harvested with a conventional header, the high-residue fallow resulting from stripper header harvest influenced the microclimate at the soil surface by reducing soil temperatures and wind speeds, which resulted in increased seed-zone moisture retention. Maintenance of adequate seed-zone moisture with high surface residues may enable growers to plant winter canola at a convenient late summer planting date, rather than having to rely on early fall rains and/or cool postplant temperatures. More uniform soil moisture in chemical fallow appears to improve canola stand establishment compared to tilled fallow.

We established a uniform stand of no-till winter canola on 28 July 2013 in stripper header wheat and triticale stubble compared to conventionally planted winter canola into traditional summer fallow. Plants were in the large rosette stage (complete canopy cover, 16'' row spacing) in the fall. Plants survived cold temperatures in December 2013; however, in February 2014 ambient air temperature reached -7 F, and with no snow cover to protect the plants, the winter canola planted in this trial did not survive. The plots have been replanted with spring barley, and will be harvested with the stripper header. This will provide another year of microclimate monitoring in stripper header stubble, and show if there is a difference in effect between high residue winter crops and lower residue spring crops.

New Long-Term Winter Triticale, Winter Canola, and Winter Pea Cropping Systems Study Initiated Near Ritzville

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

A new long-term no-till cropping systems study was initiated in March 2014 at the Ron Jirava farm near Ritzville. The experiment includes four winter crops: winter triticale (WT), winter canola (WC), winter pea (WP), and winter wheat (WW). There are two 4-year crop rotations involving no-till summer fallow (NTF) that will be compared to the "check" treatment of the traditional 2-year WW-tilled summer fallow (TF) system.

Crop rotation treatments are:

WC-NTF-WT-NTF
WP-NTF-WT-NTF
WW-TF

The experimental design is a randomized complete block with four replicates. Individual plot size is 100 x 32 feet. Each phase of all rotation sequences is present each year for a total of 40 individual plots covering at a total of 2.94 acres.

Winter canola will be planted with a Cross-slot drill sometime between late June to mid-July, depending on surface soil moisture conditions in the NTF and predicted air temperatures for the ensuing week (i.e., the cooler the predicted air temperatures, the better). The ongoing WC planting date experiment at this site will help to further define the optimum planting date (see related article on page 51). Fertilizer will be "stream jetted" on the surface in mid-October or later to help reduce excessive WC vegetative growth in the summer.

Winter pea will be planted deep into moisture with a deep-furrow drill into NTF during the first week of September (see related WP article on page 59). Winter pea has a large seed and is capable of emerging from deep planting depths under marginal seed-zone moisture conditions.

Winter triticale will be planted deep into NTF during the first week of September if seed-zone moisture is adequate. If moisture is not adequate, we will "dust in" the WT in mid- October. Winter triticale yields are much higher than those of winter wheat with late planting (see winter triticale article on page 60). Fertilizer for WT will be applied by stream jet in late fall.

The 2-year WW-TF check treatment will be established using the non-soil-inversion undercutter method, where fertilizer is delivered with the primary-tillage undercutter operation in late spring followed one or two rodweedings during the summer to control Russian thistle and other weeds. Winter wheat will be planted with a deep-furrow drill during the first week of September.

Farmers and researchers in the low-precipitation region of east-central Washington have long been interested in testing no-till cropping systems that are economically competitive with WW-SF. Winter triticale, winter canola, and winter pea have all shown excellent yield potential in this dry environment. Thus, with the use of NTF, the two 4-year rotation sequences hold promise as possible stable, profitable, and ecologically-friendly crop rotations for the low-precipitation zone.

Winter Canola Planting Date Effects on Soil Water Use

MEGAN REESE, BILL PAN, AND BILL SCHILLINGER
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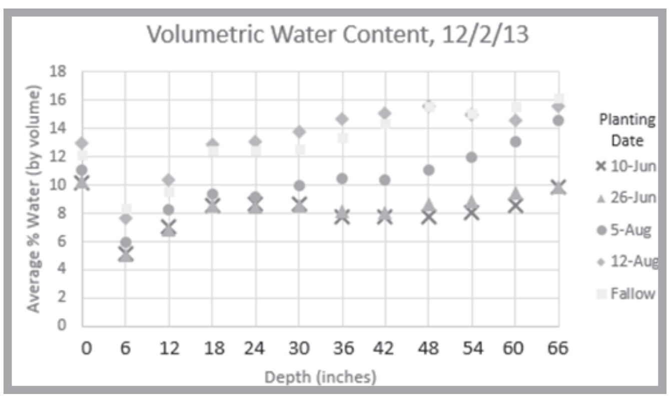
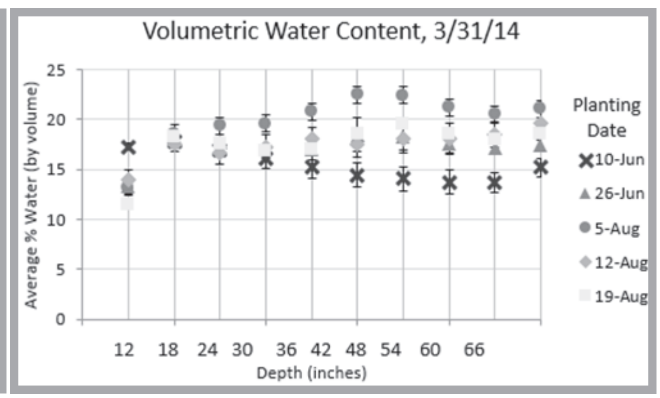
An on-farm winter canola seeding date trial was initiated in June of 2013 near Ritzville. Plots were established on June 10, June 26, August 5, and August 12, 2013, with four replications of each date. Soil available moisture and extraction depths were main focuses of this experiment, monitored down to six feet by neutron probe, gravimetrically-analyzed cores, and continuously-measuring Decagon sensors. There were clear differences in soil water content heading into winter, seen in the graph on the left with measurements taken early December. Soil recharge is also depicted from data in early spring (graph on the right).





However, this season's study has been terminated due to excessive winter-kill. Two sub-zero temperature events, combined with minimal snow cover, likely caused the high mortality. June 10 and June 26 planting dates had a 0% survival rate, while 31% of the August 5 plants survived. The August 12 planting also retained a good and commercially viable spring stand. One potential reason for this differential survival is crown height: the August 12 late planting had no stalks taller than one inch, while the June 10 and 26 plants had stalk heights averaging about four inches. The August 5 planting date was of intermediate height. Shorter crowns benefit more from the thermal storage and radiation of soil, avoid higher wind speeds, and may be more protected by snow.

A second year of this seeding date experiment will begin again this June. Russian thistle and insect ecology components will be examined next season, in addition to the soil moisture and yield data. The ultimate objective of this multi-year experiment is to identify an optimum winter canola planting window in Washington's low rainfall region by: (1) determining canola responses to variable temperature and moisture regimes, and – more specifically – (2) defining water and nitrogen use efficiencies.

Spring Canola in Rotation at WSU Wilke Farm

A.D. ESSER AND D. APPEL
WSU EXTENSION

Spring canola has been incorporated into the 4-year direct seeded crop rotation at the WSU Wilke Research and Extension Farm near Davenport, WA to help control cereal rye infestations, diversify herbicide chemistry and improve profitability. Roundup Ready '*DKL 45-51*' canola was seeded in 2012 into Dark Northern Spring (DNS) residue and yield 1,542 lb/ac. In the 4-year crop rotation, canola had the second largest economic return over costs at $341/ac and was only $12/ac behind hard white spring wheat (HWSW) and $82 and $101/ac better than barley and DNS wheat. Winter wheat and fallow were not included in rotation because of cereal rye. A mixture of three Roundup Ready canola varieties was seeded in 2013 into HSWW residue and yield 1,748 lb/ac. In the 4-year crop rotation, canola had the second largest economic return over costs at $225/ac and was $86/ac less than soft white spring wheat (SWSW) and $51 better than DNS wheat. Consequently, the SWSW was following the 2012 canola crop. Fallow was included in rotation but winter wheat was not included in rotation because of cereal rye. Overall, given current market prices, yield potential and weed species, canola has been economically competitive with cereal grains in rotation.

Feral Rye *(Secale Cereale L.)* Control in Winter Canola *(Brassica Napus)* in the Pacific Northwest

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

Oilseeds in Crop Rotation in the Intermediate Rainfall Zone

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The rotational study at the Beulah Wilke Research Farm near Davenport, WA was initiated in 2011 and is in its fourth cropping season. In total, six rotations are being evaluated for agronomics and economics. Three rotations are being evaluated in a three-year system. WW-SW-NTF represents a typical rotation for the area, while WW-SW-SC and WW-SW-SW allow researchers to evaluate the possibility of replacing fallow with a spring crop, and if there is a rotational benefit to using spring canola instead of spring wheat as the fallow-replacing crop. Three rotations are being evaluated in a four-year system. The conventional rotation is WW-SW-SW-NTF, which is compared to WW-SW-SW-CAM, where the oilseed crop camelina replaces fallow, and to WW-SC-SW-NTF, where fallow is included in the rotation, but a spring wheat crop is replaced by spring canola to calculate its rotational benefit.

Preliminary results from the 2013 harvest indicate that WW in the WW-SW-NTF rotation yielded higher (107 bu/ac) than in rotations where it had followed spring wheat (89 bu/ac), camelina (88 bu/ac), or spring canola (94 bu/ac). While there is a yield loss in the continuous cropping rotations, the economics of these rotations have yet to be analyzed, and will be in the coming year.

Characterization and Decomposition of Residue from Winter and Spring Canola Cultivars

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The residue characteristics and decomposition of spring and winter canola (*Brassica napus* L.) cultivars currently grown in the Pacific Northwest (PNW) was investigated. Above- and below-ground residue was collected post-harvest in 2011 and 2012 from Univ. of Idaho Canola Winter Variety Trials at Odessa, WA (irrigated site), Moscow and Genesee, ID, and Spring Variety Trials at Davenport and Colfax, WA and Moscow, ID. Residue was analyzed for fiber, carbon (C), and nitrogen (N) content, and decomposition in soil. Canola plant components varied in fiber and nutrient content with canola litter (leaves, small stems, pods) having lower neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), C, and C/N, and higher N than the roots and stems (Figure 1; *P*<0.05). Lower NDF, ADF, ADL and C/N along with higher N are indicators of rapid decomposition.

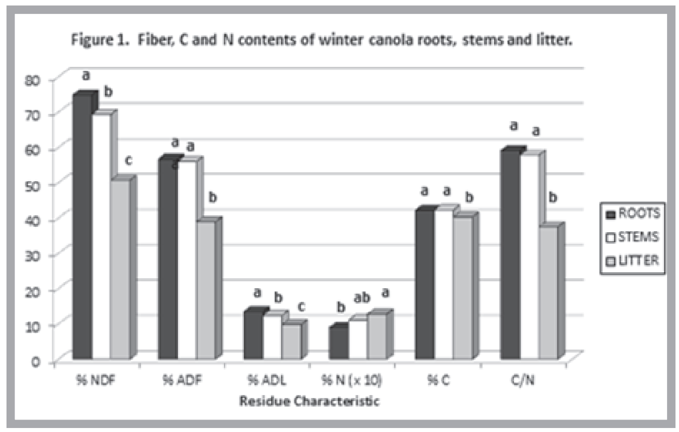

Figure 1. Fiber, C and N contents of winter canola roots, stems and litter.

Winter and spring canola stem, root and litter residue differed from one another in fiber and nutrient content, with winter canola having lower NDF, ADF, ADL, C, C/N, and higher N than spring canola. Because winter canola decomposes more rapidly than spring canola and may be used in crop rotations that include summer fallow, winter canola residue must be managed in order to avoid soil erosion, loss of soil organic matter, and degradation of soil quality. Canola stem residue decomposition in laboratory studies was highly correlated with C/N (Figure 2; *P*<0.05), and was also correlated with NDF and ADF. Buried residue, as in a conventionally tilled system, decomposed more rapidly than surface-placed residue. Residue characteristics varied with growing location, with residue from locations receiving higher precipitation having higher C/N. Residue from lower rainfall locations and winter canola cultivars shows potential to decompose more rapidly. We did not find clear differences in residue characteristics or decomposition among the seven winter and seven spring canola cultivars tested in the study. However, we have shown that decomposition occurs most rapidly when residue contains the least amounts of fiber components, highest N and lowest C/N. As marketing opportunities for oilseed crops produced in the PNW and worldwide increase, information on residue decomposition will be useful to growers who wish to incorporate canola into reduced tillage crop rotations to increase cropping diversity and prevent soil erosion. Additionally, canola residue may be managed for greatest economic success and soil quality benefits in conventional and conservation farming systems.

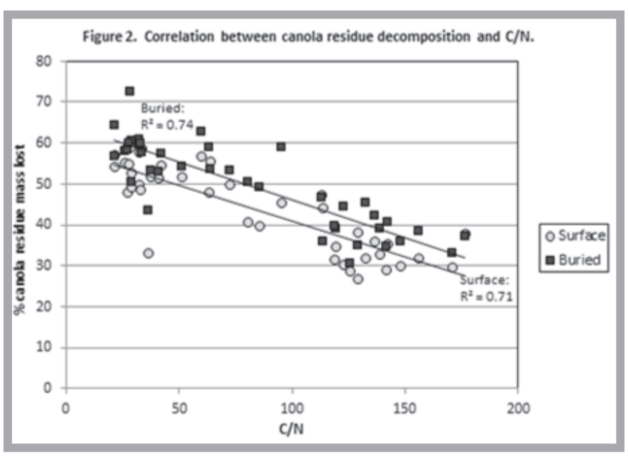

Figure 2. Correlation between canola residue decomposition and C/N.

Management of Fresh Wheat Residue for Irrigated Winter Canola Production

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Winter canola is popular with many irrigated growers as it provides excellent disease control benefits for potatoes grown in rotation. There is a belief among irrigated canola growers that fresh wheat residue must be burned and the soil then heavily tilled before winter canola is planted. These growers are convinced that fresh (i.e., newly harvested) wheat straw is toxic to winter canola. We are conducting a three-year field experiment in a Mr. Schibel's field near Odessa, WA, as well as greenhouse and laboratory tests to: (i) determine how five different winter wheat residue management practices affect the plant health and seed yield of winter canola; (ii) find the cause(s) for any decline in winter canola vigor and seed yield as affected by management of fresh winter wheat residue, and (iii) test methods to retain winter wheat residue without adversely affecting winter canola health and seed yield. Our hypothesis is that fresh wheat stubble is not phytotoxic to canola and that winter canola can be successfully produced in a direct-seed system after wheat harvest as a viable alternative to field burning plus heavy tillage.

Five winter wheat stubble management treatments are established in late August – early September, just prior to planting winter canola. These treatments are: (i) Stubble burned + disked; (ii) stubble chopped + moldboard plowed; (iii) stubble burned, then direct seeded; (iv) direct seeding into standing and undisturbed stubble (Fig. 1 & 2); and (v) winter canola broadcast into the standing (i.e., not yet harvested) wheat crop. Application of irrigation water, which totals 15 inches for the crop year, is managed by Mr. Schibel as part of his normal irrigation schedule for winter canola. No root or foliar diseases were detected in any of the treatments in 2013. Winter canola seed yields in 2013 ranged from 3014 to 3276 lbs/acre with no statistical differences (P=0.40) among treatments.

Figure 1. Plots ready for planting. On the left, the wheat residue has been chopped into short pieces and then moldboard plowed. On the right, wheat residue has been left standing and undisturbed.

Figure 2. Direct seeding winter canola into standing and undisturbed winter wheat stubble. We used a hoe opener no-till drill with 12-inch row spacing and openers staggered on three ranks. This drill was used to plant winter canola in all residue management treatments.

Winter canola stands in all five treatments for the 2014 crop year were excellent. Two sub-zero degree Fahrenheit weather events occurred during the winter of 2013-1014. No snow cover was present during either cold event. All canola plants in the broadcast into the not-yet-harvested wheat and the direct seed into standing and undisturbed wheat stubble were killed during the winter. Winter canola in the other three treatments was damaged, but survived and is doing well this spring. Since there were no root or foliar diseases present in any treatment in the fall of 2013, we feel elongation of the hypocotyl is the likely reason that canola in the two aforementioned treatments was killed likely due to increased crown height. The crown height is important because it is directly related to winter survival. Canola is more likely to be damaged by cold the further the crown is from the soil surface. We will measure hypocotyl length and crown height in all treatments in the fall of 2014.

Determining Optimal Nitrogen Requirements for Dryland Spring Canola Production

TAI MCCLELLAN MAAZ, ASHLEY HAMMAC, AND BILL PAN

Nitrogen (N) fertility recommendations vary widely within canola production regions, including the Pacific Northwest. Canola has a high N uptake efficiency (unit of total plant N per unit of supplied N) but low N utilization efficiency (unit of grain per unit of total plant N) leading to an overall low N use efficiency (NUE) (unit of grain produced per unit of N supplied) compared to wheat. This is partially due to higher protein and denser energy in canola grain (oil) compared to wheat (starch). Results from a six-year N fertility trial in the intermediate and high rainfall zones of eastern Washington indicate that spring canola can root up to 5 ft and efficiently utilize high levels of soil residual N thereby minimizing responses to N fertilizer. Our multiple site and year analysis estimates that 10 lb of N is required for every 100 lb increase in spring grain production. Potential yields were highest in 2013 for spring canola at Wilke Farm in Davenport, WA (269 mm precipitation) at 1,556 lb N per acre, though still unresponsive to additions of N fertilizer. Additionally, in 2013, almost half of the observed yields exceeded the theoretical maximum determined by the Mitscherlich equation. In contrast, the spring canola yield potential was the lowest for the 6-year study at the Palouse Conservation Field Station in Pullman, WA (508 mm precipitation) at 1,036 lb per acre, with the majority of the observed yields at PCFS falling below the theoretical maximum yield. The highest spring canola yield potential in Pullman, WA, was calculated in 2011 at 2,202 lb per ac. According to a net revenue and variable cost analysis, the addition of fertilizer N was again not needed to obtain economic optimal N yields in 2013.

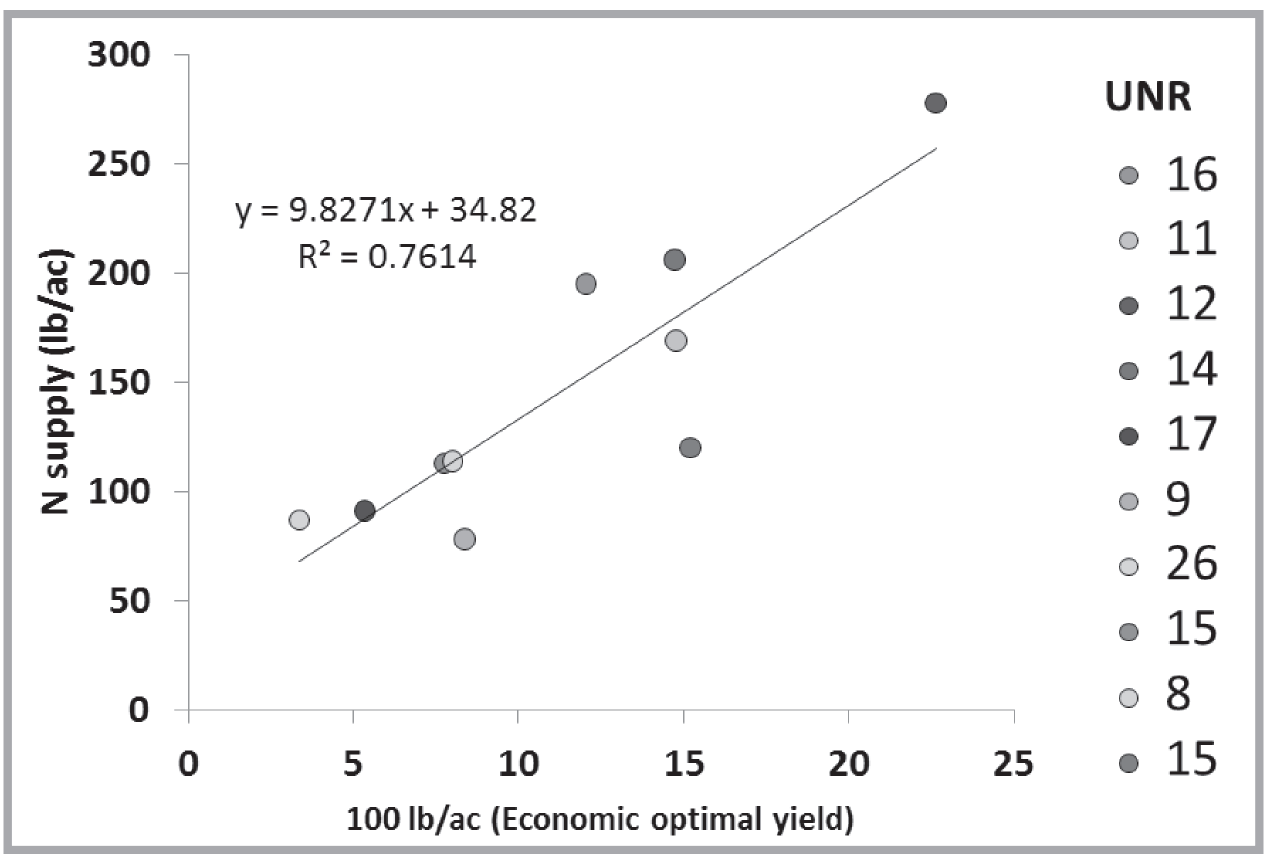

Figure 1. Multiple site-year analysis for response of spring canola yield to N fertilizer additions and N supply.

Carbon and Nitrogen Mineralization from Canola, Wheat, and Pea Residues Differing in Nitrogen Content and Carbohydrate Composition

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Conflicting studies indicate that net N mineralization can either increase or decrease when following canola relative to cereal crops. Understanding decomposition and N mineralization is critical for residue and fertility management within a crop rotation that includes canola under zero-tillage. Interactions between N fertility and biochemistry in the decomposition and N release/retention of various crops requires further study, ultimately to determine whether more or less fertilizer N is needed following canola. In 2013, we collected nine crop residues from canola, wheat, and pea crops with varying N contents and characterized the residues with NMR (Bruker DRX 400 ^{15}N CP/MAS solid state NMR and Varian Vx 400 1H NMR) and elemental analysis for total C and N, solubel and NH_4^+/NO_3^-, and dissolved organic C and N. Proximate fiber analysis (ANKOM 200 sequential fiber digestion) was performed to determine the Neutral detergent fiber (NDF), Acid detergent fiber (ADF), and Acid detergent lignin (ADL) total and step-wise mass and TC/TN determination. We conducted three laboratory experiments examining residue mass and TC and TN losses, weekly CO_2 evolution rates (GRACEnet protocol for gas sampling at 0, 2, 4, and 6 hour deployments), and net N-mineralization rates via destructive sampling for NH_4^+-N and NO_3^--N in a Palouse soil amended with 0.4% residue at over 16 weeks. We found that canola residue, like pea, had a higher proportion of soluble components. Most residue N was easily soluble and not bound up in structural carbohydrates. Dissolved organic N and NDF soluble N was strongly related to the total N content of the residues in all crop residues (R^2 = 0.97 and 0.99). Over the 16 weeks, mass and C losses from canola were similar to pea and wheat, despite differences in biochemistry. Within the first 4 weeks, the average CO_2 mineralization rate was strongly correlated to the readily available fraction of C that was NDF soluble and greatest in soil amended with canola and pea and least in wheat. N dynamics were largely explained by differences in TN, DON, and NDF soluble N with crop residues, with canola and pea residues being more enriched in N on average. However, residues with C:N ratios above 25:1 did not differ in their net N immobilization potential, suggesting overall similarities in quality. However, further research needs to consider the interactive effects of residue quantity and quality on N cycling.

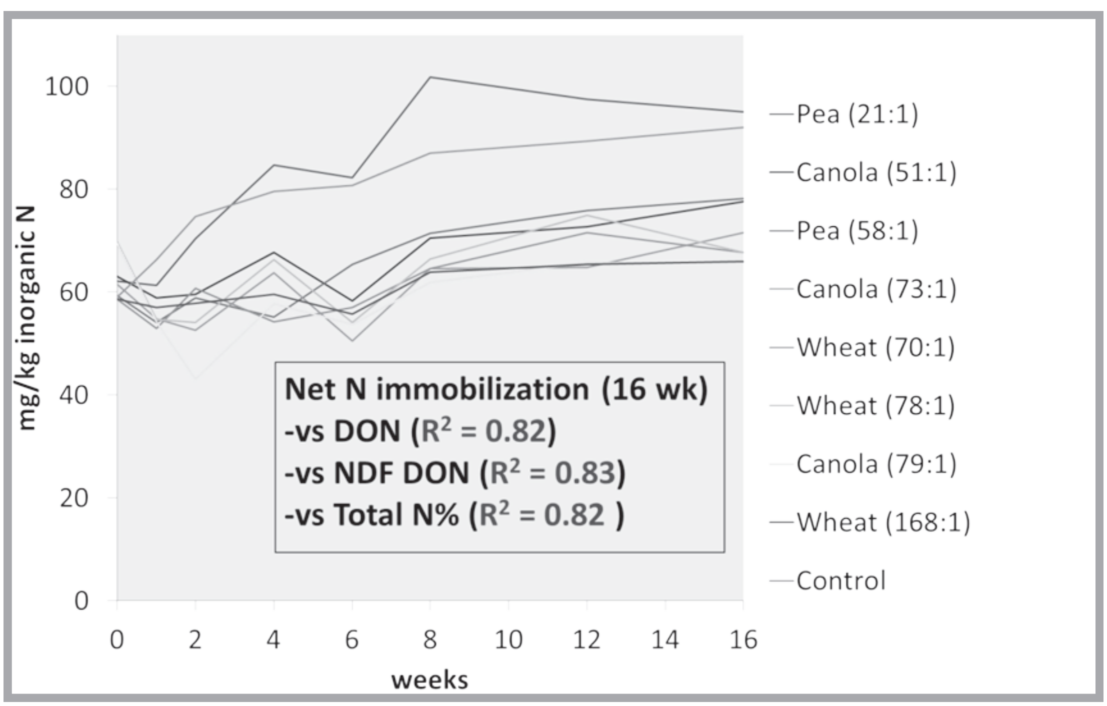

Figure 1. N dynamics following the addition of pea, canola, and wheat residues with variable C:N ratios (in parentheses). Cumulative net N immobilization over a 16-week incubation was correlated to dissolved organic N, neutral detergent fiber soluble N, and total N content. Majority of N in residues is readily soluble.

Manipulating the *AT-Hook Motif Nuclear Localized* (*AHL*) Gene Family for Bigger Camelina 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. The DNA-binding AHL proteins contain two functional units, the AT-hook motif and the PPC domain. Over-expression of one *Arabidopsis thaliana AHL* allele (*sob3-6*), with abolished DNA-binding capacity, leads to a long hypocotyl seedling phenotype with normal adult stature. Similarly, over-expression of the SOB3/AtAHL29 PPC domain alone, as well as alleles with specific mutations in the PPC domain, also confers similar long-hypocotyl seedlings with normal adult stature in *Arabidopsis* (Figure 1). All successful transformants with the long-hypocotyl phenotype also showed increased seed size and weight. We further over-expressed the *Arabidopsis sob3-6* allele in the oilseed crop *Camelina sativa*. These transgenic *Camelina* lines had larger seeds and seedlings with longer hypocotyls than their non-transgenic siblings. These transgenic *Camelina* seedlings can successfully emerge from deep planting in dry soil (Figure 2). These results demonstrate that transgenic manipulation of the *AHL* genes can improve stand establishment in dryland cropping systems. This approach may also be used in non-transgenic breeding strategies that employ specific mutations in members of the *AHL* gene family. We have recently been awarded a USDA/NIFA grant ($498,000/three years) to continue this project. Half of this award is for working with wheat, the other half for *Camelina*.

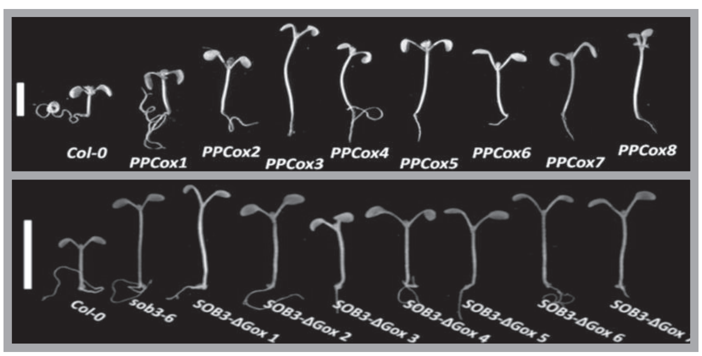

Figure 1. Over-expressing an AHL protein in Arabidopsis lacking the AT-hook domain leads to taller seedlings (top). The same phenotype can be obtained with an AHL protein that lacks six amino acids (bottom). Scale Bars= 1 cm.

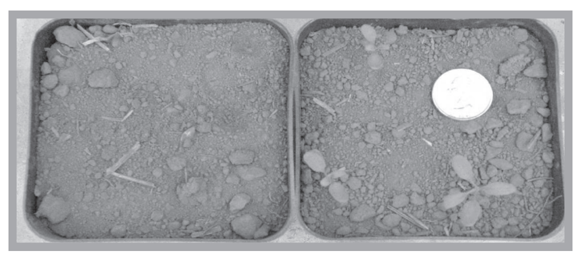

Figure 2. *Camelina* expressing the *sob*3-6 mutation emerge from deep planting in dry soil. Non-transgenic (left) and transgenic (right) seeds were planted on 1 cm of moist Palouse silt/loam and covered with 8 cm of dry silt/loam. All seeds germinated. 5 of 10 transgenic seeds emerged, 3 survived.

Rotational Influence of Spring Grown Brassica Biofuel and Other Crops on Winter Wheat

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

These studies are two year crop sequence studies on eight spring crops (spring wheat, spring barley, dry pea, lentil, camelina, yellow mustard, oriental mustard, and canola) planted in year 1 followed by winter wheat (year 2) grown across all year 1 spring crops. The year 2 winter wheat planted within each of the previous spring crop areas is divided into sub-plots receiving fertilizer rates of 32, 64, 96, 128, 160 lbs N/acre applied in a split-plot, factorial design.

Results and Conclusions from five years of spring crop comparisons:

- Performance variability among spring crop within a year is high and varies over years.
- Some crops, particularly barley and camelina, are more consistent across years.
- Market prices and yields will guide spring crop selection for growers.
- Winter wheat performance following spring crops is best after pea and lentil, followed by brassicas, and both are better than after wheat or barley.
- Wheat fertilizer response is best after legumes followed closely by brassica crops.
- These studies show the tangible rotational benefits attributable to biofuel and other spring crops that are followed by winter wheat.

Results and Conclusions from rotation effect on winter wheat in 2013:

Winter wheat yield, test weight, plant height, and grain protein from 2013 plots following eight previous spring crops are presented in Table 1. Although there were no significant (p=0.05) differences among the previous crops for winter wheat yields, highest yields followed pea and lentil, similar to earlier results that showed that legume crops grown the year pervious increased performance of winter wheat. Protein levels were also highest following spring legume crops. Thus, from an input amount, resource utilization, and food produced per unit of greenhouse gas emissions, the legume crops are standouts from the spring brassica and cereal crops because they do not require N fertilizer, they increased following winter wheat crop yields, and supported higher grain protein in the following crops. In similar experiments, the brassica crops produced higher following winter wheat performance than when winter wheat followed spring wheat or barley. All spring crops, except the grain legumes, received similar amounts of N fertilizer for their growing season. Both yield and protein increased along with increasing N fertilizer rates and the largest responses were in middle increments of N fertilizer rates, 64 to 96 to 128 lb/acre of applied N. Similar to previous results, there was no significant interaction of N rate and previous crop indicating similar N response after all spring crops. The 160 lb/acre N fertilizer rate did not increase yields compared to the 128 lb/acre rate, but did increase grain protein.

Previous Spring Crop	Wheat Yield	Test wt.	Height	Protein
	bu/acre	lb/bu	inches	%
Spring Wheat	80	61.3	28	11.0
Spring Barley	85	61.5	29	10.8
Dry Pea	92	61.8	29	11.5
Lentil	89	61.9	29	11.3
Camelina	80	61.9	30	10.5
Yellow Mustard	84	61.7	29	10.3
Oriental Mustard	86	61.8	30	10.9
Canola	79	61.9	29	11.0
Average	84	61.7	29	10.9
LSD (0.05)	n.s.	0.4	1	0.8

N Fertilizer Rate (lbs/acre)	Seed Yield	Test wt.	Height	Protein
	bu/acre	lb/bu	inches	%
32	80	61.6	29	10.3
64	81	61.8	29	10.6
96	85	61.9	29	10.8
128	89	61.7	30	11.3
160	88	61.7	30	11.5
Average	84	61.7	29	10.9
LSD (0.05)	3	n.s.	1	0.2

USDA-ARS Pea and Lentil Breeding Programs

REBECCA MCGEE AND JARROD PFAFF
USDA-ARS

WSU is home to the USDA-ARS Grain Legume Genetics and Pathology Unit, a national legume development program of international renown. 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 the human diets – they are high in protein and fiber, low in fat and have a low glycemic index.

The objectives of the spring pea breeding program are to develop adapted varieties of green or yellow peas with increased yield and improved levels of resistance to locally important diseases caused by soil borne fungal pathogens, foliar fungal pathogens and viruses. We have Fusarium wilt race 1 and Aphanomyces root rot nurseries at the Spillman Research Farm. We screen peas and lentils 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. 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 disease resistance at Spillman and the OSU Research Farm.

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, 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.

Winter Pea Crop Rotation Study at Ritzville

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[1]DEPT. OF CROP AND SOIL SCIENCES, WSU, LIND; [2]FARMER COOPERATOR, RITZVILLE

A long term winter pea (WP) cropping systems experiment was initiated at the Ron Jirava farm near Ritzville in the summer of 2010. The objective of the experiment is to determine the suitability of winter pea in the low-precipitation zone where winter wheat–summer fallow (WW-SF) has been the dominant rotation for well over 100 years.

The WP variety “Windham” was selected for inclusion in the experiment based on the experience and recommendation of Howard Nelson of Central Washington Grain Growers at Wilbur. Windham is a feed pea with upright growth habit and good cold tolerance. It can be direct combined with a regular header (i.e., swathing and/or a pick-up header not required). Winter pea has a large seed that is capable of emerging through five inches of soil cover.

Two 3-year crop rotations are tested in the experiment: (i) WP-spring wheat (SW)-SF versus (ii) WW-SW-SF. Experimental design is a randomized complete block with four replicates of each treatment. All treatment combinations are present each year, making a total of 24 plots. All plots are 100 feet long.

Yield of Windham WP was 1958, 2820, and 2086 lbs/acre in 2011, 2012, and 2013, respectively, for three-year average yield of 2288 lbs/acre. Spring wheat yield after WP versus WW was 30 and 32 bu/acre in 2012 and 44 versus 40 bu/acre in 2013 (Table 1).

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

We will continue this experiment until at least 2017. The WP in this experiment was killed by cold during the winter of 2013-2014, so we replanted these plots to the edible "Banner" spring pea on April 3. Winter pea has shown high yield potential in this experiment where average annual precipitation is only 11 inches. See a related article on page 50 for information on a new study initiated in 2014, where we are growing WP in a 4-year no-till crop rotation at this same location.

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

	Timing in fallow period				
	Beginning (Aug.)	Spring (late Mar.)	Over-winter Gain	PSE† (%)	Grain yield (bu/acre)
	Soil water content (inches)				
			A. 2012-2013		
Rotation					
SW after WP†† in 3-yr rotation	7.4	12.6	5.2	62	44
SW after WW††† in 3-yr rotation	6.4	12.5	6.1	73	40
p-value	0.03	ns	ns		0.01
			B. 2011-2012		
Rotation					
SW after WP in 3-yr rotation	6.8	8.2	1.4	34	30
SW after WW in 3-yr rotation	5.3	8.4	3.1	75	32
p-value	0.01	ns	0.02		ns

† 2011-2012 overwinter precip. = 4.11"; 2012-2013 overwinter precip. = 8.33".
†† Winter pea yields for 2011, 2012 and 2013 were 1958, 2820 and 2086 lbs/A , respectively.
††† Winter wheat yields for 2011, 2012 and 2013 were77, 85 and 87 bu/A, respectively.

Late-Planted Winter Triticale Produces Equal Grain Yield as Early-Planted Winter Wheat in the Dry Region

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Triticale is a cross of wheat x rye that is used as a feed grain. Although triticale has been produced on a small scale for several years, it has not been widely grown in eastern Washington due to the historically low market price of feed grains compared to wheat. Feed grain prices have increased in recent years. Beginning in the fall of 2010, winter triticale was incorporated into the long-term cropping systems experiment on the Ron Jirava farm near Ritzville. We had discovered through previous experimentation that winter triticale does considerably better than winter wheat from late (mid October or later) planting and thought that triticale might be a good fit for no-till summer fallow. Early planting into no-till fallow in late August-early September is generally not feasible in the low-precipitation zone due to lack of seed-zone moisture. We plant winter triticale at the Jirava study into no-till fallow.

The 2011, 2012, and 2013 crop years at Ritzville were considerably wetter than normal. Heavy region-wide rain events exceeding one inch occurred during July or August during these years; this being highly unusual. Due to abundant precipitation, there was adequate seed-zone soil moisture for early planting in no-till fallow, so we planted half of each triticale (variety Trimark 099) plot early (first week of September) and the other half late (mid-October). Winter wheat (variety Xerpha) was planted into tilled summer during the first week of September on the same date as the early-planted winter triticale. Fertilizer and herbicide inputs were the same for all treatments. Seeding rate for early-planted winter triticale and winter wheat was 40 lbs/acre and for late-planted winter triticale 60 lbs/acre.

Over the three crop years, late-planted winter triticale grain yield averaged 4149 lbs/acre and early- planted winter wheat 71 bushels (4260 lbs/acre); these yields being statistically equal (Fig. 1). Early-planted winter triticale grain yield averaged 5225 lbs/acre which significantly exceeded the average yield of early-planted winter (Figure 1).

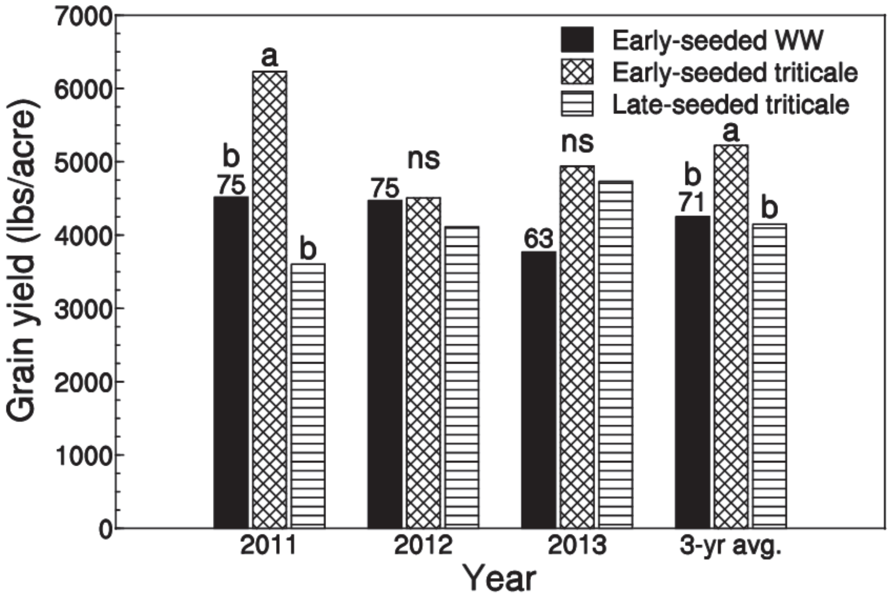

Figure 1. Grain yield of both early and late planted 'TriMark 099' winter triticale planted into no-till summer fallow versus early-planted 'Xerpha' soft white winter wheat in a long-term cropping systems experiment near Ritzville, WA. Within-year grain yields followed by a different letter are significantly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

The price a grower would receive for triticale today (April 23, 2014) in Wilbur, WA is $154 per ton versus $6.77 per bushel for soft white wheat. Therefore, the 71 bushels of soft white wheat is worth $481 per acre and the early and late-planted winter triticale is worth $402 and $319 per acre, respectively. In several recent years, growers could sell triticale for more than $200 per ton.

Long-term research in the low-precipitation wheat-fallow zone of eastern Washington has conclusively documented that late-planted winter wheat produces, on average, 36% less grain yield compared to early planted winter wheat. Our research shows that late-planted winter triticale produces equal yield as early-planted winter wheat. Additionally, early-planted winter triticale produces significantly greater grain yield than winter wheat planted on the same date (Figure 1). 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. 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, thus it is a good choice for soils prone to wind erosion.

Winter Faba Bean: A Promising New Pulse Crop for Washington State

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Since 2010 Northern European winter faba bean (*Vicia faba* L.) genotypes have been selected for winter-hardiness at three locations [Central Ferry (CF) Research Farm, Pomeroy, WA; Spillman (SP) Agronomy Farm, Pullman, WA; Whitlow

Farm (WO), Pullman, WA] in southeastern Washington. A variety trial testing the effect of two planting dates was conducted for two seasons in 2011-2 and 2012-3 (Table 1). Overwintering survival and yield were influenced by autumn planting and emergence dates, as well as winter low temperatures. The winter low at CF was -6ºC for both seasons, whereas the two sites at Pullman were colder; -12ºC over the 2011-2 and -14ºC over the 2012-3 winters. In both years, the second planting at the CF location improved survival, whereas the first planting was only slightly more appropriate at the Pullman locations (Table 1). Providing a longer establishment period (2-3 dormant nodes) prior to the first hard frost (<-3 ºC) should optimize hardiness and yield potential. However, where late season aphid-virus pressure is an issue later plantings are advised. The virus mediated reduction in % survival of the early planting at CF in 2012-3 was largely overcome by the later planting. Across much of eastern Washington, the availability of autumn soil moisture and temperature will determine the planting window of winter faba bean, but October 1 is generally recommended for the region.

Table 1: Mean percent survival over winter, plot yield extrapolated to t ha^{-1}, and yield per plant by planting date across 20 autumn planted faba bean entries at three locations (Central Ferry (CF) Research Farm, Pomeroy, WA; Spillman (SP) Agronomy Farm, Pullman, WA; Whitlow Farm (WO), Pullman, WA) for two seasons (2011-2 and 2012-3). Standard errors (SE) separate means ($\alpha<0.05$).

	CF 2011-2		CF 2012-3		WO 2011-2		WO 2012-3		SP 2011-2		SP 2012-3		SE
Planting date	30 Sept.	14 Oct.	28 Sept.	12 Oct.	29 Sept.	13 Oct.	25 Sept.	10 Oct.	7 Oct.	21 Oct.	5 Oct.	19 Oct.	
Survival (%)	82.9	85.2	59.1	72.1	62	55	60.6	55.9	55.5	52.6	70.8	36.9	1.4
t ha^{-1}	5.96	6.62	0.75	2.07	4.52	3.71	1.96	1.85	2.52	2.45	0.88	0.90	0.12
g plant^{-1}	66	57.2	7.7	26	49.6	47.5	15.9	17	32.6	29.9	6.6	7.2	1.5

There was no one variety that stood out across all site years. However, many of the selections exceeded 70% survival compared to the unselected check, which averaged 30%. Plot yields ranged from over 8t ha^{-1} to less than 1t ha^{-1}. The two cultivars Côte d'Or and Striker were among the most winter hardy, but had lower branch numbers and per plant pod counts resulting in a loss of yield potential, when compared to Hiverna a less hardy, but higher branching and pod number entry (Table 2). Yield is suspected to be the result of not only planting date but morphological (number of pods, branches, and height), biotic (insect, pathogen, weed, and virus pressure), and abiotic (temperature and moisture stress) effects and their interaction with the genotype of interest. Continued selection for winter-hardy high yielding genotypes would reduce the risk of growing winter faba bean in Washington.

Table 2: Percent survival over winter, number of branches per plant at harvest, pod number per plant, yield per plant, and plot yield extrapolated to t ha^{-1} for three of 20 autumn planted faba bean entries across three locations and two seasons. Standard errors (SE) separate entry means ($\alpha<0.05$).

ENTRY	SURVIVAL (%)	BRANCHES AT HARVEST	POD PLANT^{-1}	YIELD PLANT^{-1} (G)	PLOT YIELD (T HA^{-1})
CÔTE D'OR	73.3	3.1	31.5	26.9	2.95
STRIKER	73.8	2.7	28.3	26.9	3.00
HIVERNA	65.8	3.5	36.5	35.5	3.34
SE	*1.8*	*0.1*	*2.1*	*1.8*	*0.19*

Part 4. Pathology

Distribution of Rhizoctonia Bare Patch and Root Rot in Eastern Washington and Relation to Climatic Variables

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USDA-ARS, ROOT DISEASE AND BIOLOGICAL CONTROL RESEARCH UNIT, WSU

Rhizoctonia is a fungus that attacks the roots of wheat and barley, causing a root rot and bare patch in the dryland wheat cropping area of the inland Pacific Northwest. Over the last 7 years, we have been investigating the distribution of this pathogen, using molecular methods based on extracting and quantifying DNA from soil. We want to answer the questions- where and how much fungus is present? From 2006 to 2008, we sampled 11 grower fields and 60 WA variety testing plots. What have we discovered about the distribution of this pathogen and disease? With *Rhizoctonia solani* AG-8, we tend to find higher populations in the lower precipitation areas, especially those having sandier soils. Figure 1 shows a map of these sampling sites. The square and star symbols show sites with higher levels of DNA in the soil, compared to the triangles and circles. The populations tend to be lower in the Palouse of eastern Washington, where we typically do not see bare patch, but find uneven stands and root rot. When we look at the correlations between populations of *R. solani* AG-8 and precipitation, we find a negative relationship- the higher populations (greater DNA quantities) are seen in lower precipitation areas, and lower populations in higher precipitation areas (Figure 2).

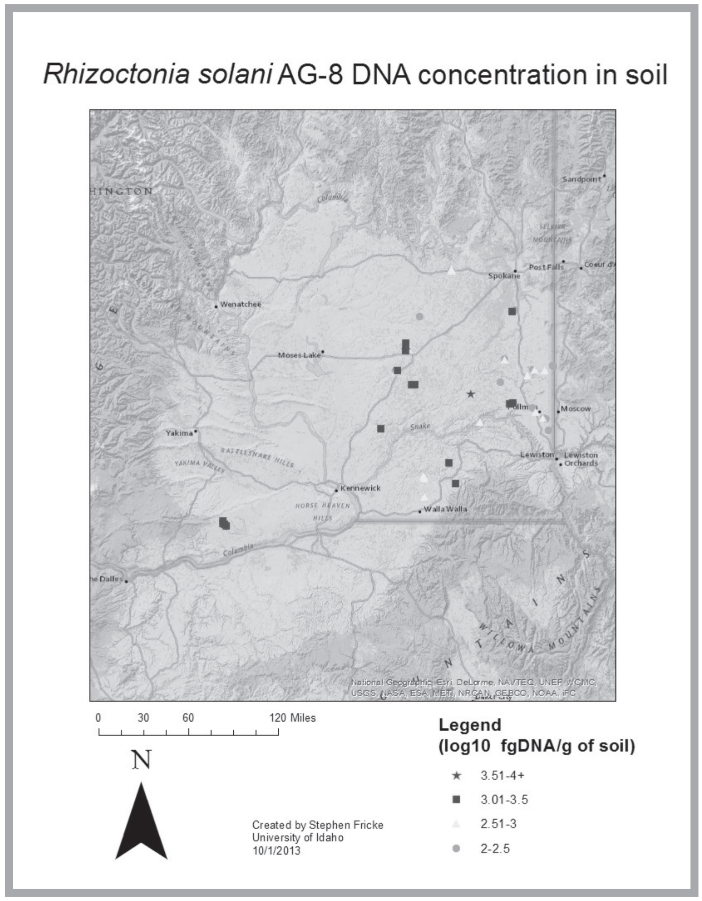

Figure 1

The DNA values are on a log scale, so the sites in the low (200 mm) precipitation areas may have 10 to 100 times more DNA than sites in the 600 mm zones. This distribution agrees with the observation that bare patch is more widespread in the Ritzville/ Connell and Walla Walla-Dayton area than in the higher precipitation zones.

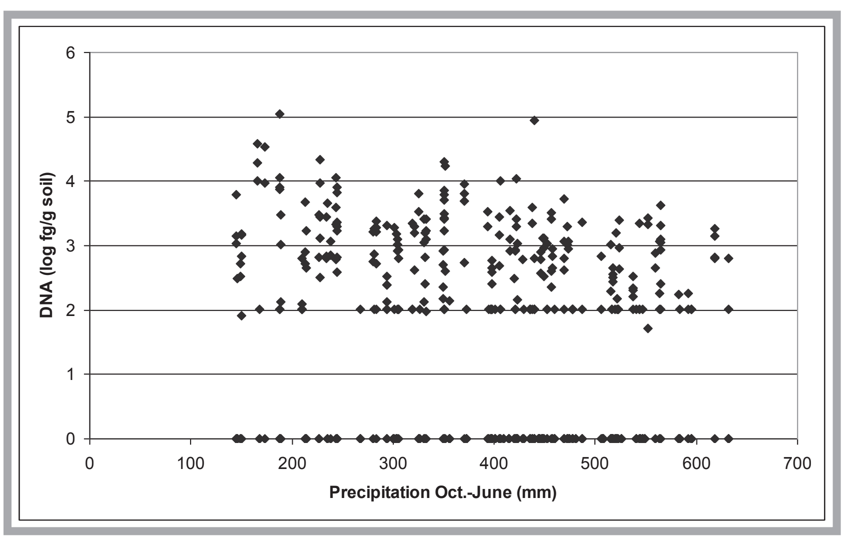

Figure 2

Soil Amendments with Green Manure Improve Soil Health and Reduce Verticillium Wilt in Potato

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Considering yield losses and complexity of management, potato early dying is the most economically damaging disease complex in potato. Verticillium wilt is a major component of potato early dying caused either by *Verticillium dahliae* or *Verticillium albo-atrum*. Both species are soilborne fungi that invade xylem elements, disrupt water transport in plants and cause vascular wilt. Pre-plant treatment of potato fields with the soil fumigant like metam sodium and telone is generally used to control this disease. These fumigants are environmentally undesirable and expensive. Due to environmental hazards and workers safety, these fumigants are increasingly being restricted and monitored by EPA. Also, there is increased interest of farmers towards improving soil quality and health. Consequently, new management tactics are necessary. Green manures are being scrutinized as potential alternatives to chemical fumigants. A micro-plot field study in Pullman, Washington evaluated the effects of various green manures on soil health and incidence of *Verticillium dahliae*, and potato yield. Green manuring is the tilling of fresh plant material into soil to improve the soil health and benefit the subsequent crop. Although the use of green manures is an old practice, most farmers have replaced green manuring with the use of synthetic chemicals over the past century. This study consists of nine treatments, which include spring wheat followed by fumigation (SW-Fum), spring wheat -no fumigation (SW-No Fum), spring wheat-barley green manure (SW-BGM), spring wheat-high glucosinolate mustard *B.juncea* (SW-high M), spring wheat-low glucosinolate mustard *B. napus* (SW-low M), barley green manure (BGM X3), high glucosinolate mustard *B. juncea* (high M X3), low glucosinolate mustard *B. napus* (low M X3); and Dale Gies soil (long time mustard green manure practitioner) (DG soil). Potato cultivar Russet Norkotah was grown and nitrogen fertilizer was applied for agronomic growth. Soil microbial activity, potentially available nitrogen, and water holding capacity as well as incidence of *Verticillium dahliae* and potato yield were analyzed following standard laboratory procedures.

The preliminary results revealed that soil dehydrogenase activity, an indicator of total microbial activity, was significantly greater in SW-BGM and high M X3 compared to SW-No Fum (Table 1) and there were no significant differences among other treatments. The mineralizable nitrogen which represents potentially available nitrogen was significantly greater in high M X3 and low M X3 compared to SW-Fum, SW-No Fum and DG soil during a short 7 day incubation. With a longer 28 day incubation, the N potentially available in SW-NoFum was significantly lower compared to all other treatments. In fact, potentially available N decreased in in this SW-No Fum treatment. The N released was higher in DG soil in 28 days incubation compared to other treatments. The water holding capacity was significantly lower in SW-Fum and SW-NoFum micro-plots compared to other treatments (table 1), indicating that all green manure treatments improved water holding capacity.

Table 1. Dehydrogenase enzyme activity and potentially available nitrogen as affected by study treatments

Treatment	Dehydrogenase activity (ug TPF g^{-1} soil)	Potentially Available N (ug NH_4-N g^{-1} soil)		Water holding capacity
		7-day incubation	28-day incubation	
SW-Fum	0.99bc	18.74cd	31.32a	0.231b
SW –No Fum	0.94c	22.84c	21.51b	0.211b
SW-BGM	1.63ab	32.10ab	29.62a	0.320a
SW-high M	1.07bc	26.96bc	37.86a	0.320a
SW-low M	1.29abc	29.08bc	38.02a	0.321a
BGM x3	1.07bc	34.64ab	37.92a	0.322a
High-M x3	1.75a	38.79a	35.95a	0.304a
Low-M x3	1.01bc	32.13ab	32.68a	0.322a
DG soil	1.24abc	14.05d	29.17a	0.331a

Data followed by same letter within a column were not significantly different (p<0.1)

The incidence of *Verticillium dahliae* in potato tubers was significantly higher in DG soil and significantly lower in high M X3. But there was not direct effect of tuber incidence on tuber yield. The potato tuber yield was significantly higher in low M X3 followed by B X3 and SW-Fum and it was significantly lower in SW-NoFum as expected (Table 2). The potato yield was generally more affected by incidence and severity of *V. dahliae* in stems. This indicates that both high-glucosinolate and low glucosinolate mustards benefited potatoes in some way.

Table 2. The incidence of *Verticillium dahliae* in progeny tubers and tuber yield as affected by treatments

Treatment	*V. dahliae* incidence	Tuber yield (g micro-plot^{-1})
SW-Fum	0.3600b	874.8a
SW –No Fum	0.3425bc	399.5c
SW-BGM	0.3575b	787.3ab
SW-high M	0.2875bc	597.8bc
SW-low M	0.3950b	828.5ab
BGM x3	0.3275bc	963.3a
High-M x3	0.1050c	751.0ab
Low-M x3	0.2500bc	999.5a
DG soil	0.6775a	788.3ab

Data followed by same letter within a column were not significantly different ($p<0.1$)

Green manures and other organic amendments can also provide benefits to farming systems in general, including maintenance of soil cover and soil integrity, soil sanitization, reduced erosion, greater soil organic matter, and soil structural improvements that improve water penetration. These improvements to crop nutrition and water relationships may also improve disease tolerance regardless of changes in soil microbial communities. More overall microbial activity and available organic nitrogen may thereby improve soil quality and in turn the plant itself. The nature of results of green manure soil amendments observed in this study support the hypothesis that these organic soil amendments enhance soil health and will help to suppress soil pathogens. To conclude, the both high and low glucosinolate brassica green manure and wheat-barley green manure showed good potential to enhance soil health and subsequent reduction of verticillium wilt. Ongoing works in this project include detailed pathogen study and comparison of two years data. Another mini study in this project includes soil and plant analysis for nitrogen re-uptake study.

Control of Rusts of Wheat and Barley in 2013

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In 2013, stripe rust was accurately forecasted using prediction models. Rust updates and advises were provided on time to growers for implementing the early disease management based on the forecasts and field surveys, which prevented wheat yield loss of millions of bushels and also prevented unnecessary use of fungicides. Wheat stripe rust occurred at the low end of the severe epidemic level assessed based on a four-level scale, low (less than 20%), moderate (20-40%), severe (more than 40% to 60%), and extremely severe (more than 60% yield loss on susceptible cultivars). Barley stripe rust, wheat leaf rust, and stem rust of wheat and barley occurred at insignificant levels, while barley leaf rust was severe in northwestern Washington. From 481 stripe rust samples collected from 28 states, we identified 34 races of the wheat stripe rust pathogen and 6 races of the barley stripe rust pathogen, and determined their distributions and frequencies. We developed 97 single-nucleotide polymorphism (SNP) markers, and determined genetic relationships of wheat stripe rust populations in various regions in the U.S. using the markers. We evaluated more than 20,000 wheat and barley entries for resistance to stripe rust; and collaborated with breeders in releasing or pre-releasing three wheat and two barley varieties and registered nine wheat varieties. We published the discoveries of new stripe rust resistance genes *Yr59* and *Yr62* with molecular markers in wheat germplasm; mapped five quantitative trait loci for high-temperature adult-plant resistance and all-stage resistance in spring wheat germplasm PI 182103; and developed ten mapping populations for identifying more resistance genes in wheat germplasm. We tested 33 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 major currently grown varieties are used for guiding rust management.

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

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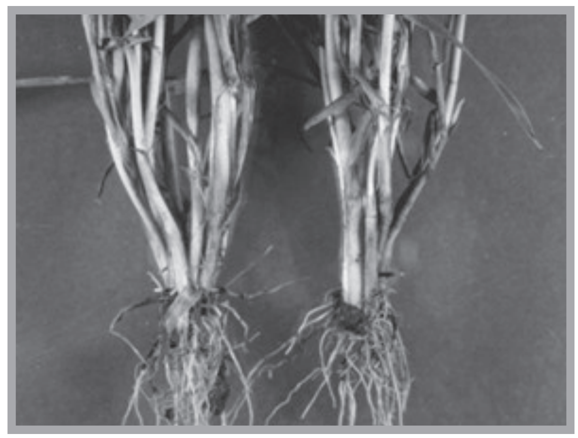
Eyespot (strawbreaker foot rot) and Cephalosporium stripe are important diseases of winter wheat in the Pacific Northwest. These diseases occur across a wide range of the wheat-producing area and have potential to cause loss in grain yield up to 50% for eyespot and 80% or more for Cephalosporium stripe. Early-seeded winter wheat is at the greatest risk of being affected by these diseases, especially when planted following summer fallow. Planting an eyespot-resistant variety is the best control, although fungicide application in spring is still important in some areas. Our research focuses on identifying new and effective resistance genes to both of these diseases. As part of that research, we test new varieties and advanced breeding lines from both public and private breeding programs for eyespot and Cephalosporium stripe resistance each year. Results of our field trial data are available on the WSU Wheat and Small Grains website (http://smallgrains.wsu.edu/disease-resources/research-reports/). We also provide ratings of varieties in the Washington State Crop Improvement Winter Wheat Certified Seed Buying Guide (http://washingtoncrop.com). Several varieties have 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 Cephalsporium stripe doesn't occur in wheat, but several varieties are tolerant including: Eltan, Bruehl, Coda, Masami, ORCF-102, Tubbs 06, WB 528, and Xerpha.



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

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

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.

Soilborne wheat mosaic (SBWM) is a new problem for Washington wheat growers that was first recognized in the Walla Walla area in 2008, but is a chronic problem in other wheat-producing areas of the U.S. SBWM is caused by a virus that is transmitted by a fungal-like organism that lives in soil. Roots are infected in the fall and symptoms appear in early spring. Because the virus lives in soil, the disease occurs in the same spots within fields each year and can be moved with soil on farm implements, shoes, or tires. So far, the problem is limited to the Walla Walla area and adjacent counties in Oregon. Planting a resistant variety is the best control, but little is known about our varieties. We are collaborating with the Oregon State University Variety Testing program to screen PNW wheat varieties for resistance in field plots near Hermiston, OR. A few varieties from the PNW have good resistance, with the hard wheats having better resistance than the soft wheats. Among soft white winter varieties, SY Ovation, Ladd, and ORCF-103 were most resistant. Among the hard wheats, Genesis, Whetstone, and AP 503 CL2 were most resistant andWB-Arrowhead, Keldin, DAS 001, IDO 1101, and OR2100081H have intermediate resistance. Variety ratings are available on the WSU Wheat and Small Grains website.

Yellow patches of Soilborne wheat mosaic in a field.

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

Weed-Suppressive Bacteria to Reduce Annual Grass Weeds

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Cheatgrass (*Bromus tectorum* L.), medusahead (*Taeniatherum caput-medusae* [L.] Nevski) and jointed goatgrass (*Aegilops cylindrica* L.) are exotic, annual grass species that negatively affect cereal production in cropland, reduce protein-rich forage for cattle; choke out native plants in the shrub-steppe habitat of the western United States rangeland; reduce habitat for sagebrush-dependent wildlife; and increase fire frequency of these lands. These three weeds are responsible for wildfires that destroy property and result in loss of life. Naturally occurring bacteria from the soil and root surface have been found to inhibit these invasive weeds.

These weed-suppressive bacteria:

- are applied in the fall and establish in the soil microbial community as weather cools;
- inhibit radicle formation, root growth and tiller initiation of these weeds;
- do not injure native plants or crops;
- grow well in fall and spring during the early root growth of the annual weeds; and
- grow along roots, which then deliver the weed-inhibitory compound.

Certain soil bacteria, *Pseudomonas fluorescens* strains, inhibit only:

- cheatgrass (downy brome),
- medusahead,
- jointed goatgrass, and
- do not inhibit any economically important or native plants.

Replicated field plots ($3m^2$ to 10A size) across many different years and locations across the west have been established and monitored. The bacteria consistently reduce annual grass weed growth by 50% within three years of one bacterial application. In long-term field trials in the western US, the bacteria reduced these fall annual grass weeds to near zero, when desirable plants (winter wheat, perennial bunchgrasses, natives) were present. The bacteria have the potential to also reduce the weed seed bank over time. Additional applications of the bacteria may be needed in 3 to 6 years, if weed seed is transported onto the site.

With the reduction of annual grass weeds, other plant species are more competitive. The bacteria suppress weed roots at a time when the weed is increasing its competitive root growth. These bacteria provide a novel means to reduce invasive weeds while potentially limiting the need for tillage and herbicides for weed control. Because of their selectivity, these bacteria can be used in management of the invasive weeds cheatgrass, medusahead and jointed goat grass in rangeland, cropland, pasture, turf, sod production, golf courses, road sides and road cuts, construction sites, and right-of -ways (road, rail, pipeline, electrical). The bacteria can be integrated into weed-management plans for croplands using both spray and seed coat technologies. We are developing rangeland restoration plans that include the bacteria. We are investigating bacteria that suppress other weeds such as wild oats, Ventenata, bulbous bluegrass, rattail fescue, annual bluegrass, and several other emerging annual grass weeds.

Screening Locally Adapted Spring Wheat Lines for Resistance to Cereal Cyst Nematode

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Cereal cyst nematode (*Heterodera avenae*) has become an increasing problem in the high precipitation areas of eastern Washington and the Palouse. Since 2010, surveys have discovered serious infestations of this nematode, which infects wheat, barley and grassy weeds. It causes severe yield loss, restricted root growth, stunting and the formation of whiteheads. There are no chemical controls or nematicides registered for wheat, and crop rotation with a non-host, such as a legume is not effective over the long run because the eggs are protected by cysts which can survive in the soil for many years in the absence of a host. The best long-term solution is the use of major gene resistance, called *Cre* genes. Many of these genes have been identified and deployed around the world, especially in Australia. These genes can prevent reproduction by the females on the roots. We wanted to determine if there was already resistance in locally adapted lines, which could then be used to introgress the genes into new WA varieties. For the past two years, we have screened adapted lines in a field infested with cereal cyst nematode near Colton, WA. Lines 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. Plants were harvested in late June and the number of white female cysts visible on the roots were assessed. In 2013, we screened 83 adapted lines from the Western Spring Regional Nursery. We identified 4 lines with resistance- UC 1711, AUBR3059W, SY Steelhead (= SY 97621-05), and WA 8163. UC 1711 and SY Steelhead also showed resistance in our 2012 trial. In addition, another 5 lines showed intermediate resistance. We will continue this screening in 2014, and are trying to develop a greenhouse screening method using infested field soil.

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