

2012 Dryland Field Day Abstracts

HIGHLIGHTS OF RESEARCH PROGRESS



Dedicated to Dr. Steven E. Ulrich



WASHINGTON STATE UNIVERSITY
EXTENSION

Department of Crop and Soil Sciences
Technical Report 12-1

WSU Dryland Research Station Field Day—Lind, June 14, 2012
WSU Wilke Farm Field Day—Davenport, June 20, 2012

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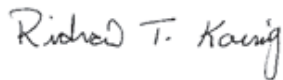
Welcome to our 2012 Field Days!

As Chairman of the Department of Crop and Soil Sciences, I am proud to present the **2012 Dryland Field Day Abstracts: Highlights of Research Progress**. This publication is intended to introduce you to the numerous research projects conducted by WSU faculty and USDA-ARS research scientists working as part of, or in cooperation with, the Department of Crop and Soil Sciences. To learn more about the Department please visit us on the web at www.css.wsu.edu. There you'll find information about faculty members and research programs in the Department.

We are engaged in many research activities of local, regional and national importance. Our 2012 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 and grain legume growers of the state of Washington and the related agriculture industries that support them. Your generous contributions have allowed us to develop an extraordinarily strong research base with products like plant varieties and knowledge you use every day in your farming operation.

This edition of the Dryland Field Day Abstracts is dedicated to Dr. Steve Ullrich, former barley breeder and now Professor Emeritus in the Department, who epitomized the vision of Crop and Soil Sciences to be leaders in scientific exploration, teaching and extension of plant and soil sciences, throughout his 33-year career at Washington State University. Dr. Ullrich retired in 2011 and his presence will be missed by students, faculty and staff in the department, as well as the eastern Washington farming community.

Sincerely,



Dr. Richard T. Koenig, Chair
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2012 Dryland Field Day
Abstracts:
Highlights of
Research Progress

Technical Report 12-1
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Cover photos: Photo on left:
Steven Ullrich addresses the crowd
about the Barley Program at the
Spillman Farm Field Day in 2009.
Photo by Vadim Jitkov.

Cover photos: Top right:
Harvesting winter wheat WSU vari-
ety test plots near Pullman, WA.
Bottom right: Chickpea, lentil, and
dry pea variety test plots near
Farmington, WA .
Photos by Stephen Guy.

Dedication to Dr. Steven E. Ullrich, Professor Emeritus

Steve Ullrich retired March 31, 2011 after 33 years of research, teaching, and service in the Department of Crop and Soil Sciences at Washington State University at Pullman.

Steve grew up in southern Wisconsin in the heart of America's Dairyland. Although he was not raised on a farm, he worked on a dairy farm throughout his teen years. He came to appreciate biology in the natural and agricultural worlds, which led him on a circuitous route landing at WSU in 1978. After graduating from high school in 1964, he received a B.S. degree from the University of Michigan in 1968; served with his wife, Mary, in the U.S. Peace Corps in Malawi in southern Africa, 1968-1970; received an M.S. degree from the University of Idaho in 1972; taught biological sciences at Fox Valley Technical Institute in Appleton, WI, 1972-1974; and received a Ph.D. degree at Montana State University in 1978 under the mentorship of 'Barley Bob' Eslick (native of Dayton, WA). His dissertation research was on genetics and breeding of high lysine barley.



Steve came to WSU to teach lower division Crops courses and research oilseed crops, which were hot commodities in the PNW in the late 1970's and early 1980's. He also came with the hope of eventually moving into the barley breeding and genetics position,



Bob Nilan and Steve Ullrich at the 2009 Spillman Farm Field Day admiring the cultivar Bob, named after Bob Nilan and Bob Eslick both world renowned barley geneticists and breeders at WSU and Montana State University, respectively.

Photo by Vadim Jitkov.

held by 'Barley Bob' Nilan. The barley program position opened unexpectedly in 1980, with the appointment of Bob Nilan as the WSU Dean of Sciences. He began transitioning into the barley program during the field season of 1980. Barley is in Steve's blood in no small measure due to the influences of the two 'Barley Bobs', and literally through various barley products such as beer, Scotch whisky, and bread, homemade cookies, brownies, and pancakes...consumed over the years. Steve's most successful barley cultivar released is named 'Bob'. In addition to 11 cultivar releases, barley genetics research was his major research thrust leading to more than 130 refereed or edited publications, including more than 90 journal articles and 10 book chapters, as well as more than 300 non-refereed, but citable articles and abstracts. Steve felt it fitting as retirement neared to accept an invitation to edit a comprehensive book on barley, which was solicited and published by Wiley-Blackwell. And as it turns out, he is co-editing another barley book in retirement to be published by the American Society of Cereal Chemists International, which focuses on barley chemistry, end uses, and end use quality. Barley end use and end use quality have been important to Steve, and the genetics of malting, feed, and food quality have been major research directions. He is also recognized as making major contributions in the genetics of seed dormancy and pre-harvest sprouting of barley. He has received more than 35 invitations for talks and seminars around the world, as well as, review articles, and book chapters.

Given his broad background and interests, and the multi-faceted aspect of crop trait improvement, Steve was particularly attracted to breeding and genetics research. Genetics research and breeding led to involvement in many scientific sub-disciplines, such as agronomy, soils, plant pathology, weed science, entomology, biochemistry, computer science, etc. One of the most valued aspects of Steve's career was the interaction with so many people in so many specialties, including undergraduate and graduate students, post docs, technologists, and colleagues at WSU, the PNW, the USA, and the world, as well as, Washington barley growers, agricultural industry representatives and WSU administrators. Of particular note is the fact that the barley research community in North America and globally is quite close and interactive. He was particularly blessed with so many competent and super people

(Continued from page 2)

working in the barley program for so many years. One does not make accomplishments in a vacuum. Research presentations and research collaborations led Steve to approximately 25 countries throughout the world. One highlight, was involvement in international agricultural development research collaborations and consultancies through the joint United Nations – International Atomic Energy Agency Division on peaceful uses of nuclear energy for crop improvement, i.e., mutation breeding. IAEA Interactions and consultancies led to work in many barley producing countries. Other highlights were a sabbatical leave at the Carlsberg Laboratory in Copenhagen and hosting a number of sabbatical and other visiting scientists from around the world. Steve is very appreciative of the support he has received from students, colleagues, and administrators, as well as barley growers and the various barley organizations and industries. Financial support from the State of Washington, WSU and the federal government and in the commercial world the Washington Barley Commission and the American Malting Barley Association were especially important and critical.

As much as he loved working with barley, other major emphases were in academic teaching and advising. The love of students and teaching was instilled in Steve while teaching secondary school in the Peace Corps, followed by community college teaching, and eventually to teaching and advising at WSU. Working with students both undergraduate and graduate has been a joy for Steve. He taught or co-taught 12 courses at WSU over the years, and taught in other courses at WSU, the University of Idaho, Sichuan Agricultural University in Ya'an, China and the Mediterranean Agricultural Institute in Zaragoza, Spain. He continuously advised undergrads and even in retirement through spring 2012 “finishing” the last of his seniors. His last grad student finishes summer of 2012. Steve’s advising work was recognized by the CAHNRS Outstanding Advising Award in 2002.

Serving on many department, college, and university committees at WSU, as well as carrying out “extension” duties as a plant breeder at grower meetings and field days was particularly rewarding. Service to professional societies, national and international barley genetics committees was valuable. He is particularly proud to have served on the National Barley Improvement Committee, the USDA Barley Crop Germplasm Committee, the Crop Science Society Barley Crop Registration Committee, and as the WSU Foundation Seed Representative on the Washington State Crop Improvement Association Board of Directors. He is a Fellow of the American Society of Agronomy and the Crop Science Society of America in recognition of research accomplishments and service.

Overall, he is most proud of the people with whom he has interacted and the accomplishments made in his career at WSU and beyond. The people in one’s life are most important. His aim was always to have balance between Career (teaching, research, service) and Family. He is very proud of his family: Mary, and their children, Nathan and Sarah and their spouses, Olivia and Brian, and their children Gavin, Soren, Elise, and Evan. Participation in their lives and with their love and support, there has been balance in his 33 years on the faculty of WSU. With retirement, the connection to WSU continues as Sarah and Brian move along in their careers on the College of Education faculty.



Steve Ullrich presents “Talkin’ Barley” at the Asotin County Field Day in 2001. Photo by John Burns.

Table of Contents

TECHNICAL REPORT 12-1 (ALSO AVAILABLE ONLINE AT [HTTP://CSS.WSU.EDU/PROCEEDINGS](http://css.wsu.edu/proceedings))

Cooperative Personnel and Area of Activity	7
Acknowledgement of Research Support, 2011-12	9

Farm Overviews

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

Variety History

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

Part 1. Breeding, Genetic Improvement, and Variety Evaluation

Winter Wheat Breeding and Genetics (Carter et al.)	21
The Western Wheat Quality Laboratory (Morris and Beecher)	21
Comparison of Linear Mixed Models for Multiple Environment Plant Breeding Trials (Walker et al.)	22
Breeding of Value-Added Barley by Incorporation of Protein-engineered Beta-Glucanase and Endochitinase (Von Wettstein et al.)	22
Epigenetics and Artificial Evolution in Breeding Wheat for Improved Health (Von Wettstein et al.)	23
End-Use Quality Assessment of WSU Wheat Breeding Lines, Influence of Flour Particle Size on Sponge Cake Quality, and Nutritional and Functional Characteristics of Organic and No-till Wheat (Baik et al.)	23
Different Haplotypes of <i>TaCBF-A12</i> , <i>TaCBF-A15</i> and <i>VRN-A1</i> are Associated with Freezing Tolerance in Hexaploid Wheat (Zhu et al.)	24
Washington Extension Variety Trials 2012 – Bringing Variety Performance Information to Growers (Guy et al.)	24
Modification of Coleoptile Length in Wheat Via Manipulation of the AHL Gene Family (Neff et al.)	25
Understanding and Improving Winter Wheat Seedling Emergence from Deep Planting Depths (Mohan et al.)	26
Facultative Growth-Dormant Seeding in The Pacific Northwest (Pumphrey et al.)	26
Effects of Genotype and Environment on the Total Phenolic Content and Antioxidant Activity of Spring Wheat Lines Grown in the Pacific Northwest (Nair and Pumphrey)	27
Variation in Heat Stress Tolerance Response of Spring Wheat Lines (Nair and Pumphrey)	27
Improving Spring Wheat Varieties for the Pacific Northwest (Pumphrey et al.)	28
Application of Biotechnology to Spring Wheat Variety Improvement (Pumphrey et al.)	29
Screening of Spring and Winter Wheat for Water Use Efficiency by Carbon Isotope Discrimination Analysis (Shrestha et al.)	29
Variation in the Micronutrient Content of Pacific Northwest Spring Wheat Lines (Nair et al.)	29

Discovering Drought Resistance Mechanisms in Wheat (Martinez et al.)	30
Identification of New Sources of Genetic Variation for Seed Dormancy and Pre-harvest Sprouting Resistance (Schramm et al.)	31
New Winter Wheat Cultivars from the USDA-ARS: ARS Amber Soft White and ARS Crescent Club Wheat (Campbell, et al)	31
Increasing Winter Wheat Productivity through Increased Coleoptile Length and Speed of Germination (Carter et al.)	32

Part 2. Pathology and Entomology

Control of Rusts of Wheat and Barley in 2011 (Chen et al.)	33
Eyespot, Cephalosporium Stripe, Snow Mold, and Soilborne Wheat Mosaic Diseases of Winter Wheat (Murray et al.)	33
Molecular Diagnostics for Plant-Parasitic Nematodes in the Pacific Northwest (Okubara et al.)	34
Anomalous Armyworm Infestations in Eastern Washington and Oregon Wheat Implicate <i>Dargida spp.</i> plus other Noctuids (Roberts et al.)	34
Controlling Wireworms with Neonicotinoid Insecticides in Wheat (Esser et al.)	35
Lignin as a Potential Defense against Plant Parasitic Nematodes (Thompson et al.)	35
Managing Risks of Virus Infections in Pulse Crops in the Palouse Region (Eigenbrode et al.)	36
Mutation Breeding of Cultivated Barley and Screening of Wild Barley for Resistance to Rhizoctonia Root Rot (Ajayi et al.)	37

Part 3. Agronomy, Economics, and Sustainability

Decomposition of Crop Residue in Dryland Ecosystems (Stubbs et al.)	38
Kentucky Bluegrass for Non-burn Seed Production (Johnston et al.)	38
Toward Better Prediction of Wind Erosion (Sharratt and Vaddella)	39
Mild Freeze-thaw Cycles Improve Freezing Tolerance of Winter Wheat (Skinner et al.)	39
Final Agronomic and Economic Results from the WAWG/NRCS Undercutter Project (Young et al.)	40
Changes in Use of Conservation Practices in Whitman and Latah Counties, 1980-2010 (Young and Kane)	41
Why Did Eastern Washington Wheat Growers Reject the 2011 BCAP Camelina Incentive Program? (Young et al.)	41
Marketing Opportunities for Dryland Organic Crops (Piaskowski and Boggs)	42
Phosphorus Use Efficiency in Washington Spring Wheat (Piaskowski and Campbell)	43
Reducing Soil Compaction to Improve Winter Wheat Yield (Esser and Klein)	43
Managing Soil Nitrogen and Weeds Using Legume and Cereal-intensive Cropping Systems during the Transition Phase for Dryland Organic Wheat Production in Eastern Washington State (Borrelli et al.)	43
Management of Wheat Density to Optimize Nitrogen and Water Use: Implications for Precision Agriculture (Brown et al.)	44
Tillage Strategies to Control Blowing Dust and PM ₁₀ Emissions from Williston Reservoir Beaches in British Columbia (Schillinger et al.)	44
Winter Triticale Produces High Grain and Straw Yields in the Dryland Region (Schillinger et al.)	45
Critical Water Potentials for Germination of Wheat (Singh et al.)	46
Evaluation of New Deep-Furrow Drill Prototypes for Conservation Wheat-Fallow Farming (Schillinger et al.)	46
Evaporation from High Residue No-till versus Tilled Fallow in a Dry Summer Climate (Wuest and Schillinger)	47
Predicting Seed-zone Water Content for Summer Fallow in the Horse Heaven Hills (Singh et al.)	48
Residue Protects Emerging Winter Wheat Seedlings from Rain-Induced Soil Crusting (Schillinger et al.)	49

No-till Summer Fallow is a Good Fit in the Western Horse Heaven Hills (Schillinger et al.)	49
Row Spacing Experiments for Deep-furrow Seeding of Winter Wheat (Schillinger et al.)	50

Part 4. Bioenergy Cropping Systems Research

Camelina: Planting Date and Method effects on Stand Establishment and Seed Yield (Schillinger et al.)	51
Camelina: Seed Yield Response to Applied Nitrogen and Sulfur (Wysocki et al.)	52
Wind Erosion Challenges for Oilseed Cropping Systems (Sharratt and Schillinger)	52
Biofuels Research in Western Washington (Miller et al.)	53
Canola and Camelina Diseases (Paulitz et al.)	54
Winter Canola Rotation Benefit Experiment (Schillinger et al.)	54
Camelina Cropping Systems Experiment at Lind (Schillinger et al.)	55
Rotational Influence of Biofuel and Other Crops on Winter Wheat (Guy and Lauver)	56
Increasing Seed Size and Seedling Emergence in the Brassicas Arabidopsis and Camelina (Neff et al.)	57
Development of Camelina Lines Resistant to Group 2 Herbicides (Hulbert et al.)	58
Biennial Canola – A Three-for One Forage + Oil + Meal Crop (Kincaid et al.)	58
Oilseed Analysis at WSU (Burke and Fuerst)	59
Winter Canola Seeding Rate and Date Study in North Central Washington (Young et al.)	59
Safflower Oilseed Production under Deficit Irrigation and Variable N Fertilization (Collins et al.)	60
Managing Feral Rye in Winter Canola through Herbicide Selection (Young et al.)	61
A Change is in the Air: Refining Canola Fertilizer Recommendations (Pan et al.)	61
Establishing Switchgrass for Biofuel in the North Columbia Basin (Fransen)	62
Extension and Outreach Activities (Sowers et al.)	62
A Decade of Direct-seed Canola in Rotation at the WSU Cook Agronomy Farm (Huggins and Painter)	63
Is Spring Canola Viable in North Central Washington? (Young et al.)	64

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 Klein, Jake—Ritzville
 Knodel, Jerry/Josh—Lind
 Koller, Randy/Roger—Pomeroy
 Kramer, Mark—Harrington
 Krause, Jerry—Creston
 Kuch, Ryan—Ritzville
 LaFave, John—Moses Lake
 Laney, Chris—Sprague
 Lange, Frank—Palouse
 Leahy, Ed—Walla Walla
 Lyle, Kevin—Connell
 Lyons, Rusty—Waitsburg
 Mader, Dan—Genesee
 Mader, Steve—Pullman
 Madison, Kent—Hermiston, OR
 Maier, Eric—Ritzville
 Marks, Scott—Connell
 Matsen, Steve—Bickleton
 McKay, Dan—Almira
 McKinleyk, Dan—Waitsburg
 McLean, John/Shirley—Coulee City
 Melcher, Rodney—Lind
 Miller, Mike—Ritzville
 Mills, Mac/Rod—St. John
 Monson, Jason—Lacrosse
 Moomaw, Cherie—Omak
 Moon, Jim—Prosser
 Moore, Jim—Kahlotus
 Morasch, Bob—Endicott
 Morscheck, Kyle—Genesee, ID
 Neil, Warren—Garfield
 Nelson, Bruce—Farmington
 Nelson, Howard—Wilbur
 Nichols, Mike—Horse Heaven Hills
 Nollmeyer, Jim—Reardan
 Olson, Rich—Garfield
 Ostheller, David—Fairfield
 Pearson, Dave—Horse Heaven Hills
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 Penner, Jay—Dayton
 Pfaff, Richard—Farmington
 Pottratz, Dennis—Fairfield
 Rausch, Chris—Lexington, OR
 Richter, Mark—Endicott
 Roseberry, Dave—Prosser
 Ruegsegger Ranch, Inc—Ritzville
 Sauer, Bruce—Lind
 Sawyer, John—Palouse
 Schafer, Derck—Ritzville
 Schibel, Jeff—Odessa
 Schmitt, Mike/Dan—Horse Heaven Hills
 Schmitz, Joe—Rosalia
 Schoesler, Mark—Ritzville
 Schultheis, Art—Colton
 Sheffels, Jerry—Wilbur
 Sheffels, Mark—Wilbur

Silflow, Brian—Kendrick, ID
 Smith, Glen—Waitsburg
 Smith, Steve—Horse Heaven Hills
 Snyder, Jerry—Ralston
 Spangler, Dennis—Connell
 Starkel, Doug—Odessa
 Stubbs, Jerry/Mike—Dusty
 Suess, Randy—Colfax
 Swannack, Steve—Lamont
 Swinger, Jr., Dennis—Lind
 Tanneberg, Jason—Mansfield
 Tanneberg, Larry—Coulee City
 Teade, Del/Steve—Colfax
 Thompson, Mark—Waterville
 Thorn, Eric—Dayton
 Tiegs, Brian—Fairfield
 Townsend, Edd—Omak
 Troutman, Wade—Bridgeport
 USDA Central Ferry Farm
 Walli, Robert—Ritzville
 Walters, Craig—Palouse
 Wesselman, Roger—Mansfield
 Weishaar, Robin—Odessa
 White, Gil—Lamont
 Zenner, Russ—Genesee

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 Bayer Corp.
 BNP Lentil
 Busch-Ag Resources
 BNP Lentil
 Busch-Ag Resources
 CalWest Seed
 Cedbeco Zaden BV
 Central Washington Grain Growers
 CLD Pacific Grain
 Co-Ag, Inc.
 Columbia Bank
 Columbia Co. Grain Growers
 Columbia Grain Int'l.
 Connell Grain Growers
 Connell Oil
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 DuPont
 Earthkeep, Inc.
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 Empire, Inc.
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Pomeroy Farm & Home Supply
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St. John Hardware
Syngenta
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Western Farm Service
WetSol
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WSU Center for Sustaining Agriculture and Natural Resources
WSCIA

Cook Agronomy Farm

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

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

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

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

The past 9 years have been used to obtain site-specific data and develop physical maps of the 140-acre farm, with the greatest detail developed for a 92-acre watershed using 369 GPS-referenced sites on a nonaligned grid. Maps are available or being developed from various sampling efforts that characterize crop yield and economic returns, soil types, weed, seed banks, populations of soilborne pathogens, soil pH, carbon sequestration, soil water and nitrogen supplies, nitrogen use efficiency and precision N applications. This has been achieved while producing a crop of hard red spring wheat in 1999, spring barley in 2000, and initiating six direct-seed cropping system rotations starting in the fall of 2001 that have continued through today. This past year, an adjacent 160 ac were added to the overall Cook Agronomy Farm bringing the total land area to 300 ac. This new acreage will provide much needed land for small plot research that can complement larger scale cropping system efforts.

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

Dryland Research Station

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

Research efforts at Lind throughout the years have largely centered on wheat. Wheat breeding, variety adaptation, weed and disease control, soil fertility, erosion control, and residue management are the main research priorities. Wanser and McCall were the first of several varieties of wheat developed at the Lind Dryland Research Station by plant breeding. Twenty acres of land can be irrigated for research trials. Numerous journal articles have been published throughout the years from research conducted at the Lind Station and in farmers' fields throughout the low-rainfall region. The articles are available online at <http://www.lindstation.wsu.edu>.



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

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

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

Palouse Conservation Field Station

The Palouse Conservation Field Station (PCFS) originated in 1930 as one of 10 original erosion experiment stations established across the United States by Congressional funding to USDA. The research programs of the stations were designed to investigate the causes of erosion and to determine the most effective and practical methods of checking and controlling soil and water losses from agricultural lands. In 1935 the Soil Conservation Service (SCS) was established and the PCFS became a part of SCS research. When

the Agricultural Research Service (ARS) was established in 1953, all SCS research, including the PCFS, was transferred to ARS. The Land Management and Water Conservation Research Unit (LMWCRU) that oversees the PCFS was officially formed in 1972 as an outcome of a major reorganization of ARS.

Historically, the LMWCRU has played a leading role in the development of science-based



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

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

Today, the LMWCRU's research is actively engaged in issues of national as well as regional prominence. In collaboration with producers, land-grant universities, national laboratories, agribusiness, grower associations and commodity groups, state and federal agencies and other USDA-ARS Units across the nation, at PCFS and other locations, LMWCRU scientists conduct research

on: 1) Integrated agricultural systems including cereal-based rotations, direct seed systems, biofuels, alternative crops, weed management strategies, and organic farming systems; 2) Management systems and decision models to prevent windblown dust and improve air quality and prevent water erosion; 3) Carbon sequestration, sustainable soil management, and mitigation of global climate change; and 4) Precision agricultural systems for effective and sustainable use of fertilizer and herbicides.

Spillman Agronomy Farm

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

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

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



William J. Spillman, breeding plots at Pullman, 1900

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

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

Wilke Research and Extension Farm

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



Wilke Farm field tour 2010

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 & powdery mildew
Madsen.....	1988	SWW Club	Louis Madsen, Dean of College of Agriculture at WSU, 1965-1973
Hyak.....	1988	SWW Club	Rail point in Kittitas Co. east of Snoqualmie 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
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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 Urghart, 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 Grant 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'

CARTER

Otto..... 2011.....SWW..... Otto Amen, long-time Washington legislator and wheat farmer

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 Traill / 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
Cougar	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

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 'Merit' 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 'Dwelle' were developed and released in 1994 and more recently 'Sierra' in 2003 and 'Dylan' in 2006. Spanish White types are a premium product and 'Troy' is the first *Ascochyta* blight resistant variety of this class to be developed.

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

DRY PEAS

Spring Green Peas

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

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

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

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

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

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

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

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

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

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

Spring Yellow Peas

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

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

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

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

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

Winter Peas

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

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

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

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

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

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

LENTILS

Brewer Types

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

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

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

Laird Types

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

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

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

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

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

Small-seeded Types

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

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

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

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

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

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

Turkish Red Types

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

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

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

CHICKPEAS

Kabuli Type

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Desi Type

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

Part 1. Breeding, Genetic Improvement, and Variety Evaluation

Winter Wheat Breeding and Genetics

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Wheat breeding in the state of Washington has seen many changes over the last three years. Even with these changes, 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 to release for production. We have begun using many of the newest tools available to the wheat breeding community to accomplish this task. These include association mapping efforts, genomic selection, marker-assisted selection, and doubled haploid production. This past year we planted large, diverse sets of germplasm for association mapping and genomic selection. In 2011 we planted over 3,000 lines that were selected through marker assisted selection efforts. We also planted 1,200 DH lines with another 3,500 in the greenhouse which will be ready for fall 2012 planting. Many research projects have been initiated with other breeding and research groups at WSU to seek solutions for various production concerns. These include drought resistance, stripe rust resistance, nematode resistance, and emergence potential. With the continual interest in Imazamox resistant wheat in the state, we initiated efforts to develop two-gene resistant lines which are being evaluated in advanced yield trials. We are thrilled about the new technology we have which will enable us to more effectively and efficiently breed wheat for the state of Washington. We have some excellent breeding lines in the program and are excited about their potential for production in the state.

Otto (WA8092) is the most recent soft white winter wheat released from the program and foundation seed will be available for purchase in the fall of 2012. It is an Eltan/Madsen cross which was backcrossed to Eltan four times. Agronomically, it performs very similar to Eltan with regard to emergence, plant height, heading date, and test weight. Otto has similar to higher yields than Eltan especially in the presence of disease pressure to which Otto is resistant. Otto has snow mold and common bunt resistance similar to that of Eltan. The stripe rust resistance is better than Eltan as it picked up seedling resistance genes from the Madsen parent. Otto also has resistance to eyespot foot rot, which will benefit many growers in the 12-15" rainfall zones where this disease is becoming more prevalent.

The hard wheat breeding program is also progressing nicely, with efforts focused on both red and white wheat. Farnum and Bauermeister account for about 30% of hard red wheat production in Washington. WA8118 and WA8119 are two breeding lines which will be considered for release in the fall of 2012. Both have good emergence, high yield potential, and good disease resistance. WA8118 also has the *Gpc-B1* gene for high grain protein content. We have entered multiple breeding lines into the variety testing program in hard wheat backgrounds that have three genes for stripe rust resistance, as well as the *Gpc-B1* gene. We are excited to see the potential of these lines under diverse production regions.

The Western Wheat Quality Laboratory

CRAIG F. MORRIS, USDA-ARS, AND BRIAN S. BEECHER, WSU

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, SDS sedimentation test, and wheat ash. Our recent publications include the characterization of a unique 'super soft' kernel trait in wheat, and transfer of soft kernel texture from *Triticum aestivum* to durum wheat, *Triticum turgidum* ssp. *durum*. A collaborative analysis of wheat endosperm compressive material properties was published in Cereal Chemistry. A study in which five polyphenol oxidase genes were genetically mapped was published in Theoretical and Applied Genetics. Two studies on total, water-unextractable, and water-extractable arabinoxylans and oxidative cross-linking in wheat flour mill streams were recently published in Cereal Chemistry. Other research includes phytochemical composition, anti-inflammatory, and antiproliferative activity of whole wheat flour, the molecular characterization and diversity of puroindoline b-2 variants in cultivated and wild diploid wheat, the prevalence of *Puroindoline D1* and *Puroindoline b-2* variants in U.S. Pacific Northwest wheat breeding germplasm pools, and their association with kernel texture, some observations on the granivorous feeding behavior preferences of the house mouse (*Mus musculus* L.), and research on the distal portion of the short arm of wheat (*Triticum aestivum* L.)

chromosome 5D controls endosperm vitreosity and grain hardness. Currently the lab is working on grant-funded research aimed at better understanding the fate of fiber and phytonutrients in whole wheat products during processing. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Babe, Cara, Diva, Farnum, JD, Kelse, ORCF-103, Skiles, Tubbs 06, Whit, and Xerpha.

Comparison of Linear Mixed Models for Multiple Environment Plant Breeding Trials

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Evaluations of cultivars and breeding lines in multiple environments under varied environmental conditions often show genotype by environment interactions. Two examples of these types of trials are the WA Cereal Variety testing program and the breeder nurseries operated by the breeding programs. Genotype by environment interactions are especially prevalent in Washington where rainfall zones and cropping systems vary considerably. These interactions indicate that cultivars don't respond consistently among environments, and when they occur, the performance of genotypes must be estimated within each environment. Instead of simply taking the mean of the replicates of a cultivar within an environment, empirical best linear unbiased predictions can provide more accurate estimates of the cultivar performance, depending upon the statistical model used. The objective of this work was to simulate and analyze data sets from multiple-environment trials, based on the WA cereal variety trial data, to determine which linear models provide the most accurate estimates of cultivar performance. Simulations varied in terms of numbers of cultivars and environments, variances and covariances of responses within and between environments, experimental design, and experimental error variance. Statistical models that accounted for genetic relationships among cultivars and also for relationships among environments (for example relationships among environments in similar rainfall regions) were consistently more accurate than other models. The outcome of this research is to recommend that cultivar performance be predicted using models that account for these relationships.

Breeding of Value-Added Barley by Incorporation of Protein-engineered Beta-Glucanase and Endochitinase

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It is the primary goal of the present project to exploit and use the excellent possibilities of breeding barley cultivars by synthesizing value adding enzymes in the developing grain. Goal in the recent years was to assess possible adverse effects of transgene expression in leaves of field-grown barley relative to i) the influence of genetic background and ii) effect of plant interaction with arbuscular mycorrhizal fungi. Goal (2) was to apply global parallel transcript profiling, metabolome profiling and metabolic fingerprinting to evaluate possible transgene-induced differences relative to cultivar specific expression patterns.

Parallel transcript and metabolome profiling and metabolic fingerprinting *on wild-type accessions and barley transgenics with (i) seed-specific expression of (1,3-1,4)-beta-glucanase (GluB) in the cultivar Baroness as well as of transgenics in the Golden Promise background with (ii) ubiquitous expression of codon-optimized Trichoderma harzianum endochitinase.*

More than 1600 differential transcripts were found between Golden Promise and Baroness, with defense genes being strongly over represented in Baroness, indicating a divergent response to subclinical pathogen challenge in the field. In contrast, no statistically significant differences between transgenics expressing endochitinase and Golden Promise could be detected based on transcriptome or metabolome analysis, while 22 genes and 4 metabolites were differentially abundant when comparing transgenics expressing betaglucanase and Baroness, leading to the distinction of these two genotypes in principal component analysis. The co-regulation of most of these genes in the betaglucanase expressing plants and Golden Promise as well as simple sequence repeat marker analysis suggests that the distinctive alleles in betaglucanase producing plants are inherited from Golden Promise. Thus the effect of the two investigated transgenes on the global transcript profiles is substantially lower than the effect of a minor number of alleles that differ as a consequence of crop breeding. Exposing roots to the spores of the mycorrhizal *Glomus* sp. had little effect on the leaf transcriptome but central leaf metabolism was consistently altered in all genotypes.

METHODS: A 44,000 barley microarray was developed based on the assembly of 444,652 barley ESTs into 28,001 contigs and 22,937 singletons, of which 13,265 are represented on the array for transcriptome analysis. Metabolome profiling and metabolic

fingerprinting was targeted to free amino acids, major leaf carbohydrates, ascorbic acid, tocopherols, glutathione, carotenoids, phosphorylated intermediates and carboxylates. It was carried out by ESI-Mass Spectroscopy on a QTrap 3200 mass spectrometer after metabolite extraction. Principal Component Analysis was according to Bijlsma *et al.* *Anal.Chem.*78: 567-574 (2006).

Publication: Global transcriptome and metabolome profiling of field-grown transgenic barley plants lack induced differences but show cultivar-specific variances. K.H. Kogel, L.M. Voll, P. Schaefer, C. Jansen, Y.Wu, G.Langen, J. Imani, J.Hofman, A.Schmiedl, S.Sonnewald, D. von Wettstein, R.J. Cook, U. Sonnewald. *Proc. Natl. Acad. Sci. USA* 107:6198-6203.

Epigenetics and Artificial Evolution in Breeding Wheat for Improved Health

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The major fraction of wheat storage proteins represented by prolamins are rich in proline and glutamine residues making them resistant to complete digestion, leaving a complex mixture of peptides from 149 storage proteins causing the severe autoimmune reaction of celiac disease in 1 to 100 human leukocyte antigen-DQ2 and -DQ8 positive individuals. Different celiac patients are sensitive to different of these storage proteins causing the destruction of the small intestine epithelium. The only effective therapy is strict abstinence from wheat containing food. The promoters of the genes encoding these Low-Molecular Weight glutenins (LMWg) and gliadins are silenced by methylation in the vegetative organs of the plant and are de-methylated by three *DEMETER* genes at the beginning of endosperm development. Since these proteins have been shown to be of no importance for baking, they can be eliminated. Progress is reported for permanently silencing these genes with artificial micro-RNAs and hairpin constructs. Alternatively TILLING mutants in the active site of the *DEMETER* genes are used in a non-transgenic approach. The promoters of the six genes encoding the High-Molecular Weight glutenins contain CpG islands preventing their methylation in all organs of the plant and are alone responsible for the network produced by di-tyrosine bonds during dough formation and baking. The LMWg and gliadin genes have to be specifically activated by promoter demethylation in the endosperm. Building upon these findings Bacterial Artificial Clones (BAC) for the 3 *DEMETER* genes were identified, the 3 genes sequenced by 454 procedure and mapped to the three homoeologous chromosomes 5. Partial silencing of the active sites of the enzyme in the homoeologous chromosomes in members of a hexaploid and a tetraploid TILLING populations have been identified by High Performance Liquid Chromatography (HPLC) and mass spectrometry. These are pyramided by crossing for complete silencing. Artificial microRNAs and hairpin RNAs targeting the active site of the wheat *DEMETER* genes have been synthesized and successfully transformed under control of an endosperm specific promoter, yielding elimination of LMWgs and gliadins. Excellent bread can be baked in the absence of these prolamins. For celiac patients sensitive to HMWG epitopes transgenic wheats expressing in the endosperm detoxifying prolylendopeptidase and barley prolamins protease are in early stages of development.

End-Use Quality Assessment of WSU Wheat Breeding Lines, Influence of Flour Particle Size on Sponge Cake Quality, and Nutritional and Functional Characteristics of Organic and No-till Wheat

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The Washington State University Wheat Quality Program (WSUWQP) provides end-use quality testing for the spring and winter wheat breeding programs at WSU. For the crop harvested in 2010, approximately 1,108 varieties/lines were tested by the WSUWQP in conjunction with the Western Wheat Quality Lab (WWQL). Test results were analyzed, summarized and reported to WSU wheat breeders, and contributed to selection of their breeding material for the next generation. We also completed the milling and compositional analysis of 343 winter wheat lines harvested in 2011 within the small time window between harvest and planting, which made the timely screening of breeding lines possible before fall planting.

The sponge cake (SC) baking test provides a reliable estimation of overall end-use quality of soft white wheat for Asian markets, whereas the quality profile for making sponge cake has not been well established. As a first step toward to the identification of soft white wheat quality traits required for making sponge cake, we investigated the sole effect and magnitude of flour particle size on sponge cake baking quality. Two different sets of wheat flours, including flours of reduced particle size obtained by re-grinding and flour fractions of different particle size separated by sieving, were tested for sponge cake baking quality. The obtained results suggest that: 1) particle size reduction of flour by re-grinding improves sponge cake volume, despite increased starch damage and

flow-water batter viscosity; 2) the finer the flour particles, the smaller the viscosity of flour-water batter and the bigger the volume of sponge cake; and 3) flour particle size, rather than protein content, has a major influence on sponge cake volume.

We have analyzed soft white (SW) and hard red (HR) wheat grain produced in organic, no-till, and conventional cropping systems for grain characteristics, ash, protein, total phenolic content, antioxidant capacity and baking quality. Soft white wheat grain produced with no tillage exhibited significantly greater kernel diameter and weight than the grain of conventional tillage. No-till cultivation lowered protein content and antioxidant capacity, whereas it imparted no apparent effects on quality of cookies, cake and pan bread. Organic SW wheat grain was higher in test weight, kernel diameter and kernel weight than non-organic grain. Organic cultivation appeared to produce harder kernel of HR wheat than conventional cultivation without affecting kernel weight and size. Compared to non-organic wheat grain, organic SW wheat grain was lower in flour protein content by 2.19% with low fertility, and higher by 0.8% with high fertility. Organic SW wheat tended to produce larger volume of sponge cake and smaller volume of bread.

Different Haplotypes of *TaCBF-A12*, *TaCBF-A15* and *VRN-A1* are Associated with Freezing Tolerance in Hexaploid Wheat

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Extremely low temperatures in winter can cause severe damage to winter wheat. Breeding of freeze-tolerant winter wheat is an urgent task in the face of an increasingly variable world climate. At present, the two main loci associated with freezing tolerance in wheat are *FR-1* and *FR-2*. *FR-1* is tightly linked to *VRN-1*, or is a pleiotropic effect of *VRN-1*. The *V* and *W* alleles of *VRN-A1* were hypothesized to be associated with freezing tolerance. *Fr-A^m2* was cloned in diploid wheat (*Triticum monococcum*), and includes a cluster of 11 C-repeat Binding Factor (*CBF*) genes. The genes *TmCBF12*, *TmCBF14* and *TmCBF15* in this cluster were hypothesized to play critical roles in freezing tolerance of *T. monococcum*. Orthologs of *TaCBF12*, *TaCBF14* and *TaCBF15* in the A, B, and D genomes of hexaploid wheat (*T. aestivum*) were sequenced within a diverse panel of 70 cultivated winter wheats collected from different parts of the world, in order to exploit haplotypes of these nine genes, if associated with freezing tolerance. Two haplotypes of *Fr-A2* which contains one indel polymorphism and three SNPs (single nucleotide polymorphisms) in *TaCBF-A12* and one indel polymorphism and five SNPs in *TaCBF-A15* were found in the diverse panel. An F2-derived F3 population of 58 individuals from winter wheat populations 'OFW#5'/'Eltan' and 'OFW#5'/'Tiber', was used to test the association between the two haplotypes and survival in artificial freezing trials. A significant association ($P < 0.1$) was found between the haplotypes mentioned above and survival. In addition, two alleles of *VRN-A1*, *VRN-A1v* and *VRN-A1w*, which are distinguishable by a single-nucleotide polymorphism (SNP) in exon 4, were segregating in these populations and were also found to be significantly associated with freezing tolerance. Larger winter wheat populations are currently being evaluated for associations between freezing tolerance and polymorphisms at the *TaCBF-A12*, *TaCBF-A15* and at *VRN-A1* loci. These results are the first molecular markers that we have identified to be associated with freezing tolerance in winter wheat. If the association between freezing tolerance and allelic diversity is proven in the larger population, they will be useful tools to breed for increased freezing tolerance in winter wheat.

Washington Extension Variety Trials 2012 – Bringing Variety Performance Information to Growers

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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. Beginning in 2011, the WSU Variety Testing program started field evaluations of dry pea, lentil, and chickpea varieties in Eastern Washington. All grain legumes are evaluated 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 are on the Variety Testing Web site

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



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. In addition to the identification of many partial AHL sequences, we have cloned four full-length AHL sequences from the wheat genome and named them *Taq1*, *Taq2*, *Taq3*, and *Taq4*. These sequences were identified using a combination of comparative genomic and PCR cloning techniques. The four wheat AHL sequences were constructed into both prey and bait vectors for yeast-two-hybrid analysis, which allows us to test protein-protein interactions amongst the family members. The results show that the wheat AHL proteins *Taq2* and *Taq3* interact to each other. We have also shown that *Taq2* and *Taq3* can also interact with the Arabidopsis AHL SOB3 protein. These results strongly suggest that the biochemical function of AHL proteins can be conserved between dicot and monocot species. RT-PCR reactions have been done for *Taq2*, *Taq3* and *Taq4* at early stages of plant development. In addition to confirming expression of each gene in coleoptiles, the results revealed differential expression patterns for *Taq2*, *Taq3*, and *Taq4* in the early stages of wheat seedling development. Immature wheat embryos (14-16 days after flowering) were used as explants to induce callus for transformation of mutant and wild type wheat AHL sequences (Figure 1). This transgenic approach will allow for phenotypic analysis of agronomic traits for wheat expressing different forms of these genes.



Fig. 1. Wheat callus used for transformation of wildtype and mutant forms of AHL genes. Close up (left). Growth chamber with many wheat transformation experiments (right).

Understanding and Improving Winter Wheat Seedling Emergence from Deep Planting Depths

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Farmers in the winter wheat-summer fallow region of the Inland Pacific Northwest plant seed as deep as seven inches below the soil surface to reach adequate soil moisture for germination and emergence. Successful emergence through a thick, dry, soil mulch is critical for stand establishment and grain yield potential. Winter wheat varieties that can emerge quickly and successfully from these depths under limited moisture conditions are needed. The present-day semi-dwarf cultivars in PNW contain Rht1 and Rht2 dwarfing genes that do not emerge as well as the taller varieties that were grown in the 1960s. The Rht mutations seem to reduce coleoptile length and thus impede seedling emergence. Funded by the Washington Grain Commission, our objectives are to improve seedling emergence of the present-day varieties and to study the genetics and variation of this trait among cultivated wheats of the world. First, with the objective to transfer the emergence trait from the available resources, both Buchanan (hard red) and Moro (soft white club) were used as donor parents. Focusing on the Xerpha $\times$ Buchanan cross, about 14,000 BC₁ seeds were developed. Evaluation of the BC₁F₁ seedlings showed a complex inheritance for the coleoptile length trait as only about 25% of the seedlings showed coleoptile length similar to that of the donor parent. We have developed a few lines with coleoptile lengths more than 100 mm and they appear to have grain quality better than Xerpha. These lines will be field-tested at Lind this year for emergence from deep planting, as well as for agronomic traits. To meet the second objective, 670 lines of our world collection of varieties were evaluated for coleoptile length, field emergence, 1000 kernel weight and plant height. Coleoptile lengths ranged from 40 to 120 mm with most of the cultivars showing a range of 40 to 80 mm. Average coleoptile length of spring entries was similar to that of winter lines. To test the emergence capabilities, these lines were evaluated in a replicated field emergence experiment at the Lind station (Fig. 1). The lines were planted deep with 4.7 inches of soil covering seeds. On the 7th day after planting, only 1% of the entries had emerged, and 25% showed emergence on the 8th day. Although there was a general correlation between coleoptile length and emergence, we observed that there were factors other than coleoptile length that were also important for emergence. Some of the best emerging lines had coleoptile lengths of only 50 to 60 mm. Similarly, some entries with coleoptile lengths longer than 90 mm showed very poor emergence. We also observed that coleoptile lengths longer than 90 mm either did not increase emergence or had a negative effect. Our results suggest that emergence for deep planting depths is a complex trait and we need a better understanding of the underlying genetic and molecular mechanisms in order to improve it in a targeted manner.



Fig. 1. Counting the number of emerged wheat seedlings from the world collection at Lind in early September. Fifty seeds of each of the 670 lines were planted with four replications, thus we determined the emergence status of 134,000 individual seeds at 24-hour intervals for several days.

Facultative Growth-Dormant Seeding in The Pacific Northwest

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On November 19, 2010, we planted 18 HRS and 18 SWS cultivars in Walla Walla, Washington to test for performance in a dormant seeded (~facultative growth) production system. The same 18 HRS cultivars were planted in April 2011 adjacent to the fall planted trial. Nine winter wheat cultivars were planted alongside the trials for check comparisons. Plots were planted, evaluated, maintained, harvested, and processed by both the Spring Wheat and Winter Wheat Breeding Programs. This experiment is being replicated in 2011-2012 and lines which perform well over both years will be communicated to producers interested in dormant-seeding wheat. In addition, 18 near-isogenic winter wheat lines, with four vernalization alleles were also tested and spring growth habit observed. The purpose of these experiments is to intentionally select lines which have facultative growth habit.

Based on the results of 2011 experiments, we see trends that suggest the importance of selecting spring wheat lines with stronger

photoperiod sensitivity in dormant-seeding systems. A significant, positive correlation was found between yield and heading date for both hard red and soft white spring wheat trials. This is in contrast to spring-planted hard red spring wheat, where yield and heading date were negatively correlated. This information is valuable for selection of parents to be used in directed breeding efforts focused on dormant-seeded spring wheat.

Effects of Genotype and Environment on the Total Phenolic Content and Antioxidant Activity of Spring Wheat Lines Grown in the Pacific Northwest

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Increasing awareness about the efficacy of whole grains in maintaining general health and well-being has generated tremendous interest in various cereal phytochemicals. Diets rich in whole grains have been shown to reduce the risk of chronic ailments like diabetes, cardiovascular disease, and several forms of cancer. Wheat, a staple global food source, is also a rich source of beneficial antioxidants. The objectives of this study were to determine the effects of genotype (G) and environment (E) on total phenolic (TP) content and antioxidant activity (AA) of 47 diverse spring wheat lines grown in Washington. Three replicates each of 16 hard red, 8 hard white and 23 soft white spring lines were grown in Endicott, Farmington, Lind and Reardan. Flour samples were analyzed for TP content and AA using modified Folin-Ciocalteu and DPPH radical scavenging methods, respectively. Overall, TP content ranged from 1.5-2.9 $\mu\text{GAE/g}$ wheat flour with an average of 2.1 $\mu\text{GAE/g}$, while, AA varied between 1.3 and 24.3% with an average of 12.1%. Overall, hard lines showed significantly higher average TP content and AA values than the soft lines (Fig. 1). According to the Fisher's least significant difference (LSD) test at $P < 0.05$, average TP content was significantly different between all four locations with Reardan showing the highest value. On the basis of average AA values, LSD grouped Lind, Endicott and Reardan into one group and Farmington into another, suggesting that the growing locations used in this study were not highly variable for AA (Fig. 2). Significant genotypic variation was observed for both AA and TP content suggesting the potential for genetic improvement of these traits. There were also significant effects of E and GxE on both AA and TP content indicating the role of soil and growing conditions on wheat phytochemicals. These results suggest that selection of wheat lines with higher AA and TP content combined with multi-location trials will be helpful in the development of nutritionally enhanced wheat varieties.

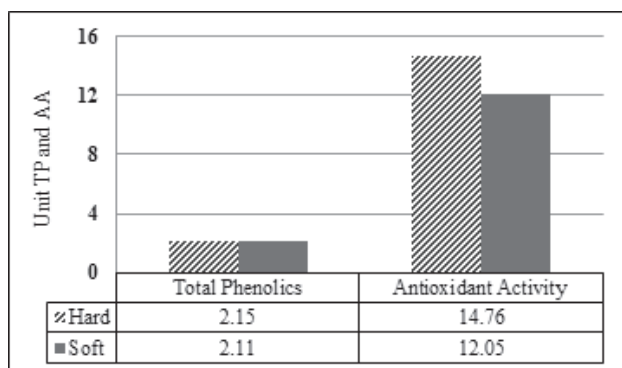


Fig. 1. Average values of total phenolic (TP) content and antioxidant activity (AA) of hard and soft spring wheat classes.

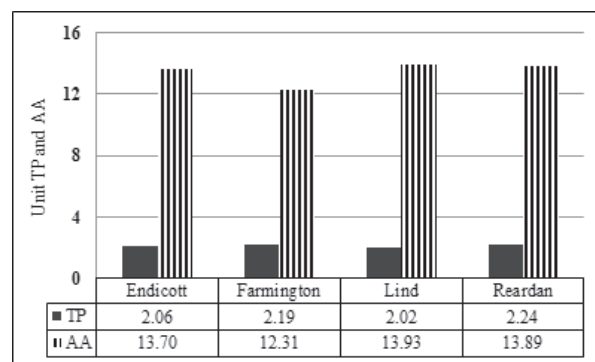


Fig. 2. Average values of total phenolic (TP) content and antioxidant activity (AA) of all genotypes at each location.

Variation in Heat Stress Tolerance Response of Spring Wheat Lines

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Heat stress is a growing global occurrence limiting agricultural productivity. While wheat does possess intrinsic mechanisms to combat heat stress, various breeding and crop management approaches can be employed to further manipulate wheat production systems to improve productivity. The objective of this research was to identify variation in tolerance response of spring wheat lines subjected to heat stress under controlled conditions. Three pots (with three plants per pot) each of 45 spring wheat lines were subjected to 36°C/24°C (day/night) temperature with 80% humidity at anthesis; concurrently, control plants were kept at 22°C/15°C. Heat stress response was measured on the primary flag leaf of each plant with a SPAD chlorophyll meter, which

estimates chlorophyll concentration, at 0, 3, 6, 9 and 12 days following anthesis. Heat stress response, calculated as a percentage of control measurements for each genotype, varied significantly ($P < 0.05$) among the genotypes. As expected, there was a progressive decline in the chlorophyll content of plants over a prolonged period of heat exposure. SPAD values ranged from 97.1-111.3% of control plants, with an average of 103.4%, just before exposing to heat stress. After 12 days of elevated temperatures, SPAD values ranged from 13.3-95.1% of optimal temperature control plants with an average of 46.3% (Fig. 1). Though additional experiments are required to validate the observed heat stress response, results obtained in this experiment suggest that significant variation in heat tolerance is already present in elite spring wheat breeding germplasm, and improvements through breeding will be an important component for mitigating the effects of increasing temperatures.

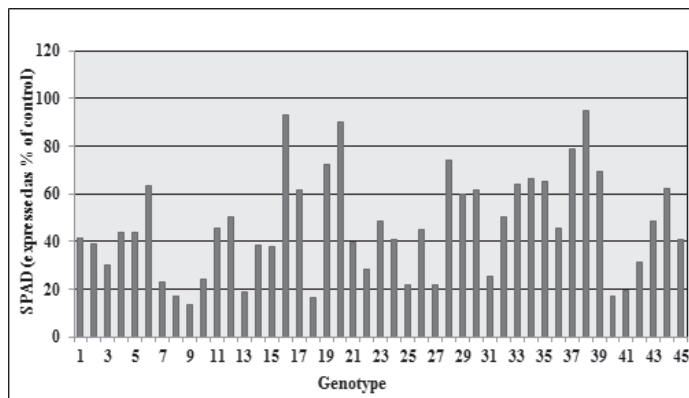


Fig. 1. Heat stress tolerance response of spring wheat lines measured as SPAD chlorophyll content 12 days after exposure to 36°C/24°C (day/night) cycle, expressed as percent of control values of same genotype grown under 22°C/15°C conditions.

Improving Spring Wheat Varieties for the Pacific Northwest

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The Spring Wheat Breeding project had a successful year in 2011 thanks to high quality screening nurseries and suitable experimental conditions at all locations. Another severe stripe rust epidemic in 2011 provided the conditions necessary to select and advance elite germplasm with high yield potential and adequate disease resistance.

WSU soft white spring varieties Louise, Alpowa, Whit, and Wakanz accounted for 73% of the SWS acres planted in Washington State in 2011. Babe (released 2009) made an entrance to the variety acreage report in 2011 with 3,900 acres planted. WSU hard red spring varieties Hollis, Tara 2002, Kelse, and Scarlet accounted for 24% of HRS acres planted in 2011. JD (released 2009) and Eden spring club varieties occupied 100% of the reported spring club acres. In total, 48% of the 2011 Washington spring wheat acres were planted to WSU spring wheat varieties. Newly released WSU spring wheat varieties Diva and JD will likely be adopted on significant acres over the next few years.

Glee (formerly WA8074) is a new hard red spring wheat that was approved for release in March 2012. The name Glee was chosen to honor and celebrate the memory of Virginia "Ginny" Gale Lee, a remarkable person and graduate student in the Spring Wheat Breeding project at Washington State University. Before her untimely death due to a rare and aggressive cancer in December 2010, Virginia was enthusiastically engaged in scientific research to minimize the impact of rust diseases on wheat production in Washington and around the world.

Glee is broadly adapted with good stripe rust resistance, Hessian fly resistance, superior test weight, and excellent yield potential in high rainfall and irrigated production areas. Glee has similar maturity with superior stripe rust resistance, test weight, and yield performance compared to the two leading HRS varieties based on acreage in Washington State in 2011 (Hank and Jefferson; >54,000 cumulative acres). The test weight advantage of Glee may be of particular interest to growers due to frequent grading discounts in the intermediate rainfall production regions. Glee possesses desirable end-use quality.

Dayn (formerly WA8123) is a new hard white spring wheat approved for release in March 2012. Dayn has relatively high grain protein content, a high level of stripe rust resistance, above average test weight, early maturity, medium height, and an excellent yield record in dryland and irrigated areas of Washington, Idaho, and Oregon. Dayn has good straw strength, with excellent yield potential in irrigated production systems. Dayn is susceptible to Hessian fly.

Application of Biotechnology to Spring Wheat Variety Improvement

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Biotechnology is an integral component of the Spring Wheat Breeding program. The objective of this work is to support/enable the most effective and efficient selection procedures for development of superior Washington spring wheat varieties. In addition to routine early-generation grain quality selection carried out through this project, we are conducting several research projects of direct relevance to our breeding efforts. This project also supports our two-gene Clearfield breeding effort, which has progressed ahead of schedule.

DNA Marker development: Genotyping of 283 spring wheat elite lines and released varieties was completed with 9000 SNP markers in 2011. Analysis of this data using complimentary field trial data collected in 2011 revealed SNP markers associated with multiple stripe rust resistance genes, Hessian fly resistance, and multiple loci that influence heading date and other agronomic traits. Additional trials will be conducted on these materials in 2012 to verify and identify additional associations.

Thirty-one SNP markers were used to genotype 384 elite SWS breeding lines (every SWS line that has been advanced through our preliminary yield trials the past three years) in an effort to validate DNA markers linked to grain quality QTL from the SWS wheat variety Louise.

Clearfield spring wheat: Two rounds of selection and crossing with elite breeding lines and varieties have been completed to generate 34 BC₃F₁ and 39 BC₄F₁ two-gene Clearfield populations. In total, 725 plants were screened with Clearfield trait DNA markers and 165 two-gene Clearfield plants were identified. An additional 376 plants were screened to identify 48 two-gene Clearfield plants from nine BC₂F₁ populations and 43 two-gene Clearfield plants from seven BC₃F₁ populations. These additional plants were submitted to the WSU Wheat Doubled Haploid Facility for the production of doubled haploids to shorten the varietal development timeline. We have harvested seed from the first round of doubled-haploid production, and are currently increasing seed in the greenhouse for field evaluations in 2012.

Screening of Spring and Winter Wheat for Water Use Efficiency by Carbon Isotope Discrimination Analysis

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WSU AND USDA-ARS

Breeding for drought tolerance through selection for yield is complicated due to the higher influence of environmental factors. An alternative is to select for individual physiological traits that are less influenced by the environment. Carbon isotope discrimination (CID) is a potentially valuable physiological technique for indirect selection of water use efficiency (WUE) of wheat because of the high heritability of CID values. To determine the relationship between CID and wheat variety performance under terminal drought stress conditions in the Pacific Northwest (PNW), Washington State University's soft and hard spring wheat variety trials located at Pullman (>50 cm annual rainfall, $n=40$, 2009) and Connell (<30cm rainfall, $n=48$, 2010), WA, and soft and hard winter wheat variety trials located at Lind (<30cm rainfall, $n=90$ in 2010 and 2011), WA, were screened. All genotypes were planted in an alpha lattice design with three replications. Flag leaves were sampled when boots started to swell or ¼ of inflorescence started to be visible. Leaf samples were dried at 80°C for 48 hrs, finely ground and analyzed by mass spectrometry. The agronomy and phenological traits including yield, test weight, protein, plant height and heading measured in all rainfall regions (<30cm to >50cm rainfall) on spring and winter wheat, were used to correlate with CID. The CID values have shown good correlations with yield, test weight, protein and plant height. So far low CID values (high WUE) have been correlated with yield and test weight in spring wheat but not in winter wheat. To further examine the relationships between performance and WUE in spring wheat, we will examine CID in two mapping populations in the drought nursery at Lind this summer.

Variation in the Micronutrient Content of Pacific Northwest Spring Wheat Lines

SINDHU NAIR, MIKE PUMPHREY AND KEVIN MURPHY; DEPT. OF CROP AND SOIL SCIENCES, WSU

Micronutrients are indispensable for proper human growth and development. Although wheat is primarily recognized as a source of energy and proteins, it is also rich in phosphorous (P), magnesium (Mg), calcium (Ca), iron (Fe), zinc (Zn), copper (Cu) and

manganese (Mn). As one of the primary global food sources, wheat can be utilized as a vital carrier for the effective delivery of micronutrients to people. The objective of our research was to identify variation in the micronutrient content of spring wheat cultivars and advanced lines grown in different locations throughout Washington. Three replicates each of 16 hard red, 8 hard white and 23 soft white spring lines were grown in Endicott, Farmington, Lind and Reardan. Flour samples were analyzed for micronutrient content by inductively coupled argon plasma techniques at the USDA-ARS Grand Forks Human Nutrition Research Center in North Dakota. Significant effects of location, possibly governed by soil conditions, were observed on the micronutrient content of wheat. Similarly, depending on the micronutrient, significant genotypic variation in the seed micronutrient content was detected at different locations suggesting the potential for genetic improvement. At all the locations, except for Fe at Farmington, hard wheat had higher average values for all the micronutrients than soft wheat (Table I). Historical selection for low ash content may have contributed to the observed reduced micronutrient concentration in soft white wheat. Hard red wheat lines showed higher mean values for all the micronutrients than both hard and soft white types used in this study, except for Cu and Fe content (Table II). These results indicate that elite spring wheat varieties have significant variation for micronutrient contents and biofortification of wheat through breeding can be achieved as a cost-effective solution for improving nutrition.

Table I. Average values of micronutrient content at each location.

(μg/g)	Ca		Cu		Fe		Mg		Mn		P		Zn	
	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
Endicott	367 ^b	355 ^b	3.7 ^d	3.2 ^d	32 ^b	30 ^b	1493 ^a	1287 ^a	50 ^b	42 ^b	3508 ^a	3158 ^a	24 ^c	23 ^b
Farmington	581 ^a	381 ^a	4.0 ^c	3.5 ^c	36 ^b	55 ^a	1348 ^c	1118 ^c	41 ^c	37 ^c	3463 ^a	2937 ^b	37 ^a	27 ^a
Lind	332 ^d	315 ^c	5.9 ^a	5.1 ^a	57 ^a	36 ^b	1429 ^b	1273 ^a	36 ^d	33 ^d	2739 ^c	2270 ^d	25 ^b	22 ^c
Reardan	356 ^c	310 ^c	4.4 ^b	3.9 ^b	36 ^b	34 ^b	1349 ^c	1153 ^b	53 ^a	47 ^a	3301 ^c	2820 ^c	21 ^d	20 ^d

*

Mean values followed by same letters are not significantly different at $P < 0.05$.

Table II. Range, mean and standard deviation (SD) values of micronutrient content averaged across genotypes and locations.

		Ca	Cu	Fe	Mg (μg/g)	Mn	P	Zn
Hard Red (n = 16)	Range	363 - 478	3.6 - 5.2	33 - 49	1323 - 1553	42 - 48	3003 - 3608	25 - 30
	Mean	417	4	37	1424	46	3335	27
	SD	30.8	0.5	3.9	63.9	2	146.6	1.5
Hard white (n = 8)	Range	333-438	3.8 - 5.3	33 - 68	1267 - 1443	37 - 50	2873 - 3312	22 - 29
	Mean	392	5	47	1367	44	3087	25
	SD	32.9	0.5	12.6	70.9	4.2	184.9	1.9
Soft white (n = 23)	Range	295 - 389	3.4 - 4.3	28 - 107	1105 - 1295	34 - 47	2656 - 3017	22 - 25
	Mean	340	4	39	1208	40	2796	23
	SD	25.4	0.3	17.7	52.6	3.2	90.2	0.9

Discovering Drought Resistance Mechanisms in Wheat

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Breeding for improved wheat drought tolerance has the potential to improve cropping systems on the dry side of Washington both by decreasing risk and by reducing the number of fallow seasons required to obtain sufficient stored soil moisture. Drought tolerance can be achieved through multiple mechanisms, and combining these mechanisms should allow us to increase wheat drought tolerance. Previous work showed that the cultivar Louise has excellent water use efficiency, whereas Alpowa has a pattern of growth and development that allows it to escape drought pressure. We are investigating the association between specific physiological traits and productivity under drought by comparing the performance of 180 Louise/Alpowa recombinant inbred lines under side-by side irrigated and non-irrigated conditions. In 2011, we identified specific lines that yielded better relative to the entire population without irrigation, but did not show superior performance under irrigation. The combination of mechanisms resulting in superior response to water stress are being further characterized in 2012.

Identification of New Sources of Genetic Variation for Seed Dormancy and Pre-harvest Sprouting Resistance

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Pre-harvest sprouting (PHS), in which germination occurs on the mother plant under cool and wet conditions, can cause severe economic and quality losses in wheat. Some seed dormancy is desirable to prevent PHS, but deep or prolonged dormancy may interfere with proper emergence and stand establishment if dormancy has not abated by the time seeds are planted the next season. In general, greater dormancy is associated more with wheat with red grain color than white. The PNW produces the majority of the soft white wheat grown in the United States, and in recent years, hard white wheat has been growing in popularity due to higher flour yields and potential export opportunities. Because of the importance of white wheat in the PNW, it is important to identify new sources of PHS resistance that can be incorporated into breeding material. To further the understanding of wheat seed dormancy, mutants have been isolated with altered germination responses to the plant hormone abscisic acid, which is involved in the acquisition and maintenance of seed dormancy in plants. Mutants have been isolated in both red and white genetic backgrounds. The mutants isolated in the white Zak background demonstrate that increased dormancy can be achieved even in a background with low initial dormancy using a mutation breeding approach. These mutants have been evaluated for germination behavior under greenhouse and laboratory conditions and were planted in the field in 2011 and 2012 for evaluation of PHS resistance using field-grown material in greenhouse spike wetting experiments. These mutants may be a source of improved PHS resistance due to altered dormancy. In addition, breeding lines and cultivars from the WSU spring and winter variety trials in Pullman were sampled to assess dormancy and PHS resistance of adapted genetic material. Various soft white spring, hard white winter, hard red winter, and hard red spring cultivars were compared to resistant and susceptible controls with known dormancy and PHS susceptibility. All market classes showed a range of PHS susceptibilities. Interestingly, the most resistant cultivar other than resistant controls was a soft white spring. When dormancy tests were conducted using the same soft white spring cultivars, seed dormancy was not strongly correlated with spike wetting test results. However, seed dormancy alone is not the only factor contributing to PHS susceptibility. Physical characteristics of the spike, such as head type and floral anatomy, may also contribute.



Fig. 1. An example of the controls for the PHS spike wetting experiment show a range of resistance to susceptibility.

New Winter Wheat Cultivars from the USDA-ARS: ARS Amber Soft White and ARS Crescent Club Wheat

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Major epidemics of stripe rust occurred in the PNW in 2010 and 2011. Most currently grown soft white winter wheat cultivars, including 'Brundage 96', 'ORCF 102', 'Eltan', 'Xerpha' and 'Westbred 528' possess only adult plant resistance and were rated as moderately susceptible. 'ARS-Amber' soft white winter wheat and 'ARS-Crescent' winter club wheat were developed by the USDA-ARS with assistance from the Washington Agricultural Experiment Station and the Oregon Agricultural Experiment Station with the

goal of combining all-stage and adult plant resistance to stripe rust, with competitive agronomic characteristics and excellent soft wheat end use quality. Both cultivars were developed using the bulk-pedigree breeding method with early generation selection for maturity, height, resistance to stripe rust, strawbreaker foot rot and cephalosporium stripe followed by later generation selection for yield, test weight, freezing tolerance, emergence, and end-use quality. ARS-Amber was tested under experimental number ARS960277L with the pedigree: Eltan/4/WA7217/3/WA6581//Paha//Tres/5/WA7665//Madsen//Tyee'. ARS Amber has maturity, plant height, and cold tolerance that are equal to Xerpha. In USDA-ARS trials, ARS-Amber has test weight that tends to be lower than Tubbs and Xerpha in the very dry environments but equal to or higher than check cultivars in high rainfall trials. Grain yield of ARS-Amber is less than Tubbs and Xerpha in very dry environments and higher than both of those lines in >15 inch rainfall environments. ARS-Amber also has shown tolerance to acid soils (rated 1 on a 1-5 scale where 1=resistance and 5=susceptibility) and to Fusarium crown rot (caused by *Fusarium pseudograminearum*) (rated 3.4 on a 1-10 scale where 1=resistance and 10=susceptibility), both limiting yield factors in parts of its target production zone. Current test data indicates that the release is best suited to the intermediate rainfall region of dryland cropping region in eastern Washington. ARS-Crescent was tested under experimental number: ARS970163-4C with the pedigree: 'Dusty'//Madsen sib/Dusty/3/WA7665/'Rulo'. ARS-Crescent is an intermediate to tall, awned white kernel club wheat with yield potential as good as 'Bruehl', coleoptile length equal to Bruehl, maturity and winter tolerance equal to Eltan, resistance to stripe rust and strawbreaker foot rot, and good test weight and end use quality. Because of its height and maturity, it is recommended for the traditional club wheat cultivation areas in WA. It is intended to compete with Bruehl in the non-snow mold areas of WA. ARS-Crescent has a good level of HTAP resistance that should completely protect crop under low to moderate levels of stripe rust epidemic and yield loss should be minimal under extremely severe epidemics like in 2010 and 2011.



ARS Amber (left) and ARS Crescent (right) breeder seed growout at Othello, 2011.

Increasing Winter Wheat Productivity through Increased Coleoptile Length and Speed of Germination

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One of the main production issues faced with growing winter wheat in the summer fallow/winter wheat rotation areas of east central Washington is emergence potential. With varying levels of soil moisture requiring planting depths of up to 8", wheat must be able to germinate under harsh conditions and emerge through layers of soil. As a result, this is a primary objective of the WSU Winter Wheat Breeding Programs efforts. The Otto and Doris Amen Dryland Research Foundation graciously provided funding to: 1) screen and select winter wheat breeding lines for longer coleoptiles; and 2) to screen entries for speed of germination and emergence at low water potentials (dry soils).

Differences in speed of germination among 52 wheat lines were observed in a laboratory test under four different water potentials. Genotypes from the soft market class germinated faster than the hard market class, although not statistically significant. While significant differences among genotypes were difficult to detect, cultivars Bitterroot, Boundary and Brundage 96 were among the fastest germinating entries at each level of water potential. This information will be used to help determine which lines will germinate and emerge faster under the dry soil conditions experienced during planting.

Breeding lines from the winter wheat breeding program are screened each year in the greenhouse to identify lines with long coleoptiles. Based on results from this screening, WA8156 (HRW) was selected for its long coleoptile and has been entered into the WSU Uniform Variety Testing Program. WA8156 had the longest coleoptile of any entry in the 2010-2011 Advanced Hard Trials as well as the 2010-2011 Variety Testing hard nursery. Many other breeding lines have been identified as having long coleoptiles and are being advanced through the breeding program towards variety release.

This research will continue to help the winter wheat breeding program at WSU select for entries that exhibit superior emergence in the driest production areas of Eastern Washington.

Part 2. Pathology and Entomology

Control of Rusts of Wheat and Barley in 2011

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In 2011, the unusually severe stripe rust epidemic was accurately forecasted using our predication models. Rust updates and advises were provided on time to growers during the crop season, guiding on-time applications of fungicides, which reduced stripe rust damage and resulted in bumper harvest. We identified 35 races of wheat stripe rust and 8 races of barley stripe rust and determined their frequencies and distributions in the US. We developed more than 30 molecular markers for stripe rust and characterized more than 300 wheat stripe rust isolates from 18 countries by virulence and molecular markers, and determined their genetic relationships. Using the molecular markers and virulence tests, our studies various studies showed that barberry is not important for stripe rust, but essential for stem rust in the Pacific Northwest; somatic recombination is important for wheat stripe rust; and somatic hybridization occurs between wheat and barley stripe rust forms. We evaluated more than 20,000 wheat and barley entries for resistance to stripe rust. As results of our tests, several wheat varieties with adequate stripe rust resistance were released or registered in 2011. We registered 70 new wheat germplasm lines with different stripe rust resistance genes and plant types better than the original resistance donors. We officially named stripe rust resistance genes *Yr52* and *Yr53* in wheat; and identified and mapped three new genes in wheat germplasm lines (PI 178759, PI 331260 and PI 480016) for resistance to stripe rust; and provide seed of the lines to various breeding programs. The new germplasm lines, identified genes and their markers will be useful in breeding new varieties with stripe rust resistance and in monitoring virulence changes in the stripe rust population. The results of our fungicide tests and yield loss tests of major currently grown varieties are essential for registering new fungicides and for guiding disease management.

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

TIM MURRAY, HENRY WETZEL III, KATHY ESVELT-KLOS, HONGYAN SHENG AND DANILO VERA; DEPT. OF PLANT PATHOLOGY, WSU

Eyespot (strawbreaker foot rot) and Cephalosporium stripe are important diseases of winter wheat in the Pacific Northwest. These diseases occur across a wide range of the wheat-producing area and have potential to cause loss in grain yield up to 50% for eyespot and up to 80% or more where Cephalosporium stripe is severe. Early-seeded winter wheat has the greatest risk of being affected by these diseases, especially when planted following summer fallow. Planting eyespot-resistant varieties like Madsen have become the primary control, although fungicide application in spring is still important in some areas. Our research is focusing on identifying new and effective sources of resistance to both of these diseases. As part of that research, we invite both public and private breeding programs to submit new varieties and advanced breeding lines to our field tests for eyespot and Cephalosporium stripe resistance. Currently, Alto, Tilt and Topsin-M are the only fungicides registered for eyespot. We are testing potential new fungicides for activity against eyespot and have identified two candidates for further testing in 2012.

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. Improving methods to identify new resistant varieties in the lab and greenhouse is a major focus of our current research activities. In conjunction with the WSU winter wheat breeding program, we are also testing current and new varieties for snow mold resistance in field plots near Mansfield and Waterville, WA.

Soilborne wheat mosaic (SBWM) is a new problem for Washington wheat growers having been first recognized in 2008 in the Walla Walla area. This disease 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. The problem appears limited to the Walla Walla area at the current time, but we have been collaborating with scientists from Oregon State University to screen PNW wheat varieties for resistance. A few varieties from the PNW have some resistance, with the hard red winter wheats having the best resistance as a class.

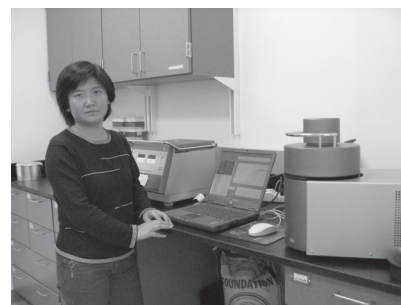
Results of our field test data are available online at the WSU Variety testing website (<http://variety.wsu.edu>) and Plant Disease Management Reports (<http://www.plantmanagementnetwork.org/pub/trial/PDMR/reports/2012>). This research is part of our long-term goal to improve resistance of winter wheat varieties to these important diseases and thereby reduce yield losses for Washington State wheat growers.

Molecular Diagnostics for Plant-Parasitic Nematodes in the Pacific Northwest

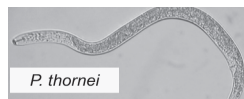
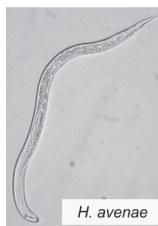
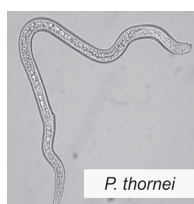
PATRICIA OKUBARA¹, GUIPING YAN² AND RICHARD SMILEY²

¹USDA-ARS, ROOT DISEASE AND BIOLOGICAL CONTROL RESEARCH UNIT, PULLMAN; ²COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER, OSU, PENDLETON, OR

Plant-parasitic nematodes affect the health and yields of wheat, barley and other crops of Pacific Northwest (PNW). The root-lesion nematodes *Pratylenchus thornei* and *P. neglectus* are estimated to cause \$51 million losses to the wheat industry each year. Crops used in rotation with wheat, including pea, chickpea, lentil, canola and mustard, are also susceptible to root-lesion nematodes. The cereal cyst nematodes *Heterodera avenae* and *H. filipjevi* pose additional threats to wheat and barley production, causing estimated annual losses of at least \$3.4 million. We have developed rapid, sensitive and specific conventional and real-time PCR assays for *P. thornei*, *P. neglectus*, and *H. filipjevi* in PNW soils. Conventional PCR assays detect 60 and 150 *P. thornei* and *P. neglectus* juveniles per pound of soil, respectively, well below the calculated economic threshold of 1,000 juveniles per pound of soil. Our real-time PCR assay for *P. thornei* detects 450 juveniles per pound and correlates well ($r^2=0.76$) to the conventional extraction and counting method. The molecular diagnostic assays circumvent time-consuming quantification and microscopic examination of the nematodes, thereby facilitating surveys and management assessments. Real-time PCR assays for *P. neglectus* and *H. avenae* are being developed.



Top: Guiping Yan conducting real-time PCR assays. Left: Micrographs of the nematodes



Anomalous Armyworm Infestations in Eastern Washington and Oregon Wheat Implicate *Dargida* spp. plus other Noctuids

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Unusual, armyworm-type damage to wheat and barley crops in Lincoln County, WA, and Umatilla County, OR, in 2007 and 2008 prompted concern and further investigation. Damage in each county was restricted to areas about 20 miles in diameter.

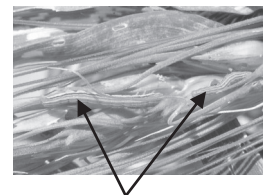
Universal Moth Traps baited with an armyworm sex attractant (pheromone) were effective in trapping male moths. Traps located across the cereal-producing counties of eastern Washington in 2009 and 2010, and Umatilla County, OR, in 2010 and 2011, confirmed the presence of the original suspect, the wheat head armyworm *Dargida diffusa* (Walker). However, the native species *Dargida terrapictalis* (Buckett) was the predominant Noctuid moth captured.



Dargida diffusa –
“true” wheat head armyworm



Dargida terrapictalis –
“false” wheat head armyworm

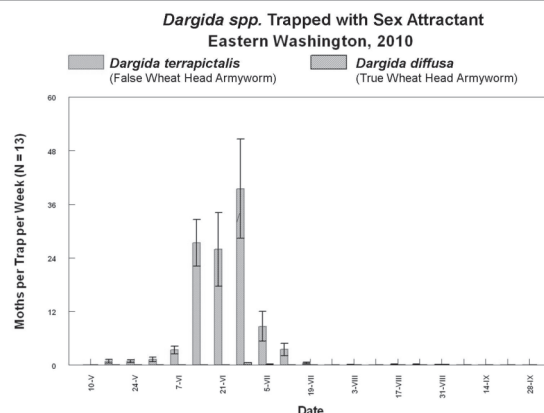


Armyworm larvae on wheat head

After 2008, unfortunately, the absence of larvae feeding in the field precluded positive identification of the pest. So the host range and pest status of *D. terrapictalis* remain unconfirmed. Three other grass-feeding Noctuids were captured and may also be part of the pest spectrum.

A naturally-occurring but unidentified parasitic wasp contributed to the apparent disappearance of this pest. No-till (high residue) farming practices were implicated in the Washington State pest occurrence, but the correlation did not hold with infestations in Oregon and Idaho.

The seasonal flight pattern of the male moths was determined for crop-scouting. Since 2009, growers in the affected areas have used trap data and scouting techniques to confirm that armyworm infestations were not a concern, thus saving \$150,000 per year in insecticide applications.



Controlling Wireworms with Neonicotinoid Insecticides in Wheat

ESSER,^{*} A.D.¹, K.S. PIKE², AND R. DEWALD³

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

Wireworm (*Limonius* spp.) populations and crop damage have been increasing in wheat (*Triticum aestivum* L.) production across eastern Washington. Today nearly all cereal crop acres throughout eastern Washington are treated for wireworm control with neonicotinoid insecticides such as Cruiser® (thiamethoxam) and Gaucho® (imidacloprid) at rates between 0.190-0.315 oz/cwt. At these rates, the neonicotinoids are toxic to wireworms but at sub-lethal doses, or in other words they repel or provide some seedling protection only. Our objective is to determine if we can find a lethal dose of neonicotinoid insecticide and reduce wireworm populations. An on-farm test (OFT) was initiated in the spring of 2008 to examine spring wheat treated with 2.00 oz/cwt of Gaucho vs. a non-Gaucho treated spring wheat control. At this location 2.00 oz/cwt Gaucho had a trend for improved yield, economic return over costs, and reduced wireworm populations and concluded additional research is needed. A second OFT was repeated in the spring of 2010. Spring wheat treated with 2.00 oz/cwt Gaucho significantly improved yield, economic return over costs, and wireworm population data will be collected this spring using a modified wireworm solar bait trap and this data will be presented.

Lignin as a Potential Defense against Plant Parasitic Nematodes

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Root lesion nematodes (RLN) (*Pratylenchus thornei* and *P. neglectus*) are a characterized soil borne pathogen of wheat. In the Pacific Northwest (PNW) these species of nematode were found in 95% of sampled fields. Nematicide tolerance trials have estimated RLN can cause between 37% and 50% yield loss in PNW cultivars. Resistance to these pathogens has been found in wheat landraces from Iran. One of these sources of resistance to both nematode species, AUS28451, has been crossed to local

cultivars and a mapping population has been developed. The mechanism of resistance to *P. thornei* and *P. neglectus* is poorly understood; understanding how resistance works can increase the efficiency of resistance breeding. Early observational studies show that, Louise a susceptible PNW-adapted spring wheat cultivar is readily penetrated by RLN but that AUS28451 has little to no root penetration (Fig. 1). AUS28451 has increased amounts of lignin, a cell wall fortifying compound, and this trait is being examined as a potential cause for the nematodes inability to penetrate the roots. Lignin stained root cross sections of Louise and AUS28451 show more intense staining (red) in AUS28451 than Louise, particularly in the epidermal cell layers (Fig. 2). Lignin extractions using a thioglycolic acid (TGA) precipitation method have also shown that AUS28451 has more root lignin than Louise (Fig. 3). This data indicates that lignin amounts might be associated with for *P. thornei* and *P. neglectus* resistance. We are continuing to investigate this association in a recombinant inbred mapping population derived from Louise and AUS28451.

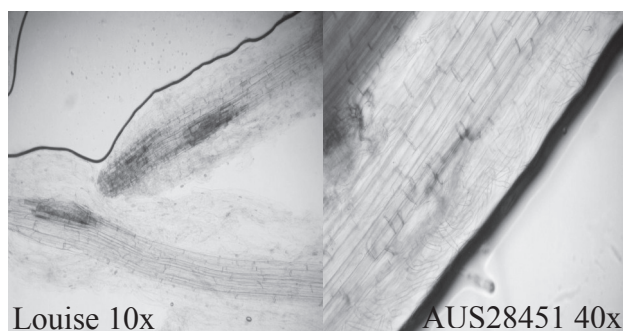


Fig. 1.

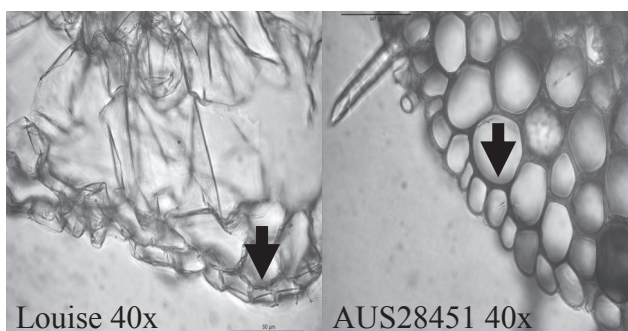


Fig. 2.

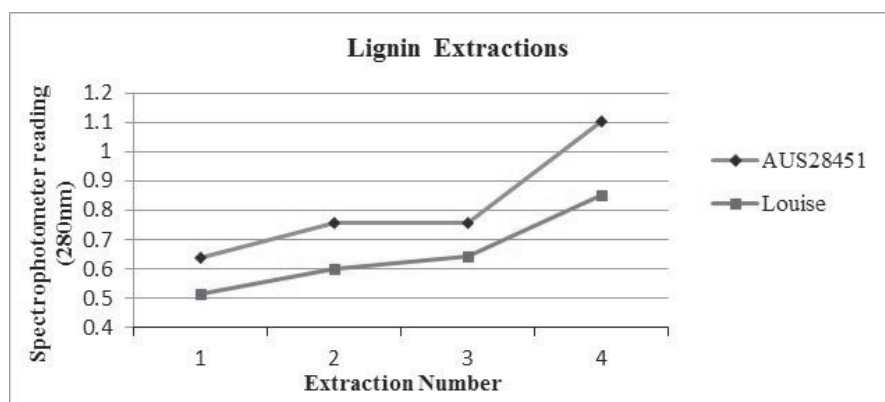


Fig. 3.

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

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

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

Some farmers apply insecticides routinely to avoid crop damage, while others defer treatment until aphid numbers warrant the cost of treatment. Both approaches require an uncertain decision, and may result in unnecessary treatment costs or economic yield loss. This project provides several tools that improve the management options available to producers.

1) Early Warning System: Since 2007 a geo-referenced network of 30 pan trap locations has been used to monitor aphid arrival. PCR (polymerase chain reaction) is used to test the aphids from these sites to determine if they carry PEMV/BLRV. These sites are also surveyed twice per season for the presence of PEMV/BLRV in the pulse crop itself. The data are integrated into Geographic Information System (GIS) data layers and made available online. Also, virologists at the University of Idaho are identifying

alternative host plants for both the virus and aphid.

Email listservs are used to alert farmers and crop consultants of aphid infestations and whether they carry virus – which greatly influences potential damage to legume crops and the aphid population levels at which growers should apply insecticide. This information is also posted to the Aphid Tracker website at <http://www.cals.uidaho.edu/aphidtracker/index.asp>.

2) Decision Tools: We have developed the first research-based economic injury level for pea aphid in pea crops on the Palouse. In addition, 5 years of field survey results were used to estimate the spatially variable character of disease prevalence on the landscape, as well as a region-wide estimation of aphid density based on historical meteorological data and an index of aphid abundance from 1986-2006. These elements have been incorporated into online tools to help producers decide about seed treatments and early season sprays for aphid control.

Online calculators have been constructed from these data:

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

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

Mutation Breeding of Cultivated Barley and Screening of Wild Barley for Resistance to Rhizoctonia Root Rot

O. AJAYI, S. ULLRICH, T. PAULITZ, K. CAMPBELL AND K. MURPHY; DEPT. OF CROP AND SOIL SCIENCES, WSU AND USDA-ARS

Rhizoctonia root rot and bare-patch caused by *Rhizoctonia solani* G-8 is one of the most important diseases that limit crop yields in no-till/direct seeding systems in the Pacific Northwest (PNW), and in turn, limiting the widespread adoption of this system in this region. But in the PNW, spring cropping with no-till/direct seeding offers a potentially better approach to increasing cropping intensity and circumventing the negative impacts tillage has on the environment, mainly on soil and water due to erosion. However for spring barley, an important rotational crop with winter wheat, peas and lentils, Rhizoctonia root rot appears to be the most important disease under direct seeding systems. The role of barley as a rotational crop highlights the possibility for its use in managing the disease if resistant barley cultivars are included in the normal 2-3 year rotations with winter wheat under reduced tillage in any growing environment. Furthermore, it has been shown that barley in rotation with winter wheat improves the productivity of winter wheat. Therefore, the objective of our research is to identify potential sources of resistance to *R. solani* AG-8 in barley. Since there is no known resistance in the natural populations of barley available to breeders, we employed two approaches to achieve the set objective. Firstly, we employed induced mutation as a means of creating new genetic variation. The first experiment involved screening sodium azide barley mutants for disease reaction to *R. solani* AG-8, verifying the resistance in putative mutants, and carrying out genetic analysis to determine the mode of inheritance of resistance to the pathogen. Ten putative M₃ individuals from 2 different barley lines, 05WA-316.99 and 'Lenetah' have been verified for resistance and crosses have been made to the wild type to begin inheritance studies. Secondly, given the importance of wild crop relatives to crop improvement, our second experiment involved exploring the possibility of identifying resistance to the disease in the direct progenitor of cultivated barley *Hordeum vulgare* subsp. *spontaneum*. Of the entire pool of 316 accessions in the Wild Barley Diversity Collection that was screened for resistance, 6 accessions showed potential as gene donors for Rhizoctonia resistance with one accession, WBDC 021 showing the greatest potential based on the disease ratings and other growth parameters measured. Further testing is currently being carried out to verify the resistance of these accessions to *R. solani* AG-8 and also to *R. oryzae*, another pathogen known to cause root rot of wheat and barley and found with *R. solani* AG-8 in production fields. The overall goal is to release resistant barley cultivars to farmers in the PNW, thereby, providing a more sustainable and environmentally sound means of managing the disease.

Part 3. Agronomy, Economics, and Sustainability

Decomposition of Crop Residue in Dryland Ecosystems

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

Residue management is a major concern for growers who wish to practice conservation farming in the dryland Pacific Northwest. Residue from crops and cultivars vary in fiber and nutrient content, and thus in decomposition potential. Winter wheat (WW), spring barley (SB), winter canola and spring canola cultivars were characterized for fiber and nutrient content. We analyzed cereal residue from four locations (Lind/Ritzville, Lamont, Dayton, Pullman, WA) over four years (2008-10) and found that cultivars varied in their neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), carbon (C), and nitrogen (N) content. Plant hemicellulose, cellulose and lignin can be estimated through NDF, ADF and ADL analysis, and higher NDF, ADF, and ADL are indicators of slower residue decomposition. Acid detergent lignin was highest in spring barley, and lowest in soft white winter wheat. Cultivars that could be classified as having characteristics for either rapid or slow decomposition are listed in Table 1. Decomposition of wheat and barley residue enclosed in fabric bags and buried in the field varied with cultivar, location and crop type. Soft white club WW decomposed most slowly (17.7% of mass lost) compared to SB (22.6%) and hard white WW (23.2%) ($P < 0.05$).

Table 1: List of wheat cultivars which had characteristics for either rapid or slow decomposition in laboratory analyses and field buried bag studies.

Decomposition Potential	Market Class	Cultivars
Rapid	Spring Barley	<i>Champion, Legacy</i>
	Soft Winter Wheat	<i>Eltan, Xerpha</i>
	Hard Winter Wheat	<i>Bauermeister, MDM</i>
Slow	Spring Barley	<i>Radiant</i>
	Soft Winter Wheat	<i>Bruehl, Cara, AP700CL, Madsen, Finch</i>
	Hard Winter Wheat	<i>Farnum, Palomino</i>

Canola produces lower amounts of residue than wheat; however, little is known about the residue characteristics of spring and winter canola cultivars currently grown, and how those factors affect decomposition and soil quality. Winter and spring canola residue was collected in 2011 from Univ. of Idaho Canola Variety Trials. The stalks of canola residue contained higher NDF, ADF and ADL than the litter (small stalks, leaves, pods), and spring canola residue contained higher NDF, ADF and ADL than winter canola residue ($P < 0.05$). Information on differences in residue decomposition among wheat, barley and canola cultivars will assist growers in selecting cultivars for reduced tillage systems that conserve soil and water, and enhance build-up of soil organic matter.

Kentucky Bluegrass for Non-burn Seed Production

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

Open-field burning of Kentucky bluegrass (*Poa pratensis* L.) post-harvest residue, which maintains grass seed yield and stand longevity, has been eliminated in Washington. The objective of our study was to develop bluegrasses that have sustainable seed yield without post-harvest field burning and still maintain acceptable turfgrass quality. This long-term study consisted of 10 Kentucky bluegrass (*Poa pratensis* L.) entries; eight are USDA/ARS Plant Introduction (PI) accessions and two are commercial cultivars ('Kenblue' and 'Midnight'). The selected PI accessions, in previous research, had expressed high seed yield without burning of post-harvest residue and good turfgrass quality. Several agronomic yield parameters were then evaluated over a 2-yr period and individual plants were reselected within each accession, or check, with the highest seed weight, highest seeds/panicle, highest panicles/area, and highest seed yield. Remnant seed of the original USDA/ARS population were also included. Turfgrass plots were established in 2006 and seed production plots (irrigated and non-irrigated) in 2007 at Pullman, WA. The turfgrass trial was evaluated monthly according to NTEP (National Turfgrass Evaluation Program) protocol to determine turfgrass quality. Seed

production plots were harvested (2008 to 2011) and seed yield was determined (2011 data presented).

Results for 2011 (4th harvest) indicated that selection for seed yield components had a variable response and Kentucky bluegrass seed yield was primarily dependent on accession. Accession PI 368241 showed the best promise of being able to provide good turfgrass quality and seed yield under non-burn management in both non-irrigated and irrigated seed production (Fig. 1 and 2). One selection within Kenblue, seed/head, had good turfgrass quality and seed yield. These studies will be followed during 2012 to determine if the seed yields are sustainable.

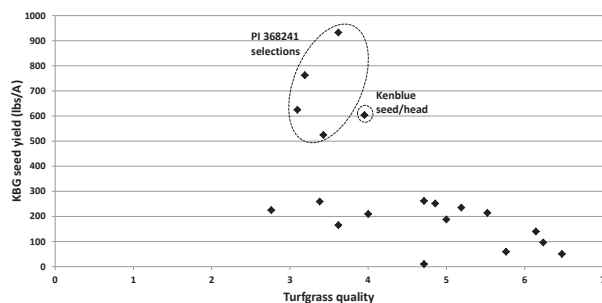


Fig. 1. Kentucky bluegrass non-irrigated seed yield vs. turfgrass quality (rated 1-9; 9 = excellent quality) at Pullman, WA, 2011.

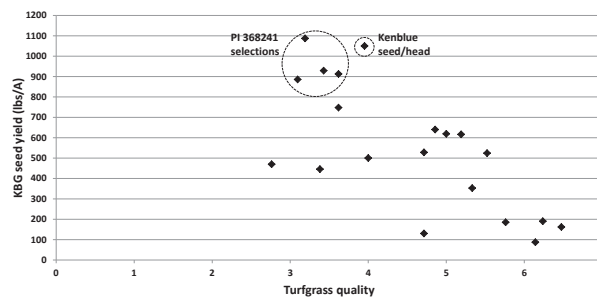


Fig. 2. Kentucky bluegrass irrigated seed yield vs. turfgrass quality (rated 1-9; 9 = excellent quality) at Pullman, WA, 2011.

Toward Better Prediction of Wind Erosion

BRENTON SHARRATT, USDA-ARS AND VENKAT VADDELLA, WSU, PULLMAN

The Wind Erosion Prediction System (WEPS) was developed for assessing the impact of land management practices on wind erosion and to identify lands that are highly susceptible to wind erosion. Although WEPS has been tested and found to perform adequately across the Columbia Plateau, there have been many occasions when WEPS has failed to predict wind erosion during high wind events. Failure of WEPS to predict wind erosion is believed to be caused by overestimation of the threshold friction velocity of soils in the Columbia Plateau. Wind erosion only occurs when the friction velocity exceeds the threshold friction velocity of the surface, thus overestimation of threshold friction velocity will result in suppressed or no simulated erosion. Threshold friction velocities of soils found across the Columbia Plateau region are virtually unknown. We determined the threshold friction velocity of a sandy loam and four silt loams found in eastern Washington by systematically increasing wind speed and simultaneously measuring saltation activity and dust (particles $\leq 100 \mu\text{m}$ in diameter) concentrations above the soil surface inside a wind tunnel. An increase in saltation activity or dust concentrations above background levels signified the attainment of the threshold friction velocity. The threshold friction velocity of the sandy loam was about 0.14 m s^{-1} (0.3 mph) whereas the threshold velocity of the four silt loams ranged from 0.19 to 0.25 m s^{-1} (0.4 to 0.6 mph). The threshold friction velocities measured in this study were lower than the minimum threshold velocity required to initiate erosion in WEPS. These low threshold friction velocities may contribute to the occasional failure of WEPS to predict wind erosion in the Columbia Plateau.

Mild Freeze-thaw Cycles Improve Freezing Tolerance of Winter Wheat

DAN SKINNER, KIM GARLAND-CAMPBELL, AND BRIAN BELLINGER, USDA-ARS AND DEPT. OF CROP AND SOIL SCIENCES, WSU

Autumn months in winter wheat-growing regions typically experience significant rainfall and several days or weeks of mild subfreezing temperatures at night, followed by above-freezing temperatures in the day. Hence, the wheat plants usually are first exposed to potentially damaging subfreezing temperatures when they have high moisture content, are growing in very wet soil, and have been exposed to several mild freeze-thaw cycles. These conditions are conducive to freezing stresses and plant responses that are different from those that occur under lower moisture conditions without freeze-thaw cycles. We have studied the impact of mild subfreezing temperature and freeze-thaw cycles on the ability of 22 winter wheat cultivars to tolerate freezing in saturated soil. Seedlings that had been acclimated at $+4^\circ\text{C}$ for 5 weeks in saturated soil were frozen to potentially damaging temperatures (-14 to -16°C) under four treatment conditions: (1) without any freeze-thaw pre-freezing treatment; (2) with a freeze-thaw cycle of -3°C for 24 hours followed by $+4^\circ\text{C}$ for 24 hours, (3) as in treatment (2) but with thawing at $+4^\circ\text{C}$ for 48 hours after

the -3°C freeze, and (4) as in treatment (2) but with the freeze-thaw cycle repeated twice. Plants that had been exposed to one freeze-thaw cycle survived significantly more frequently than plants frozen without a freeze-thaw pre-freezing treatment (Fig. 1). Thawing for 48 hours did not improve survival compared to thawing for 24 hours (Fig. 1). Subjecting the plants to two cycles of freezing and thawing (for 24 hours) resulted in greater survival than one cycle (Fig. 1). These results indicated that cold-acclimated wheat plants actively acclimate to freezing stress while exposed to mild subfreezing temperatures, and further acclimate when allowed to thaw at +4° C for 24 hours. Because thawing for 48 hours did not improve survival compared to thawing for 24 hours, it appeared the processes involved in this freeze-thaw enhanced freezing tolerance were essentially complete within 24 hours of returning to above-freezing temperatures. However, because two freeze-thaw cycles resulted in greater survival than one cycle, it appears the process can be restarted, or a second process started, by again returning to subfreezing temperatures after an initial freeze-thaw cycle. Further study of the response to freeze-thaw cycles may result in the discovery of previously unknown genes that contribute to the ability of wheat plants to survive the winter.

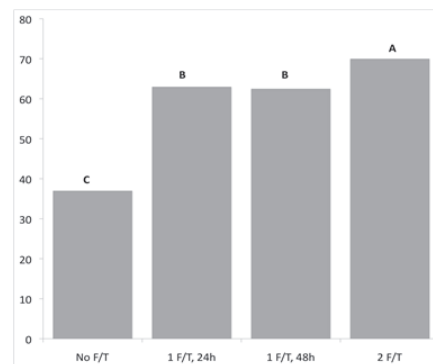


Fig. 1. Average survival of 22 winter wheat cultivars after 0, 1, or 2 freeze-thaw cycles with freezing at -3°C, followed by thawing at +4°C for 24 or 48 hours. Bars with the same letter indicate nonsignificant differences.

Final Agronomic and Economic Results from the WAWG/NRCS Undercutter Project

DOUG YOUNG, SCHOOL OF ECONOMIC SCIENCES, WSU; BILL SCHILLINGER, DEPT. OF CROP AND SOIL SCIENCES, WSU; HARRY SCHAFER, MANAGER, WAWG/NRCS UNDERCUTTER PROJECT

The Washington Association of Wheat Growers/Natural Resources Conservation Service (WAWG/NRCS) Undercutter Project was targeted to the winter-wheat/summer fallow region of Washington and Oregon that receives 12 or less inches average annual precipitation. The undercutter method of summer fallow employs wide-blade V-sweeps for primary tillage plus fertilizer injection, followed by as few as one non-inversion rodweeding operation. The undercutter method increases surface residue and roughness that provides significantly more protective cover against wind erosion compared to traditional conventional tillage.

Forty-seven growers located in 10 counties in Washington and Oregon enrolled in the program. Participating growers received a 50 percent cost share for purchase of a new undercutter capable of injecting fertilizer on the condition that they use their undercutter for primary spring tillage plus fertilizer injection on at least 160 acres per year for three years. These growers were interviewed regarding the agronomic and economic performance of undercutter versus conventional fallow twice per year during 2008-2010. Interview results showed that participating farmers achieved statistically equal winter wheat grain yields on the same farms within years for the two systems which implied equal economic gross returns. Similarly, statistically equal glyphosate, fertilizer, seed, and other input use implied equal costs for these inputs. Furthermore, there were no significant cost differences between systems in fertilizer application or primary spring tillage. Consequently, economic budgeting shows that the undercutter and conventional tillage systems averaged equal profitability. These results obtained from actual farms over three years confirm data of equal profitability based on an earlier 6-year field experiment conducted at Lind, WA that compared undercutter and conventional tillage systems. Surveyed farmers' subjective satisfaction with the undercutter also improved over time. Furthermore, in all years, 40% or more of farmers expected greater profit with the undercutter.

On the other hand, farmers reported a "learning curve" with the undercutter and variable performance on different soils. Participants complained most frequently about maintaining depth control at speeds greater than 4 miles/hr, blade wear, difficulty operating in heavy residue, shank kickbacks not setting properly, and problems with large soil clods leaving some air voids between the surface and the depth of tillage. Blade wear can be reduced by at least 50% by chrome plating which also permits soil to more easily slide over the undercutter blade, thus reducing drag. Large clods can be readily sized, and air voids eliminated, with a light weight rotary harrow-type implement that attaches directly to the back of the undercutter frame. Many of the farmer participants installed such an attachment on their undercutter.

This study provides promising economic results for the environmentally-friendly undercutter tillage fallow system. With the demonstration of equal profitability through paired comparisons of undercutter and conventional systems within the same farms and years during this 3-year study, we conclude the undercutter system offers a costless air quality gain to society and soil conservation benefit for farmers. This study provides a rare multi-year on-farm statistical confirmation of a promising conservation tillage method.

Changes in Use of Conservation Practices in Whitman and Latah Counties, 1980-2010

DOUG YOUNG, SCHOOL OF ECONOMIC SCIENCES, WSU AND STEPHANIE KANE, SOCIAL SCIENCE RESEARCH UNIT, U OF I

STEEP researchers surveyed 306 randomly selected farmers in 1980, and 279 in 2010, in Latah, ID and Whitman, WA counties. The results in Table 1 show great growth in direct seeding in these eastern Palouse counties over three decades. Most other conservation practices have also enjoyed greater use recently. The results are not acreage-weighted, but show some degree of use or awareness by responding farmers. In part, this progress might be attributed to conservation research and extension by STEEP and other groups over the past from 1974 to the present. Increased stewardship values over time do not appear to underlie the results because in 2010 65% of respondents would forego income/acre ranging from \$3-\$20 to reduce erosion compared to only 48% in 2010. Lower fractions were also concerned by off-site erosion damage in 2010.

Table 1. Percentage of farmers in Latah and Whitman counties reporting use or awareness of conservation practices in 1980 (italicized, first row) and 2010 (second row)

Practice	now using	used in the past	plan on using in the future	interested in, but not sure	do not plan to use	not aware of it	not applicable
a. Minimum tillage *	<i>56</i> 64	<i>7</i> 13	<i>2</i> 5	<i>18</i> 3	<i>13</i> 3	<i>0</i> 0	<i>3</i> 10
b. Direct seeding or no-till ****	<i>5</i> 37	<i>2</i> 17	<i>4</i> 8	<i>27</i> 13	<i>14</i> 14	<i>0</i> 0	<i>4</i> 11
c. Divided slope farming/Strip cropping, ns	<i>37</i> 38	<i>8</i> 19	<i>2</i> 1	<i>15</i> 3	<i>17</i> 20	<i>1</i> 0	<i>20</i> 19
d. Seeding critical areas to grass, L	<i>61</i> 57	<i>11</i> 8	<i>5</i> 5	<i>4</i> 7	<i>11</i> 14	<i>0</i> 1	<i>8</i> 7
e. Leave stubble stand during winter, **	<i>27</i> 43	<i>28</i> 16	<i>1</i> 4	<i>3</i> 5	<i>22</i> 19	<i>0</i> 0	<i>1</i> 12
f. Sediment basins or gully plugs, ***	<i>14</i> 30	<i>3</i> 8	<i>3</i> 5	<i>16</i> 6	<i>30</i> 27	<i>5</i> 5	<i>31</i> 18
g. Terraces, ***	<i>3</i> 10	<i>1</i> 3	<i>2</i> 1	<i>10</i> 5	<i>35</i> 52	<i>1</i> 1	<i>48</i> 28

Notes: Row percentages may not sum to 100 due to rounding.

The one-tailed Jonckheere-Terpstra test is used throughout. NA responses are excluded in the statistical tests. **** implies change at .0001 signif. level, *** at .001 level, ** at .01 level. * at .05 level. ns = not significant. "L" denotes less adoption in 2010 vs 1980.

Why Did Eastern Washington Wheat Growers Reject the 2011 BCAP Camelina Incentive Program?

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Wheat growers must have sharp pencils when evaluating shifting markets, evolving government commodity programs, new regulations, investment opportunities from business firms, new technologies offered by researchers, new products from agribusinesses, and incentive programs to solve national problems. The recent Biomass Crop Assistance Program (BCAP) is an example of an incentive program to reduce U.S. dependence on fossil fuels. The BCAP, with signups in summer 2011, offered annual payments, subject to deductions, as incentives to eligible operators to produce camelina oilseed for bio-based products and

advanced biofuels. In Washington, camelina incentives equaled \$102/ac in Spokane County, \$99.50/ac in Whitman County, \$91/ac in Garfield County, \$64/ac in Adams County, and \$56/ac in Franklin County. *Despite the sizeable incentives, not a single Washington farmer signed a BCAP contract to grow camelina.*

Table 1 reports the breakeven (BE*) camelina prices, yields and variable costs to permit this new oilseed to compete successfully with traditional grain and legume crops in different precipitation zones of eastern Washington. Breakeven prices (P_{BE*}) for camelina always substantially exceeded the base offer price for the oilseed during summer 2011. Breakeven yields for camelina (Y_{BE*}) also exceeded experiment-based yields for the crop by precipitation zone. Similarly breakeven variable costs (VC_{BE*}) were far lower than actual (base) variable costs for camelina. The final column in Table 1 shows that using the BCAP subsidy to reduce variable costs (Base VC – BCAP) still leaves these costs above breakeven levels (VC_{BE*}).

Table 1. Breakeven (BE*) camelina prices, yields and variable costs by E. WA ppt zone

Zone (av. in. ppt/yr)	Price (\$/cwt)		Yield (cwt/ac)		Variable Cost (\$/ac)		
	Base	P_{BE*}	Base	Y_{BE*}	Base	VC_{BE*}	Base VC - BCAP
HIGH (>17")	12.10	20.23	16.35	27.36	142	8.82	44.50
MEDIUM (15"- 17")	12.10	22.08	13.53	24.53	149	15.89	51.50
LOW (12"-15")	12.10	24.89	8.96	18.45	149	34.20	89.00
ARID (7"-12")	12.10	39.32	4.40	12.96	134	30.43	74.00

Note: BCAP subsidy averaged \$97.50/ac for HIGH and MEDIUM zones and \$60/ac for the two drier zones.

This analysis demonstrated that Washington dryland farmers were economically rational to decline participation in the BCAP camelina program. They could make more money by remaining with their traditional rotations of soft white winter wheat, edible pulses, and summer fallow. The BCAP subsidies were insufficient to reverse that conclusion. Further barriers to BCAP participation were added by the short notice, length and complexity of the contracts offered to farmers.

Marketing Opportunities for Dryland Organic Crops

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One of the many challenges to organic dryland farming is finding buyers for the crops produced, typically dry grains, feed and forages. Unlike the conventional export market, there is neither a well-established organic market, nor infrastructure for the transport and storage of organic grains and feed. One alternative, direct marketing to consumers, is challenging and time-consuming. Some growers have formed cooperatives to use their collective political and selling power to win contracts and build an alternative market for their products. However, there is not always an appropriate cooperative to meet the needs of particular growers, and building a cooperative is a tremendous task.

Despite these challenges, there is currently a demand for Pacific Northwest-grown organic grains and feed. Several companies are actively seeking producers of organic grains and feed in the Pacific Northwest. A list of 10 businesses, their crop needs and contact information can be found at http://csanr.wsu.edu/pages/Grain_Buyers_&_Sellers. These buyers are interested in purchasing wheat, barley, feed grains, hay, legumes, and other grains such as oats and triticale. At this time, the demand for local organic grain products is outstripping supply, resulting in the purchase of grain from other regions of the U.S., North America and overseas.

Additional work is needed to develop regional organic grain and feed markets to ease the costs and knowledge gap of transitioning to certified organic. In 2011, approximately 10,991 acreages in Washington were certified organic for grain, oilseeds and beans, and another 26,823 were certified organic for forage production, representing 42% of the total organic acreage in Washington. There is much that can be done to meet the needs of this growing grower pool, especially given how few resources are available to organic producers looking for alternatives to the export commodity markets.

Phosphorus Use Efficiency in Washington Spring Wheat

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Declining reserves, skyrocketing prices and environment pollution associated with phosphorus (P) fertilizer are spurring efforts to develop crops and cropping systems that use this resource more efficiently. Sales of fertilizer across Washington Counties indicate that phosphorus fertilizer application is prevalent across Eastern Washington. Despite that, there is a net export of P from the soil due to crop harvest.

Field trials were conducted in six environments in 2009 and 2010 to test the responsiveness of five spring wheat cultivars to P fertilizer. The trials were planted across the dryland grain production region of Eastern Washington representing conventional, organic and no-till management. Each site consisted of two fertilizer treatments, 20 lbs/acre of P fertilizer and no additional P, and five cultivars, Alpowa, Blanca Grande, Louise, Otis and Walworth, arranged in split-plot design with four replicates. Data on P uptake in the leaves and seeds over time were taken along with yield data.

A cultivar-dependent yield response to P was found in conventional and organic environments regardless of whether soil phosphorus levels tested as “sufficient” (>15 ppm, bicarbonate assay) or “insufficient” (<12 ppm). P fertilizer increased the tillering and final spike density of the wheat crop resulting in greater yield when there was sufficient rainfall to fill the grains. There was no response to P in the no-till sites. The most efficient users of P are most clearly differentiated in low P, drought-prone environments such as Lind, WA. Alpowa and Louise are efficient users of phosphorus, both yielding the highest and taking up the most P in the leaves and grain. They consistently outperformed three other spring wheat cultivars: Blanca Grande (hard white), Otis (hard white), and Walworth (hard red). Further studies are needed to determine the extent of genetic variation for P use efficiency among regionally adapted wheat cultivars.

Reducing Soil Compaction to Improve Winter Wheat Yield

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Producers in the dryland (<12 inches annual precipitation) cropping region of eastern Washington continue looking for methods to improve water infiltration, reduce restrictive soil compaction layers, maintain crop residue to prevent wind erosion and improve winter wheat grain yield. The Case IH Ecolo-til 2500 minimum-till ripper is an implement designed to minimize residue decomposition, reduce soil compaction, and increase water infiltration. The objective of this research is to determine if this implement benefits dryland winter wheat- summer fallow production. A 10-acre on-farm test was initiated in the fall of 2008 after winter wheat harvest examining two treatments: 1. Case IH Ecolo-til 2500 operation; 2. Check (no treatment). The on-farm test was repeated in 2009. The study was a RCBD with five replications each year. Data collected included soil compaction to a depth of 18 inches, soil moisture to a depth of 4-ft in 1-ft increments, grain yield, and grain quality. Overall the Case IH Ecolo-til 2500 minimum-till ripper significantly reduced soil compaction in the subsequent winter wheat plots between 7.8-14.0%. No differences in soil moisture were detected between treatments. Grain yield varied between treatment and years ($P<0.04$) with the Case IH Ecolo-til 2500 minimum-till ripper treatment increasing yield 3.4% in the 2008 site. No difference in grain yield was detected in 2009. Grain protein and test weight remained equal between treatments each year.

Managing Soil Nitrogen and Weeds Using Legume and Cereal-intensive Cropping Systems during the Transition Phase for Dryland Organic Wheat Production in Eastern Washington State

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Nine crop rotation systems were evaluated in Pullman, WA, during the transition to organic production (2003-05) to address soil fertility and weed management challenges experienced by dryland organic cereal growers in Eastern WA. Systems ranged from intensive small grain production to intensive legumes for forage (FOR; alfalfa + oat/pea) or green manure (GRM), and included systems with alternating small grains and legume GRM. The entire study was sown to certified organic spring wheat (SW) in 2006

and winter wheat (WW) in 2006-07. Regardless of the rotation system produced during the transition phase, soil inorganic N levels were similar among all systems (102 lbs acre⁻¹) at the start of organic production. However, SW had higher grain yields (3427 lbs acre⁻¹) following intensive FOR or GRM than systems that contained small grains for at least one year during the transition (2514 lbs acre⁻¹). Although organic soil properties improved following legumes compared to small grains, mid-season mowing of GRM and FOR reduced weed pressure throughout the transition and resulted in higher SW yields during certified organic production. Effective weed control strategies and management proved to be as important as increasing soil N for successful organic wheat production. Winter wheat was more competitive with weeds than SW. Higher WW yields (3748 lbs acre⁻¹) were found following systems that included legumes for at least one year of the transition compared to cereal or grain intensive systems (3006 lbs acre⁻¹). Spring and WW protein levels were higher when legumes were included for at least one year during the transition. Soil inorganic N levels (60 lbs acre⁻¹) were low across all systems following two years of organic wheat production and supplementing soil N throughout organic production is recommended. Additionally, further research should identify crop types and cultivars that are competitive in low-input, organic production systems.

Management of Wheat Density to Optimize Nitrogen and Water Use: Implications for Precision Agriculture

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In the Palouse region of the Pacific Northwest, USA, relationships between productivity, N dynamics and cycling, water availability, and environmental impacts result from intricate spatial and temporal variability. This complicates application of precision agriculture principles to improve crop and soil management. This research aims to investigate site-specific factors regulating nitrogen use efficiency (NUE) and the fate of N throughout the growing season of winter wheat (*Triticum aestivum* L.). Nitrogen and plant density field trials with winter wheat are underway at the Washington State University Cook Agronomy Farm near Pullman, WA under long-term no-tillage soil management. A key objectives of this research is to evaluate yield-water availability-NUE relationships among three landscape positions differing in yield potential and soil properties to improve overall N management. Preliminary data show that plant density manipulation combined with precision N applications resulted in greater wheat yield with less seed and N inputs. These findings indicate that improvements to NUE and sustainability of Pacific Northwest dryland agriculture should consider landscape-scale patterns driving productivity.



Tillage Strategies to Control Blowing Dust and PM₁₀ Emissions from Williston Reservoir Beaches in British Columbia

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Williston Reservoir in northern British Columbia was created when BC Hydro constructed Bennett Dam on the Peace River in 1968 to generate hydroelectric power. Williston Reservoir is the largest body of freshwater in British Columbia with a surface area of 685 square miles and a shoreline of 1100 miles. The First Nation Tsay Keh band was forced to relocate to the north end of the reservoir as a result of the water impoundment. When reservoir levels are at low pool in the spring, 25,000 acres of beach is exposed. Beaches are exposed for only two months during May and June and are covered with water during the remainder of the year. High

winds of more than 20 miles per hour cause dust storms from exposed beaches that impacts visibility and air quality in Tsay Key village. With funding and coordination by BC Hydro, we conducted a comprehensive 3-year field research project to evaluate methods to control blowing dust with various tillage practices. The basic tactic for the tillage is to bring silt-clay soil from the subsurface to the surface to provide durable roughness. Measurements included sand transport on the tilled versus check treatments using BSNE traps, detailed GPS mapping of sand transport into the tilled treatment from the check borders, surface roughness, and measurement of PM₁₀ concentrations with E-Samplers. These measurements were obtained after every wind storm. A separate tillage spacing experiment, using both twisted-point chisel and lister implements, was conducted to evaluate the comparative effectiveness of the implements and determine whether the entire beach area needs to be tilled to control blowing dust or if alternating strips of tilled and non-tilled ground would be adequate. Results show that when there is silt or clay within 12 inches of the soil surface, tillage will produce a rough and stable soil surface. We know from our experiences that, to minimize blowing dust from Williston Reservoir, as much beach area as feasible should be tilled as any non-tilled areas will serve as source areas of blowing dust.



Fig. 1. Tillage experiments at North Davis Flats Beach on Williston Reservoir in 2010. The photo was taken from a helicopter. These experiments covered 385 acres of land area.

Winter Triticale Produces High Grain and Straw Yields in the Dryland 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. This could change soon, however, due to the yield potential of winter triticale and the current high feed grain prices.

Winter triticale has been incorporated into the long-term cropping systems experiment on the Ron Jirava farm near Ritzville. We discovered through experimentation that winter triticale does considerably better than winter wheat from late (mid October or later) planting and we thought that triticale might be a good fit for no-till fallow. Early planting into no-till fallow in late August-early September summer is generally not feasible in the low-precipitation zone due to lack of seed-zone moisture. Winter triticale at the Jirava study is planted into no-till fallow.

The last two crop years at Ritzville have been considerably wetter than normal. With 12.30 inches of crop-precipitation in 2010, we produced 76 bushels/acre of 'Xerpha' winter wheat on tilled fallow and 4250 lbs/acre of late-planted 'TriMark 099' triticale (Fig. 1). Recrop no-till soft white spring wheat yielded 39 bushels/acre, or about half as much grain as the winter wheat and winter triticale.

Due to abundant precipitation in 2010, there was adequate soil moisture for early planting in the no-till fallow, so we planted half of each triticale plot early (Sept. 7) and the other half late (Oct. 20). Precipitation was again plentiful during the 2011 crop year with 13.01 inches received. Early-planted winter wheat yielded 75 bushels/acre whereas early-planted winter triticale yielded 6230 lbs/acre; the equivalent grain mass of 104 bushels of wheat (Fig. 1). The price a grower receives for triticale today (May 1, 2010) in

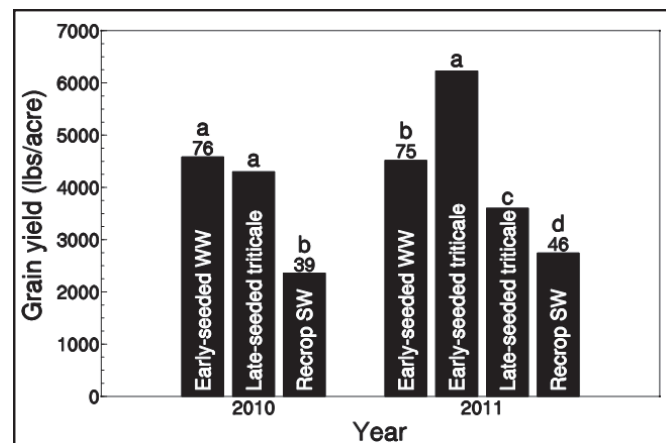


Fig. 1. Grain yield of 'Xerpha' winter wheat planted into tilled fallow, 'TriMark 099' winter triticale planted into no-till fallow, and continuous annual no-till 'Louise' spring wheat in the long-term cropping systems experiment near Ritzville, WA. Within-year grain yields followed by a different letter are significantly different at the 5% probability level.

Wilbur, WA is \$205 per ton versus \$6.40 per bushel for soft white wheat. Therefore a 75 bushel crop of wheat is worth \$480 per acre whereas 6230 lbs of triticale is worth \$639 per acre. Inputs for both crops were identical. The late-planted winter triticale produced 3570 lbs/acre (Fig. 1) for a value of \$366 per acre. Recrop soft white spring wheat produced 46 bushels/acre.

In early September 2011 we again had adequate seed-zone moisture in no-till fallow, so winter triticale was once more planted both early and late. Winter triticale can be grown in the same manner and with the same inputs and equipment used for winter wheat. For example, in-crop grass weed herbicides such as Maverick™ and Olympus™ can be used on triticale. Winter triticale grows taller and produces more residue than wheat (Fig. 2), thus it is a good choice for soils prone to wind erosion. If the price for feed grain remains high, we recommend that growers consider planting winter triticale on some of their acreage.



Fig. 2. Early-planted (right side) and late-planted (left side) winter triticale in 2011 near Ritzville, WA.

Critical Water Potentials for Germination of Wheat

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Low soil water potential limits or prevents germination and emergence of rainfed winter wheat. This phenomenon is particularly pronounced in the winter wheat-summer fallow region of the Inland Pacific Northwest where wheat is routinely sown deep to reach moisture with 4 to 6 inches of soil covering the seed. Wide differences in seedling emergence among winter wheat varieties have been reported, but no previous experiments have examined germination differences among varieties as a function of water potential.

The objective of our laboratory study was to quantify seed germination of five commonly-sown winter wheat varieties (Moro, Xerpha, Eltan, Buchanan, and Finley) at seven water potentials ranging from 0 to -1.5 MPa. Germination was measured as a function of time for a period of 30 days. At higher water potentials (0 to -0.5 MPa), all varieties had germination of more than 90%. At the lowest water potentials (-1.0 to -1.25 MPa), however, Moro consistently exceeded the other entries for speed and extent of germination with total germination of 74% at -1.0 MPa and 43% at -1.25 MPa. Since its release in 1966, Moro is sown by growers when seed-zone water conditions are marginal. Scientists have long known that coleoptile length is an important factor controlling winter wheat seedling emergence from deep sowing depths. In addition to having a long coleoptile, our data suggest that Moro's known excellent emergence ability to germinate from deep sowing depths in dry soils may also be attributed to the ability to germinate at lower water potentials than other varieties.

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

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We have completed the first year of a 3-year field experiment to evaluate the performance of several deep-furrow drill prototypes to determine their suitability for planting winter wheat into tilled summer fallow under high surface residue conditions. Six deep-furrow drill prototype configurations (four from WSU Lind, one from the McGregor Co., and one from Blake Strohmaier) were evaluated on Sept. 1, 2011 at the Ross Heimbigner farm near Ritzville, WA. The stubble from the 2010 winter wheat crop, ranging from 14 to 19 inches in height, was left standing and undisturbed over the winter and averaged 5400 lbs/acre. After a spring glyphosate herbicide application, we conducted primary spring tillage at a depth of five and a half inches on May 14 with a Haybuster Undercutter sweep with 60 lb N and 10 lb S per acre injected with the undercutter implement. Only one rodweeding was required to control weeds during the summer. Seed-zone moisture conditions at time of planting were excellent. The experiment was set up in a randomized complete block design with four replications of each of the six drill treatments. All the drill prototypes planted Bruehl club wheat in 300-ft-long strips.

There have already been several lessons learned from this project, including: (i) an HZ-type drill with 20-inch row spacing and a 150-type drill (i.e., staggered shank openers) with large packer wheels easily passed through heavy, loose residue, (ii) HZ-type drills with 16-inch row spacing and large packer wheels require some type of residue clearance mechanism in front of each boot, such as the offset spider wheel on the McGregor prototype, to avoid plugging, and (iii) there appears to be no advantage of having wide packer wheels (4-inch and 6-inch wide packer wheels halves) compared to narrower versions.

The 2012 experiment site is located on the Eric Maier farm northwest of Ritzville. The site produced 65 bu/acre Bruehl winter wheat in 2011. We cut the wheat in half of the experiment area at 14 inch height and the other at 22 inch height. We will undercut + fertilize at 5.5 inches depth in the spring, just like last year, and rodweed (only as needed to control weeds) at 4 inch depth. Therefore, we expect to have an even more challenging planting situation this year.



Fig. 1. Clockwise from left: (1) the WSU HZ-type drill with adjustable row spacing (seen here at 20-inch spacing); (2) the McGregor HZ-type drill on 16-inch row spacing with offset spider-wheel row cleaners in front of each opener and; (3) the WSU 150-type staggered-shank hoe-opener drill on 16-inch row spacing. These drills were equipped with 36-inch-diameter packer wheels and all three were successful planting through a deep tillage mulch with heavy residue in the 2011 experiment. Substantial modifications to the WSU drills have been carried out for the 2012 experiment.

Evaporation from High Residue No-till versus Tilled Fallow in a Dry Summer Climate

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Farmers in the low-precipitation (< 12 inch annual) region of the Inland Pacific Northwest practice summer fallow to produce winter wheat in a 2-year rotation. No-till fallow (NTF) is ideal for control of wind erosion but is not widely practiced because of seed-zone soil drying during the summer, whereas adequate seed-zone water for germination and emergence of deep-sown winter wheat can generally be retained with tilled fallow (TF). Successful establishment of winter wheat from late August – early September planting is critical for optimum grain yield potential. A 6-year field study was conducted to determine if accumulations of surface residue under long-term NTF might eventually be enough to substitute for TF in preserving seed-zone water over summer. Averaged over the six years, residue rates of 1300, 5400, and 9400 lbs/acre (1x, 4x, and 7x rates, respectively) on NTF produced incrementally greater seed-zone water but were not capable of retaining as much as TF (Fig. 1). Total root zone (0-to 6-ft) over-summer water loss was greatest in the 1x NTF whereas there were no significant differences in the 4x and 7x NTF versus TF. Average precipitation

storage efficiency ranged from 33% for 1x NTF to 40% for TF. We conclude that for the low-precipitation winter wheat-summer fallow region of the Inland Pacific Northwest: (i) Cumulative water loss during the summer from NTF generally exceeds that of TF; (ii) there is more extensive and deeper over-summer drying of the seed-zone layer with NTF than with TF; (iii) increased quantities of surface residue in NTF slow the rate of evaporative loss from late-summer rains, and (iv) large quantities of surface residue from April through August will marginally enhance total-profile and seed-zone water in NTF, but will not retain adequate seed-zone water for early establishment of winter wheat except sometimes during years of exceptionally high precipitation or when substantial rain occurs in mid-to-late August.

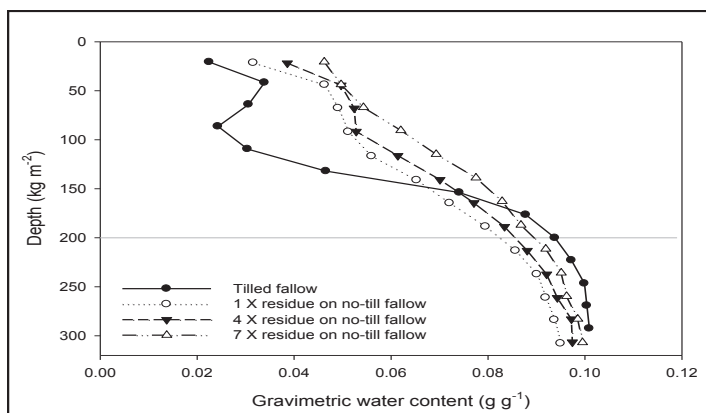


Fig. 1. Average seed-zone water content over the six-year period (each point is the mean of six years and four replications). Treatments are significantly different at 200 kg m⁻² (which is five inches below the surface, a typical seeding depth). All non-adjacent means at 200 kg m⁻² (i.e. five inch depth) are significantly different at $P < 0.04$. The year by treatment interaction was not significant.

Predicting Seed-zone Water Content for Summer Fallow in the Horse Heaven Hills

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The Horse Heaven Hills in south-central Washington contains the world's driest rainfed wheat production region. The climate is Mediterranean with average annual precipitation as low as six inches. The cropping system is winter wheat-summer fallow. Tillage is used in the spring of the 13-month fallow to establish a dry soil mulch to help retain seed-zone water to establish winter wheat planted deep into fallow in late August. However, the Horse Heaven Hills is often so dry that even tillage-based summer fallow (TF) cannot retain adequate seed-zone water, and farmers must then wait until the onset of rains in mid October or later for planting. In such dry years, farmers would be better off practicing no-till fallow (NTF) to protect the soil from wind erosion; but no predictive tools are available to assist in these decisions.

The objectives of our study were (1) to predict seed-zone water contents and water potentials in late August or early September based on soil water content measured in early April, and (2) to compare seed-zone water in TF and NTF. Experiments were



Fig. 1. Scientists and a research technician measure surface soil bulk density in a no-till fallow plot on the Mike Nichols farm in the western portion of the Horse Heaven Hills.

conducted for five years at each of two sites. Soil water content was measured in both early April and late August. Soil properties and residue loads were characterized to calibrate the Simultaneous Heat and Water model (SHAW). Seed-zone water was simulated in late August based on measured soil water contents made in early April and compared with observed water contents. The SHAW model correctly predicted seed-zone water content 80% of the time. The amount and timing of rainfall occurring in April, May, and June proved to be the most important factor controlling the seed-zone water content in late August, suggesting that farmers should delay their decision on whether to practice TF or NTF until late in the spring.

Our data suggest that farmers should consider delaying their decision on whether to practice TF or NTF until as late as mid June. If at that time, their measured soil water at the 6 to 7-inch depth exceeds 15% by volume, farmers should practice TF and if water content is less than this amount they should practice NTF. There are, however, some practical limitations to our recommendations. Average farm size in the Horse

Heaven Hills is approximately 7500 acres, with half in winter wheat and half in summer fallow. Given that a farmer can cover about 160 acres per day with a primary tillage implement, it takes approximately 24 days to complete primary spring tillage. If the farmer waits until mid June to begin primary spring tillage, substantial evaporative soil loss may occur on non-tilled ground by mid July.

Data from our study also suggest that farmers in the extreme dry western region of the Horse Heaven Hills should practice NTF in all but very wet years as they rarely have adequate seed-zone water for late-August planting, even with TF. The widespread practice of NTF would dramatically reduce wind erosion and likely save on operating costs compared to TF. In addition, farmers committed to practicing NTF in the long term could receive monetary payments from federal farm programs that reward environmental stewardship.

Residue Protects Emerging Winter Wheat Seedlings from Rain-Induced Soil Crusting

W.F. SCHILLINGER, T.A. SMITH, AND S.E. SCHOFSTOLL; DEPT. OF CROP AND SOIL SCIENCES, WSU DRYLAND RESEARCH STATION, LIND

Farmers in the low-precipitation region of the Pacific Northwest practice a 2-year tillage-based winter wheat- summer fallow rotation. Winter wheat is planted deep into moisture in late August or early September and seedlings emerge through 4 to 6 inches of dry soil cover. Rain showers that occur after planting create fragile soil crusts that the emerging first leaf often cannot penetrate. A rainfall simulator was used to conduct a 5-factor factorial laboratory experiment to evaluate emergence of WW planted deep in pots. Factors were: (i) rainfall intensity and duration (0.05 inch per for 3 hours, and 0.10 inch per hour for 2 hours); (ii) timing of rainfall after planting (1, 3, and 5 days after planting + controls); (iii) variety (standard-height vs. semi-dwarf), (iv) residue on the soil surface (0, 750, and 1500 lbs/acre); and v) air temperature (70° and 86°F). The high-intensity rain caused a 2.3-fold reduction in emergence compared to the low-intensity rain. Emergence improved proportionally with increasing quantities of surface residue (Fig. 1). The standard-height cultivar had four times greater emergence than the semi-dwarf. Air temperature and timing of rainfall had no significant effect on WW emergence. Results show that planting a WW cultivar with long coleoptile and first leaf as well as maintaining high quantities of surface residue to intercept rain drops will enhance WW stand establishment after rain showers to benefit both farmers and the environment.

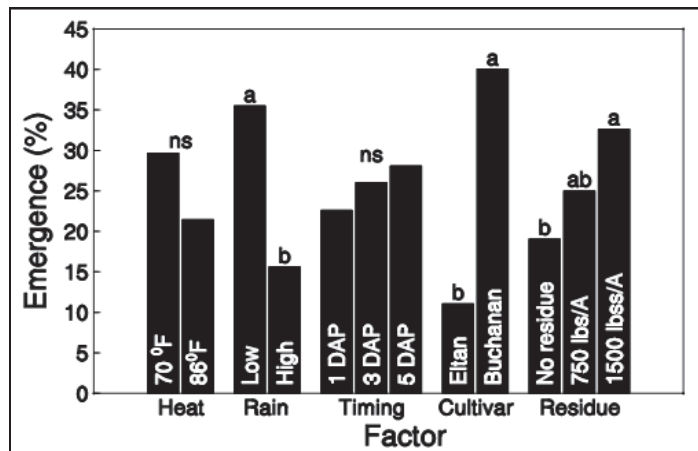


Fig 1. Percent emergence of Eltan and Buchanan winter wheat varieties planted deep into pots as affected by rainfall intensity and duration, residue cover, timing of rainfall, and heat. Data are the average from three runs. Data are combined for the two varieties. DAP = days after planting

No-till Summer Fallow is a Good Fit in the Western Horse Heaven Hills

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Blowing dust from excessively tilled summer-fallowed fields in the Horse Heaven Hills (HHH) is a major air quality concern in the Tri-cities, Washington. We conduct a 5-year on-farm field experiment at two HHH sites to determine the effects of no-till summer fallow, conservation tillage summer fallow, and traditional tillage summer fallow on: i) seed-zone moisture in late August, ii) wheat plant establishment, iii) wheat grain yield, and iv) dust emissions.

Beginning in March 2006, replicated experiments were established on the David Pearson and Mike Nichols farms. The Pearson

farm is located in the central HHH on deep Ritzville silt loam soil. Annual precipitation at the Pearson site averages 8.0 inches. The Nichols farm is located in the western HHH on deep Warden silt loam soil and annual precipitation averages 6.0 inches. Both sites are representative of the wind-erosion prone winter wheat–summer fallow Horse Heaven region.

Wheat growers Nichols and Pearson managed all aspects of field operations. The experimental design at both sites was a randomized complete block with four replications. Individual plots were 200 ft long and 60 ft wide. Total plot area at each site is 9.5 acres.

Tillage treatments were:

- Traditional tillage summer fallow with primary tillage in April with a tandem disk to a depth of five inches followed by a shanking aqua $\text{NH}_3\text{-N}$ in May and rodweeding only as needed to control Russian thistle and other weeds.
- Conservation tillage summer fallow with primary tillage in April with an undercutter sweep + injection of aqua $\text{NH}_3\text{-N}$ at a depth of five inches, followed by rodweeding only as needed to control weeds.
- No-till summer fallow where the stubble from the previous wheat crop is left standing and undisturbed and weeds are controlled with application of glyphosate and other herbicides. Nitrogen fertilizer was delivered at the time of planting with a no-till drill.

We collected numerous data from the two sites, but here we concentrate only on seed-zone water content of summer fallow measured late August and 'Finley' hard red winter wheat grain yield. Seed-zone water content was always lowest in no-till fallow compared to conservation tillage and traditional tillage at both sites all five years (data not shown). At the Pearson site, seed-zone water content in tilled fallow was adequate for late-summer planting in all five years, but replanting was required in 2009 due to crusting rain showers that prevented emergence from the first planting. However, at the drier Nichols site, seed-zone water was adequate for late-summer planting in only one year (2006) out of five. Seed-zone water in no-till fallow was never adequate for late-summer planting at either site.

Wheat grain yield at the Pearson site was significantly higher with conservation tillage and traditional tillage (i.e., early seeding) compared to no-till fallow (i.e., late planting) in four out of five years as well as the five-year average (Fig. 1). Therefore, growers in the central HHH will likely want to continue the practice of conservation tillage summer fallow. However, at the extremely dry Nichols site, where planting of winter wheat was delayed until mid-to-late October in all tillage treatments in all but one year, there was no real grain yield advantage of one system over the other. We do not know why there were considerable within-year grain yield differences among tillage treatments at the Nichols site (Fig. 1) when all plots were planted on the same day, but the bottom line is there was no clear advantage of one system over the other. Since it was not possible to maintain adequate seed-zone water even with tillage-based fallow 80% of the time at the Nichols site, we feel that growers in the western HHH would be better off practicing no-till summer fallow except when over-winter precipitation is exceptionally plentiful (see related article on predicting seed-zone water content by Singh et al. in this booklet). The practice of no-till summer fallow in the western HHH will: i) certainly reduce dust emissions, ii) likely prove economically attractive due to elimination of costly tillage operations, and iii) result in equivalent wheat grain yields compared to tillage-based fallow.

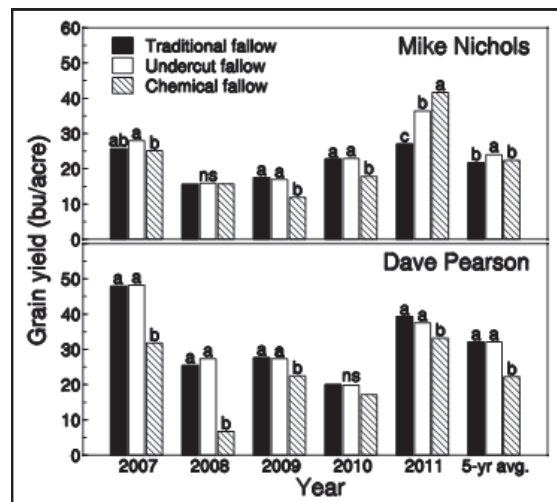


Fig. 1. Hard red winter wheat 'Finley' grain yields with three fallow systems at two sites over five years in the Horse Heaven Hills region of Benton County, WA. Within-year and 5-year average grain yield values followed by a different letter are significantly different at the 5% probability level. ns = no significant difference.

Row Spacing Experiments for Deep-furrow Seeding of Winter Wheat

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Row spacing experiments were conducted at Lind and Ritzville during the 2011 crop year. The purpose of these experiments is to determine if row spacing can be extended beyond the traditional 16 and 18 inches without detrimental effects on winter wheat

yield and weed control. Row spacing treatments in the experiment are 16, 18, 20, 22, 24, and 32 inches. All treatments are replicated four times and planted in 100 x 16 ft strips. Xerpha was planted in early September 2010 at both locations.

At Lind, winter wheat grain yields ranged from 29 to 35 bu/acre. There were no significant differences in grain yield, although the 16 and 18 inch spacings, overall, produced more grain than the other spacing treatments (Fig. 1). Grain yields were relatively low because we were unable to apply an air application of fungicide to control stripe rust since the Lind Station contains many wheat breeding nurseries and the breeders do not want fungicide applied to their material.

At Ritzville, winter wheat grain yield ranged from 63 to 76 bu/acre (Fig. 1). The 16 and 18 inch spacing treatments produced significantly higher grain yield than the 20, 22, 24, and 32 inch spacing treatments.

Yield component data (data not presented) show that the number of heads per unit area declined with increasing row spacing. Keep in mind that all treatments received the same number of seeds per unit length of row, but not the same number of seeds per acre because the metering flutes on the HZ drill cannot be precisely adjusted. This means that while we planted 50 lbs/acre of seed on the 16-inch row spacing, the planting rate for the 32-inch row spacing treatment was only 25 lbs/acre. We were unable to plant the same number of seeds per acre since the metering flutes of the John Deere HZ drill used in this experiment are not precise enough to calibrate for small planting rate changes. We have addressed this problem by purchasing a special Raven seed metering device (funded by Ritzville wheat farmer Bill Heinemann) and, beginning in 2012, we will conduct the row spacing experiments with both the same number of seeds per row and the same planting rate (i.e., 50 lbs) per acre in all treatments.

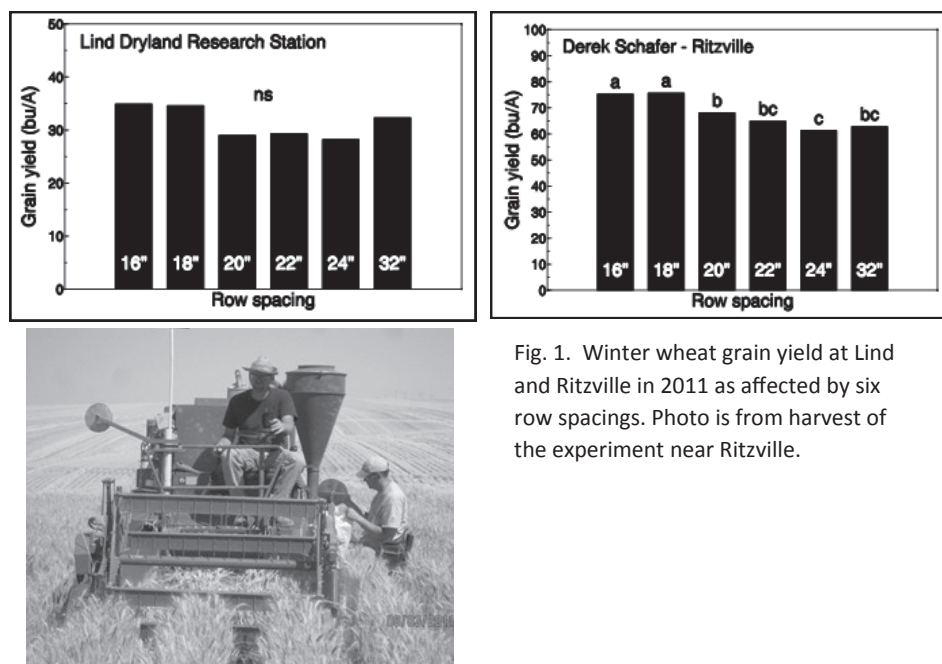


Fig. 1. Winter wheat grain yield at Lind and Ritzville in 2011 as affected by six row spacings. Photo is from harvest of the experiment near Ritzville.

Part 4. Bioenergy Cropping Systems Research

Camelina: Planting Date and Method effects on Stand Establishment and Seed Yield

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There has been keen interest in camelina (*Camelina sativa* L. Crantz) in recent years due to the unique fatty acid composition of the seed oil for human and animal consumption and, more importantly, the value of the seed oil to provide "green energy" to fuel commercial and military aircraft. The objective of our research was to evaluate several planting dates and two planting methods

for camelina stand establishment and seed yield. Field experiments were conducted for three years at four distinct rainfed agro-environments in the Pacific Northwest, USA. Average crop-year precipitation at the sites during the three years was: Lind WA, 9.0 inches; Pendleton OR, 16.6 inches; Moscow ID (one year only), 29.9 inches; and Corvallis OR, 39.1 inches. Camelina was planted on an average of five dates at each site (n=55) from early October to mid April at a rate of 5 lbs/acre by either drilling seed at a shallow depth or broadcasting seed on the soil surface. Although camelina has excellent cold hardiness, the best plant stands

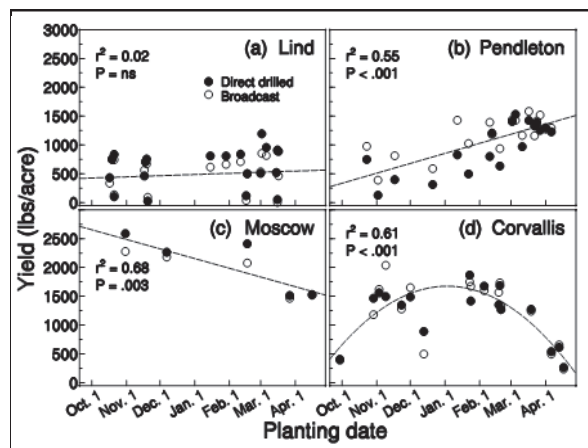


Fig. 1. Effect of planting date and method (direct drilled or broadcast) on camelina seed yield at four locations over three years.

were achieved with the late-winter and early-spring plantings. Four divergent planting date yield responses across sites were: no yield differences at Lind; increased yield with later planting dates at Pendleton; reduced yield with later plantings at Moscow (one year data) and; a curvilinear response at Corvallis with the lowest yields from plantings in early fall and those after March 1 and highest yields from late-fall and mid-winter plantings (Fig. 1). Both drilling and broadcast were effective for planting camelina with no overall advantage of either method. Seed yields ranged from < 100 lbs/acre during an extreme drought year at Lind to 2600 lbs/acre at Moscow. Averaged across the four Pacific Northwest agro-environments in this study, we recommend: (i) late February-early March as the best overall planting date because of optimum stands and seed yield and having effective control of winter-annual broadleaf weeds with herbicide applied just prior to planting, and (ii) the broadcast method of planting as it generally equaled or slightly exceeded drilling for plant stand establishment and seed yield and can be accomplished more quickly at less expense.

Camelina: Seed Yield Response to Applied Nitrogen and Sulfur

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Camelina has received worldwide attention in recent years as a biofuel crop and as a rotation option for producers of small grain cereals. The objective of our study conducted during the 2008, 2009, and 2010 crop years was to determine camelina seed yield and nitrogen use efficiency (NUE) as affected by six applied nitrogen (N) rates at four sites in the Pacific Northwest. An N + sulfur (S) variable was also included. In 2010, seed oil as affected by applied N and S was also evaluated. The four sites and their average annual crop-year precipitation during the three years were: Lind, WA (9.0 inches); Pendleton, OR (16.6 inches); Moscow/Pullman, ID (27.4 inches); and Corvallis, OR (42.7 inches). The majority of the average annual precipitation at these sites is distributed in the winter and summers are comparatively dry. Camelina responded differently to applied N among sites based upon precipitation and available soil N. Seed yield did not respond to N rate treatments at Lind, presumably due to sufficient soil residual N and limited precipitation. Response of seed yield to applied N was mediated by increased precipitation at Pendleton, Moscow/Pullman, and Corvallis. Maximum seed yield increases attributable to applied N ranged from 19% at Pendleton to 93% at Moscow/Pullman. Based upon the results of this study, camelina seed requires about 5 lbs N per acre per 100 lbs of expected seed yield. Camelina NUE was greatest at Moscow/Pullman although it decreased gradually with increasing applied N rates at all sites. Lind, Pendleton, and Corvallis were the same with a NUE of -0.06 pound of seed for every added pound of N. Nitrogen use efficiency was greatest at Moscow/Pullman and Corvallis, and least at Lind. Camelina did not respond to applied sulfur at any site. Seed oil content was not affected by applied N or S.

Wind Erosion Challenges for Oilseed Cropping Systems

BRENTON SHARRATT, USDA-ARS, PULLMAN; AND WILLIAM SCHILLINGER, WSU

The volatility of petroleum reserves, rising price of petroleum products, and climate change has created a worldwide interest in renewable fuels. The United States has set a goal of producing 36 billion gallons of biofuel by 2022 with 21 billion gallons being

derived from advanced biofuels. The Pacific Northwest is expected to contribute 5% of this need for advanced biofuels. Although a considerable effort is now underway to ascertain the potential of growing oilseeds for advanced biofuels, little is known concerning the environmental impact of growing oilseed crops in rotations in this region. Of interest is the impact of growing oilseeds on wind erosion and PM₁₀ (particles $\leq 10\mu\text{m}$ in diameter) emissions, which are acute environmental concerns in the drier areas of the Columbia Plateau.

In September 2011, we examined the potential for wind erosion and PM₁₀ emissions at the end of the fallow phase of a winter wheat-fallow versus a winter wheat-camelina-fallow rotation at Lind, WA and a winter wheat-fallow versus a winter wheat-safflower-fallow rotation at Ritzville, WA. An undercutter implement was used for primary spring tillage and then a rodweeder was used to control weeds for the duration of the fallow phase of the rotations at both sites. A portable wind tunnel (Fig. 1) was used to assess total horizontal sediment flux and PM₁₀ concentrations after sowing but prior to wheat emergence. Total sediment flux was measured using an isokenetic wedge-shaped sampler while PM₁₀ concentrations were measured using Dusttrak aerosol monitors. Our results indicate a 15% increase in sediment flux in the camelina rotation at Lind and an 80% increase in sediment flux in the safflower rotation at Ritzville compared with the winter wheat-fallow rotation. Most apparent was lower residue cover following the oilseed crops, which likely contributed to the higher sediment flux from fallow after the oilseed versus winter wheat crop. Our results suggest that, even with conservation tillage best management practices, wind erosion may be accentuated by growing oilseeds in tillage-based fallow systems in the Columbia Plateau.



Fig. 1. A portable wind tunnel was used to measure soil sediment flux and PM₁₀ emissions, shown here at the Ron Jirava farm near Ritzville.

Biofuels Research in Western Washington

TIM MILLER, CRAIG COGGER, AND ANDY BARY; DEPT. OF CROP AND SOIL SCIENCES, WSU

Biofuel crop production research in western Washington has included canola, camelina, rapeseed, mustard, and flaxseed, with different experiments focused on seeding rate and date, and on nitrogen (N) fertilizer timing, rate, and source. The experiments were done at WSU Mt. Vernon and WSU Puyallup from 2008-2011.

Canola was the most successful biofuel crop grown in the western Washington experiments. We identified mid August to early September as the fall planting window, with later plantings likely to yield poorly or fail. Fall planted canola yielded 3000-5000 lbs/acre. Spring planted canola (late April planting) averaged 2000-4000 lbs/acre. Organically-managed canola competed well against weeds when planted within the fall window, and our research indicated that it could be a viable rotation crop in western Washington. The organic canola oil would have much greater value as a food crop than a biofuel crop. Volunteer canola plants showed the potential to become problem weeds in subsequent crops under organic management, and would need to be managed carefully.

Additional experiments with canola focused on biosolids as a nutrient source, and showed similar production using two very different biosolids sources (heat-dried biosolids with 6% N and lagooned/dewatered biosolids with 2% N) each applied at two rates. Spring planted canola competed well against weeds in these experiments. Rapeseed yields were similar to canola and may also be a viable biofuels crop.

Camelina was much less successful than canola, with variable yields in the experiments (often less than 1500 lb/acre) and one crop failure. Neither winter nor spring plantings were productive, and we did not identify a successful camelina production strategy for western WA. Flax also performed poorly; yields in 2008 ranged from 1100-1600 lbs/acre, but only from 300-500 lbs/acre in 2009. Getting flax to harvest maturity is a major concern with this species, as seed pods in both years were quite wet at harvest.

Mustard also had variable and generally low yields, ranging from about 800-2800 lbs/acre. Mustard was an excellent competitor against weeds, and may have more of a role as a niche cover crop than a biofuels crop.

In summary, canola appears to be the most viable biofuels crop in western Washington, but still faces serious obstacles, including lack of local processing capacity, and exclusion zones where canola cannot be grown because of risk of contamination of brassica seed crops. Although not a biofuel use, organic production of canola could yield organic canola oil for food and organic canola meal for dairies, beef cattle, and poultry that is limited in supply and could command a high price.

Canola and Camelina Diseases

TIMOTHY PAULITZ, SCOT HULBERT, EBRAHIEM BABIKER, AND KURT SCHROEDER; USDA-ARS AND WSU

In 2011 our project focused on identifying potential canola (primarily *Rhizoctonia*) and camelina (downy mildew) diseases in WA, and screening for resistance to those pathogens.

Canola: Previous work with resistance to *Rhizoctonia* diseases has been done with *R. solani* AG 2-1, and little is known about the virulence of two other groups common in the PNW: AG-10 and *Ceratobasidium* spp. We screened 20 canola cultivars to test for resistance/tolerance to soils inoculated with the diseases. None of the cultivars exhibited resistance to AG 2-1; all were killed in the experiment. One *B. napus* hybrid (Visby) showed high level of tolerance to damping-off from *R. solani* AG 8, AG 10 and the binucleate *Rhizoctonia*, while two genotypes (Amanda and Baldur) exhibited high level of tolerance to *R. solani* AG 10.

Camelina: Downy mildew of camelina was observed in fields in 2010 and 2011, with an incidence of less than 5%, but it may be impacting yield. We planted seed infested with downy mildew, and found that infected plants resulted from infested seed, indicating that the disease is seed transmitted. The pathogen was confirmed as *Hyaloperonospora camelinae*. Growers should use certified or tested seed, and seed treatment with mefenoxam may control the disease.

We will continue to monitor and investigate canola and camelina diseases in 2012. We will verify the identity of pathogen on camelina and relation to *H. parasitica* (downy mildew of Brassicas) with DNA work, and confirm if isolates from camelina are cross-pathogenic to canola.



Fig. 1. Flowering stem of camelina infected with downy mildew (*Hyaloperonospora camelinae*).

Winter Canola Rotation Benefit Experiment

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A winter canola rotation benefit study was initiated in August 2007 at the Hal Johnson farm located east of Davenport, WA. Average annual precipitation at the site is 18 inches. The traditional 3-year winter wheat (WW)-spring wheat (SW)-no-till fallow (NTF) rotation is compared to a 3-year winter canola (WC)-SW-NTF rotation. All crops are produced using direct seeding. Experimental design is a randomized complete block with six replications (total area per site is 0.9 acres). Fertilizer rate is based on soil test. All crops are planted and fertilized with a no-till hoe-opener drill and grain yield is determined using a plot combine. In addition to grain yield, soil volumetric water content is measured in all plots just after harvest in August, in mid March, and again after grain harvest.

Excellent stands of WC were once again achieved from mid August 2010 planting into no-till summer fallow. The WC plants survived the winter in good shape and produced a revised seed yield of 2910 lbs/acre in 2011 (Fig. 1 and Fig. 2). This is, by far, the best WC seed yield obtained during the first four years of the experiment. Winter wheat planted into no-till fallow produced 115 bu/acre in 2011; the highest WW yield so far obtained (Fig. 1).

One very interesting phenomena in 2011 was that SW after WC produced a significantly higher 67 bu/acre compared to 60 bu/acre after WW (Fig. 1) despite the fact that there were no differences in soil water content after harvest of WC and WW in August 2010. These data show that WC provided a significant rotation benefit to spring wheat compared to WW that was not related to

water.

Another interesting data set from 2011 show that WW extracted 2.3 inches more water than WC by time of harvest. These soil water differences were highly significant statistically and apparent in all six replicates. Our previous experience had indicated that WC extracts more soil water than WW, but that was obviously not the case in 2011.

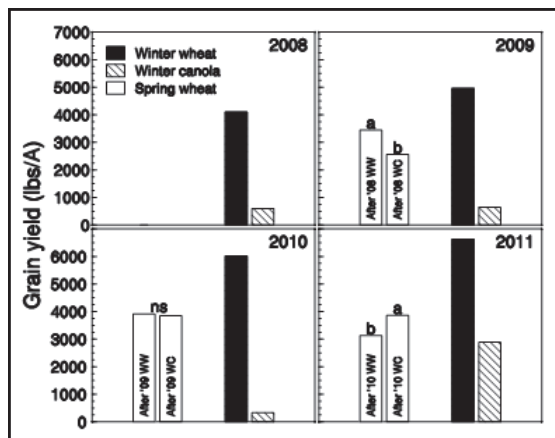


Fig. 1. Grain yield of winter wheat (solid bars) versus winter canola (striped bars) in 2008, 2009, 2010, and 2011. Both crops were planted into no-till fallow on the Hal Johnson farm. Subsequent grain yield of spring wheat (solid white bars) grown after either winter wheat or winter canola is shown for 2009, 2010, and 2011.



Fig. 2. WSU research technician in winter canola plot on the Hal Johnson farm NE of Davenport, WA

Camelina Cropping Systems Experiment at Lind

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A camelina cropping systems experiment was established at the WSU Dryland Research Station at Lind in the 2008 crop year. This experiment will be conducted for nine years to evaluate the traditional 2-year winter wheat-summer fallow (WW-SF) rotation with a 3-year winter wheat-camelina-summer fallow (WW-C-SF) rotation. Experimental design is a randomized complete block with four replications. Each phase of both rotations appears each year in 30 ft x 250 ft plots (total = 20 plots). More than 90% of dry cropland acres in the less than 12-inch annual precipitation zone are in WW-SF. The logical fit for camelina in this dry region is in a 3-year WW-C-SF rotation.

The experiment is located on a south-facing slope. Soils on south-facing slopes are exposed to intense sunlight and drying, thus maintaining adequate seed-zone water content for deep-furrow planting of winter wheat can be a problem in dry years. Crop-year (Sept. 1 – Aug. 31) precipitation was 6.85, 8.46, 11.58, and 11.70 inches in 2008, 2009, 2010, and 2011, respectively. Due to inadequate seed-zone water in late August of 2007 and 2008, we were unable to establish WW with deep-furrow planting into carryover moisture and instead planted WW in late October after the onset of fall rains. For this reason, combined with low crop-year precipitation, WW grain yields were low in 2008 and 2009 (Fig. 1).

For the 2008, 2009, and 2010 crop years, camelina was planted in mid October. However, we learned from the camelina planting date and method experiment (also at the Lind Station, see related article in this booklet) that the best camelina seed yield potential appears to be from a late February-early March planting. A later planting date allows for application of glyphosate herbicide just before planting to control tumble mustard, tansy mustard, and flaxweed; these broadleaf weeds establish during the fall and winter. For these reasons, we changed the planting date on or about March 1 beginning in 2011 (Fig. 2).

Grain yields in both the WW-SF and WW-C-SF rotations are shown in Fig. 1. Average seed yield of camelina ranged from less than

100 lbs/acre in 2008 under extreme drought to 690 lbs/acre in 2011. Winter wheat grain yield in the WW-SF rotation has, to date, been generally slightly (but not significantly) higher than in the WW-C-SF rotation (Fig. 1). We believe the reason for this is because soil water in the 6-ft profile has been depleted more after camelina than after WW (data not shown). We believe that broadleaf weeds, mainly Russian thistle, are responsible for this large soil water extraction in camelina. Russian thistle becomes established in April and there are currently no in-crop broadleaf herbicides that can be applied to camelina. However, before planting the 2012 crop, we applied Sonalan® soil-residual herbicide before planting camelina on half of the plot area to determine its effectiveness for control of Russian thistle.

Growers need to be mindful that camelina produces relatively little residue. With heavy tillage, soil erosion may be a problem during or after camelina production. To reduce the potential for soil erosion, we recommend that (i) camelina be planted directly into standing and undisturbed WW stubble, and (ii) non-inversion conservation tillage (i.e., apply glyphosate, undercut for primary spring tillage, and rodweed only as needed to control weeds) be conducted during the 13-month-long fallow period after camelina seed harvest. Funding for this research is provided by the WSU Biofuels Project.

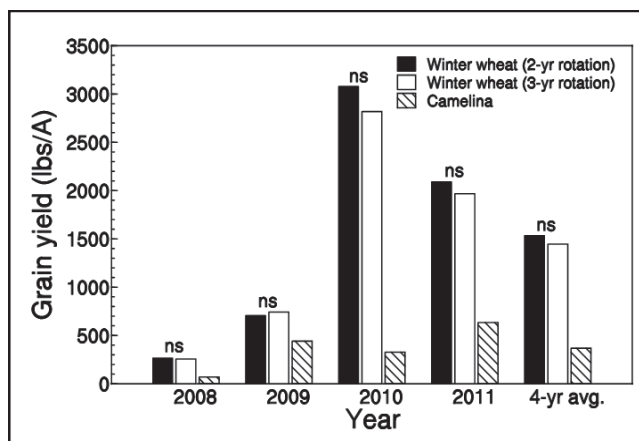


Fig. 1. Grain yield of winter wheat grown either in a two-year winter wheat-summer fallow rotation or a three-year winter wheat-camelina-summer fallow rotation as well as camelina seed yield during the first four years of a long-term camelina



Fig. 2. Camelina plant stands in the cropping systems experiment at Lind. Camelina seed is direct drilled in early March into standing and undisturbed winter wheat stubble with a Kile no-till drill equipped with paired-row hoe-type openers. Fertilizer is delivered below the seed with the drill.

Rotational Influence of Biofuel and Other Crops on Winter Wheat

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

In this study, eight spring crops (spring wheat, spring barley, dry pea, lentil, camelina, yellow mustard, oriental mustard, and canola) are planted in year1 followed by winter wheat (year2) grown across all year1 spring crops. The winter wheat planted within each of the previous spring crop areas is divided into sub-plots and fertilizer rates of 32, 64, 96, 128, 160 lb N/acre are applied with a split application of 70% in the fall and 30% in the spring. The spring crops are managed with uniform fertilizer applications to all crops except the pea and lentil that did not receive fertilizer.

Results from four spring crop years are in Table 1 and preliminary conclusions are:

- Spring crop productivity is variable, but barley and camelina are the most consistent
- Camelina out-yielded the other Brassica crops
- Market prices will be a large determining factor in spring crop choice
- Winter wheat yield following spring crops is highest after pea or lentil followed closely by the Brassicas and superior to following wheat or barley
- Economic return for spring crops should include their influence on the following crop
- When reliable results show wheat performance after spring crops, growers can also assign rotational benefits to biofuel

crops due to increased productivity of winter wheat and reduced N fertilizer input costs. This information boosts growers' decision-making ability to grow biofuel or any spring crop prior to winter wheat.



2010 Rotation Study Spring Crops planted to winter wheat for 2011 at Spillman Farm, Pullman, WA

Table 1. Spring Crop Seed Yields, 2008 Moscow, 2009, 2010, and 2011 Pullman

Spring Crop	2008	2009	2010	2011	2008-11 avg.	Avg. % Variation
	----- lbs/acre -----					
Spring Wheat	3750	3915	1700	2770	3035	26.4
Spring Barley	4625	5485	3520	4145	4445	13.8
Dry Pea	1830	245	840	2565	1370	61.4
Lentil	1075	740	480	1850	1035	56.8
Camelina	1895	2585	1715	1530	1930	17.0
Yellow Mustard	1390	1635	695	1415	1285	23.1
Oriental Mustard	915	2290	700	1750	1415	42.9
Canola	700	1610	670	1395	1095	37.3
Average	2025	2315	1290	2175	1950	34.8
LSD (0.05)	515	765	750	455		

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

MICHAEL M. NEFF, DAVID FAVERO, PUSHPA KOIRALA, JIWEN QIU AND JIANFEI ZHAO, DEPT. OF CROP AND SOIL SCIENCES, MOLECULAR PLANT SCIENCES GRADUATE PROGRAM, WSU

In low rainfall, dryland-cropping areas of Eastern Washington stand establishment can have a major impact on yields of camelina and canola. One approach to facilitate stand establishment is to develop varieties with larger seeds and longer hypocotyls as seedlings while maintaining normal stature as adults. Unfortunately, few mechanisms have been identified that uncouple adult stature from seedling height. The Neff lab has identified a group of plant-specific genes that, when mutated in a particular way, increase seed size and seedling height without adversely affecting adult stature. These genes encode AHL (Δ T-Hook Containing, Nuclear Localized) proteins. In the Brassica *Arabidopsis thaliana*, we have identified a unique mutation (*sob3-6*) in one of these genes, *SOB3/AHL29*, that expresses a protein with a disrupted DNA-binding domain and a normal protein/protein interaction domain. In *Arabidopsis*, this mutation confers normal adult plants that produce larger seeds and seedlings with hypocotyl stems that are up to twice as long as the wild type. We have shown that a similar DNA-binding mutation (*esc-11*) in another AHL family member in *Arabidopsis*, *ESC/AHL27*, confers similar phenotypes as *sob3-6*. We have also shown that expressing this *Arabidopsis* mutation in the Brassica *Camelina sativa* leads to taller seedlings with no negative impact on adult size. By analyzing seed weight, we have shown that these taller seedlings are, in part, caused by an increase in seed size (Figure 1). However, the increase in height using the *Arabidopsis* mutant allele in camelina is only 30% and not the 100% realized by using the *Arabidopsis* mutant

allele in *Arabidopsis*. Even with this 30% increase in hypocotyl length in camelina, we have shown that these larger seeds and taller seedlings can dramatically enhance emergence from deep planting (8 cm) in dry soil (Figure 2).

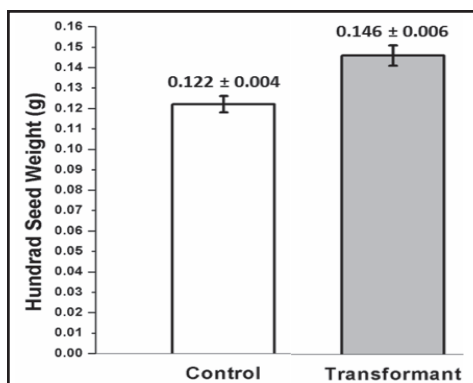


Fig. 1. Seed size is increased in *Camelina*. The average weight of 100 wild-type (control) seeds is compared to the transgenic line used in Figure 2.

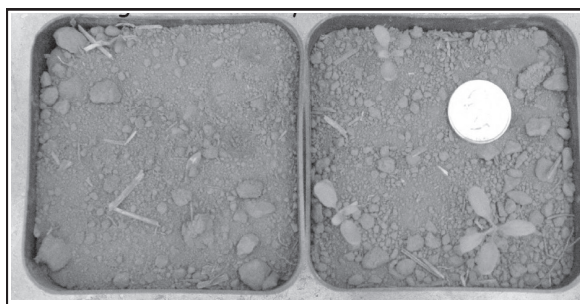


Fig. 2. *Camelina* plants expressing the *Arabidopsis sob3-6* mutation can emerge from deep planting in dry soil. Ten seeds (left: non-transgenic, right: transgenic) were planted on 1 cm of moist Palouse silt/loam and then covered with 8 cm of dry silt/loam. All seeds germinated however, no wild type seeds could emerge from this deep planting. Five transgenic seeds emerged and three survived. This experiment has been repeated twice.

Development of Camelina Lines Resistant to Group 2 Herbicides

SCOT HULBERT, IAN BURKE, AND RON SLOOT, WSU

In the high rainfall, annual cropping zone, Group 2 residual herbicides (imidazolinones and sulfonylureas) continue to pose a major constraint to producing oilseed crops, particularly canola and camelina. After extensive field, greenhouse and laboratory testing, we have identified one mutant population in camelina that shows resistance to all Group 2 herbicides tested. This mutant occurred in the Cheyenne background and we have crossed it to Calena.



Several large F2 families were planted in the field in June 2011 and sprayed with Pursuit. Seed from vigorous plants were harvested and planted in duplicate plots at Lind in late winter 2011. Seeds from single plants were again selected and were planted in yield plots this spring.

We hope to release a WSU cultivar in 2013 and we have already sent seed of the original mutant in the Cheyenne background to two different commercial breeding programs. We expect the SM4 mutation to be incorporated into several widely grown cultivars in the future, and expect this to reduce risks associated with camelina production in most regions.

Biennial Canola – A Three-for One Forage + Oil + Meal Crop

ROBERT KINCAID¹, KRIS JOHNSON¹, BILL PAN², AND SCOT HULBERT²; ¹DEPT. OF ANIMAL SCIENCES; ²DEPT. OF CROP AND SOIL SCIENCES, WSU

Growing winter canola in eastern Washington is difficult without a fallow period or irrigation. Stand establishment after crop harvest in late summer can be problematic due to low soil moisture, and if seeding dates are later than recommended for the region, the canola plants may be too small to survive low winter temperatures. Good stands are not always easy to establish in late summer even when planting into fallow. A biennial canola study on 17 acres near Pullman examined early-planted, interseeded winter canola and spring peas as a potential source of forage, and a means of seeding into available soil moisture. Peas were planted on July 1, 2010, followed by canola seeding the next day. The field was swathed and windrows harvested on September 8,

2010, and the forage was ensiled. Lactating dairy cows were fed either a control total mixed ration (TMR), or a TMR with 9% canola/pea silage that replaced a portion of the alfalfa hay and corn silage. After 21 days the canola/pea silage was increased to 15% of the TMR.

Both peas and winter canola had good stands. Swathing yielded approximately 2000 lbs forage dry matter/acre at 31% DM. Ensiling the forage crop and feeding it as part of a TMR avoided potential problems that might occur with direct grazing. Most notably, nitrate-N concentration was reduced 80% by ensilage. The canola/pea silage was palatable to the cows and substituted well for alfalfa or corn silage into a TMR without affecting milk production or composition. Plant regrowth following swathing was sufficient for winter survival, and canola harvested in 2011 yielded 2200 lbs/acre. The grain was commercially processed for oil (biodiesel) and meal (animal feed), thereby completing the trifecta from a single crop planting. Biennial forage canola appears to be a viable option in crop rotation systems in dryland areas to diversify crop production and obtain forage for ruminants.



Oilseed Analysis at WSU

IAN BURKE AND PAT FUERST, DEPT. OF CROP AND SOIL SCIENCES, WSU

The Weed Science laboratory provides oilseed quality analysis as a service in support of the field research component of the WA Biofuels Cropping Systems Research and Extension project. Data produced includes parameters such as oil yield from a seed crusher, total oil content, and fatty acid composition. Fatty acid composition is the key determinant of oil quality for biodiesel, and enables an evaluation of potential for biodiesel from canola, camelina, and other oilseed crops from seed samples produced in field plots. The objective of the research is to support research and extension personnel in developing input recommendations based not just on yield but on quantity and quality of oil.

Almost 2000 oilseed samples have been submitted for analysis by WSU researchers since 2008. The most recent set of samples (825 total) we are processing are from camelina trials at several locations in the PNW. Correlating crop yield and oil analysis by agroclimatic zones, varieties, fertilizer rates, and other factors will allow more site-specific crop recommendations to growers and processors for maximum potential seed and oil production.



Canola oil and meal after seed crushing. After being weighed, the samples are analyzed for oil composition and quality.

Winter Canola Seeding Rate and Date Study in North Central Washington

FRANK YOUNG¹, DENNIS ROE², LARRY MCGREW¹, DALE WHALEY², AND CHASITY WATT³;

¹USDA-ARS PULLMAN; ²WSU; ³COLVILLE CONFEDERATED TRIBES (CCT)

Approximately 60% of the cereal production area of the PNW are characterized by the winter wheat/summer fallow system. This system is plagued by winter annual grass weeds such as jointed goatgrass, feral rye, and downy brome. Growers are becoming more interested in producing winter canola in this region to improve pest management strategies, diversify markets (food, fuel, and feedstock), and increase sustainability. However, winter canola stand establishment is a major impediment to growers in the non-irrigated, low- to intermediate-rainfall zones, so it is considered a high risk to produce. The majority of winter canola research has been conducted in irrigated systems at Prosser and Lind, WA and pre-irrigated systems at Pendleton, OR.

The objective of this four-year project was to establish baseline production information for winter canola production in north central WA, specifically seeding dates and rates that would result in successful stand establishment. "Camas" Roundup Ready® canola was planted at 4 and 8 lbs/A on July 28, August 10, and August 18, 2010. The July 28th planting did not survive a hail and rain storm on July 31 which crusted the soil and prevented emergence. The remaining four treatments (4 and 8 lbs/A seeding on

August 10 and 18) had nice stands going into the winter. Sun and growing degree days were lacking in the spring, yet canola yield was excellent. With all seeding dates, there was no advantage to increasing seed rate with regard to yield. When averaged over the 2010 seeding dates, yield was 1,650 lbs/A at 4 lbs/A, and 1,580 lbs/A at the higher seeding rate. Canola yields for both August seeding dates were also similar – 1,605 lbs/A for August 10 and 1,620 lbs/A for August 18.

We believe the optimum time of planting is when “Mother Nature” tells you to – generally from August 5 to August 20-25 when cool weather is forecast. The past two years, growers have actually stopped wheat and canola harvest to plant their winter canola. Five new growers planted winter canola in Okanogan and Douglas Counties in August 2011. Winter canola acreage has increased from 15 acres to almost 2,500 acres since 2007. One member of the CCT planted 35 acres of winter canola in 2011. We have worked with the CCT to assist them in establishing an Agriculture Team focusing on canola production. The team has 45 acres ready to plant in the fall of 2012. A grower in Okanogan County has contracted to plant an irrigated circle of spring canola for seed increase.



Winter canola seeding rate study at Okanogan; 4 lbs/A (left) and 8 lbs/A (right).

Safflower Oilseed Production under Deficit Irrigation and Variable N Fertilization

HAL COLLINS, ASHOK ALVA AND RICK BOYDSTON; USDA-ARS AND WSU, PROSSER

Safflower is considered a low input and drought tolerant crop, but responds well to irrigation and fertilizer. In central WA, safflower may provide an oilseed crop option with lower water demands than some other broadleaf crops in irrigated cropping systems. Safflower is planted in the spring and reaches maturity in about 5 months in south-central Washington. Grain yield is about 3000 to 3500 lbs/acre with oil concentration of 35-40% depending upon variety. Our objectives are to determine 1) varietal responses of safflower to deficit irrigation and N fertilization under center pivot irrigation and 2) oil production and quality under deficit irrigation and N fertilization.

We conducted research from 2007-2011 at the USDA-ARS Integrated Cropping Systems Research Field Station near Paterson, WA. Three safflower varieties (S345, CW99OL, and S334) were planted under center pivot irrigation. Irrigation treatments were 90 and 70% of ET with approximate in-season (May-September) applications of 30 and 23 inches of irrigation, respectively. Fertilizer treatments consisted of four split N application rates at approximately two week intervals for a total of 100 or 145 lbs N/acre.

Safflower yields averaged 2770 lb/acre, and yields were significantly higher with 100 lb N/acre than 145 lb N/acre. Yields averaged over the four years of the study were not significantly different between 90 and 70% ET, suggesting a potential 4.7-7.5" water savings using a deficit irrigation strategy. Similarly, oil yield was higher under deficit irrigation, a reflection of higher yields and greater water use efficiency.

As a result of this study, we will develop an Extension bulletin to aide growers who are interested in irrigated safflower production. Deficit irrigation scheduling and N fertilization recommendations are key components of the information we will provide, as well as the chemical composition of the oil that may provide an alternative value-based market for producers.



Managing Feral Rye in Winter Canola through Herbicide Selection

FRANK YOUNG¹, DENNIS ROE², LARRY MCGREW¹, DALE WHALEY², CHASITY WATT³

¹USDA-ARS; ²DEPT. OF CROP AND SOIL SCIENCES, WSU; ³COLVILLE CONFEDERATED TRIBES

A preliminary herbicide efficacy study for the management of feral rye in winter canola was initiated in the spring of 2011. Our objective is to evaluate herbicides to improve the quality of subsequent winter wheat crops and prevent herbicide resistance in weeds. Select (clethodim), Assure II (quizalofop), and Roundup (glyphosate) were applied early spring. Because winter canola plants had canopy closure in the fall of 2010, feral rye was sprayed only in the spring. Final feral rye control in mid-May was 74%, 64%, and 99% for Assure II, Select Max, and Roundup, respectively (see table). Feral rye biomass and head counts responded similarly within each herbicide treatment. In the plots treated with Roundup no seed heads were produced, and Assure II treated plots resulted in only three feral rye seed heads/yard². This is in sharp contrast to 255 feral rye heads/yard² produced in the untreated plots. Winter canola yield increased 40% to 48% compared to the untreated check depending on the herbicide treatment.

Effect of grass herbicides on feral rye control, biomass, seed heads, and winter canola yield.^a

Herbicide	Control	Rye Biomass	Heads	Yield
	%	lbs/A	no yd ⁻²	lbs/A
Untreated	0	3,920	255	1,165
Assure II	74	823	3	1,635
Select Max	64	1,597	40	1,680
Roundup	99	290	0	1,730

^aBiomass and head counts recorded June 1, 2011. Control recorded on May 16, 2011.

Additional plots we established last fall (2011) in a severe, natural infestation of rye in Douglas Co. Assure II, Select 2EC, and Roundup were applied to CP115 winter canola (glyphosate tolerant) on October 16, 2011. Three weeks later control of the initial severe feral rye population with Roundup was excellent; however controlling this population opened up the canopy and a new flush of feral emerged. This new flush of rye was not occurring in the untreated or other two herbicide treated plots because feral rye ground cover was complete in these treatments. Assure II and Select 2EC stunted the feral rye considerably.



Feral rye at Okanogan and Bridgeport was controlled with glyphosate.

A Change is in the Air: Refining Canola Fertilizer Recommendations

BILL PAN, ASHLEY HAMMAC, TAI MCCLELLAN, MEAGAN HUGHES, JOHN RUMPH, RON BOLTON, AND RICH KOENIG
DEPT. OF CROP AND SOIL SCIENCES, WSU

Current nitrogen (N) recommendations for canola are widely variable. Our objective is to develop nutrient (primarily N and sulfur) recommendations for major oilseed crops that maximize oil yield and quality. We initiated a N x sulfur (S) experiment in 2007 at the Wilke Farm near Davenport and the Palouse Conservation Field Station (PCFS) near Pullman that includes a range of N rates (0

to 160 lb N/acre with 15 lb S/acre). Fall-spring split applications of N, and select N fertilizer treatments with no added S are also included.

Residual inorganic soil N was low at both locations in 2011, 73 lb N/acre at the Wilke Farm and 103 lb N/acre at PCFS. Spring canola grain yields at PCFS were higher than in previous years, and therefore more responsive to N fertilizer additions (see graph).

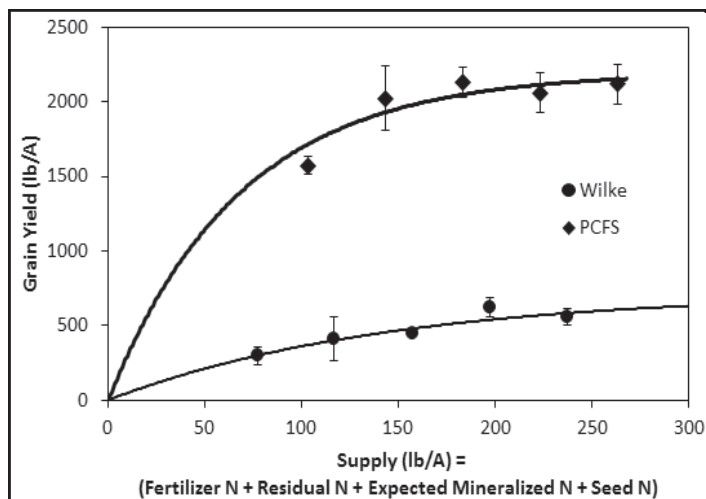


Fig. 1. Canola seed yield response to N supply at Pullman (PCFS) and Davenport (Wilke). The left-most plotted point on each response curve represents 0 N fertilizer applied.

No consistent yield responses to S additions were observed. The economically optimum N rate (at \$0.22/lb canola and \$0.56/lb N as urea) at the Wilke Farm was 69 lb N/acre, while at PCFS it was determined that no N fertilizer added under these yield response and price scenarios paid for itself.

The four year N x S fertility experiment indicates that accurate estimation of soil N supply and canola yield potential is critical in determining proper N fertilization rates. In recognition that canola can aggressively utilize residual soil N supplies if available, N fertilizer rates should be reduced when residual soil N is present. In addition, canola returns significant crop residue N to the soil following harvest. Thus, we have expanded the study in 2012 to follow the carryover N from canola residues and its effects on subsequent legumes and wheat grown in rotation. This research is leading towards a modification of existing regional guidelines for canola fertility management with a goal of maximizing yield and oil productivity.

Establishing Switchgrass for Biofuel in the North Columbia Basin

STEVE FRANSEN, WSU-PROSSER IAREC

Switchgrass biofuel research started at WSU in Prosser after observing irrigated circles of switchgrass seed produced by Rainier Seed Company in 2001. This project was initiated to investigate new 'windows' for successful establishment of switchgrass in the Columbia Basin and to evaluate long term storage of switchgrass hay for bioenergy conversion. Cellulosic biorefineries will operate daily for about eleven months per year. Crops cannot be harvested continuously over this time so the feedstock will require storage.

Date of planting studies were conducted at WSU-Othello in 2008 and 2009 and a study evaluating long-term storage as dry or high moisture hay was initiated at Othello in 2008 intending for two complete grass hay harvests in 2009, 2010 and 2011. These are the first hay results from a lowland switchgrass (Kanlow) or Eastern Gamagrass (Nemaha) from as far north as WSU-Othello (46° N). Results confirm that warm season grass hay can be consistently produced in the northern Columbia Basin region.

This study will conclude after the post-storage hay bales are processed and NIRS scanning completed on cored samples. Our studies will provide four years of data that can be used in developing guidelines for long term storage. Results from the date of planting studies have been incorporated into a switchgrass production Extension bulletin that is expected to be published in 2012.

Extension and Outreach Activities

KAREN SOWERS, DENNIS ROE, BILL PAN, AND DEB MARSH; DEPT. OF CROP AND SOIL SCIENCES, WSU

The Washington State Biofuels Cropping Systems Research and Extension Project (WBCS) has been funded since 2007, and has included 15-20 projects, 18 principal investigators, 12 collaborators, and nearly 50 agency and university affiliates, technicians, and graduate students. Written and online publications; a dedicated website; and presentations at workshops, field days, and

professional meetings are utilized to disseminate information. Oilseed crop production workshops were held in 2011 and 2012 with almost 250 people attending each year. Oilseed acreage is increasing in some areas of WA as results from WSU and USDA-ARS on-farm research, along with testimonies from experienced oilseed producers, are convincing more producers to try oilseeds in their crop rotations.

Outreach and extension efforts directly reached over 1845 people at 25 events in 2011. We are working closely with the Washington Canola and Rapeseed Commission to increase awareness of their role in furthering oilseed production in the state. A website for the WBCS was created in 2008, and usage has increased dramatically since then. There were 2000 hits last year, two-thirds of which came from 47 cities in WA. The first set of case studies about oilseed producers in the four production regions of Washington was published as an Extension manual last year and the remaining three sets are being edited for publication in 2012. The WBCS research team published a fact sheet about canola growth, development and fertility last year, and several refereed journal articles and Extension fact sheets and bulletins about canola, camelina, and switchgrass production in the PNW will be published in 2012.



A Decade of Direct-seed Canola in Rotation at the WSU Cook Agronomy Farm

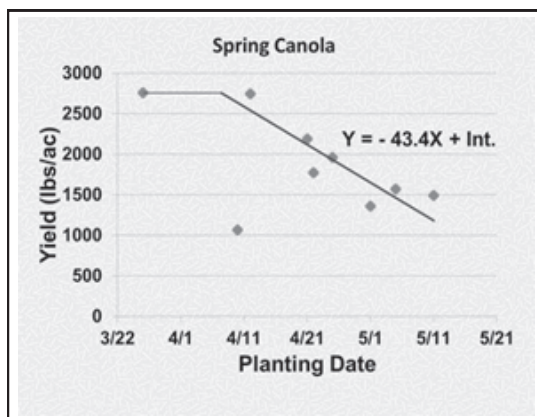
DAVID HUGGINS, USDA-ARS, PULLMAN; KATE PAINTER, U OF I

Spring canola production can diversify cropping systems within dryland cropping zones of the Pacific Northwest. No-tillage systems may be particularly well-suited to spring canola as crop residues promote seed-zone moisture conservation near the soil surface that could benefit the establishment of the small, shallow-seeded crop. Spring canola varieties that are resistant to herbicides (e.g. Roundup) can also provide useful alternatives for managing weeds such as annual grasses that are problematic in other rotational crops.

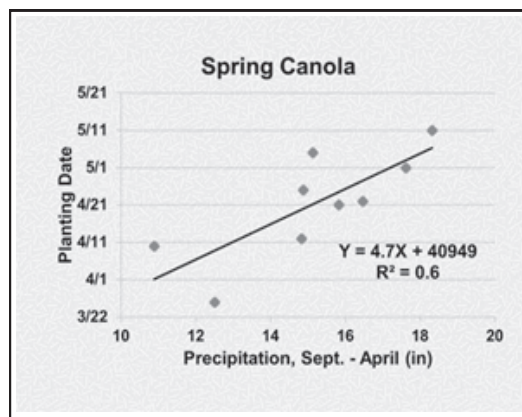
In 2001, three-year rotations including a crop rotation with spring canola were initiated at the WSU Cook Agronomy Farm. Roundup Ready spring canola was no-till planted using a Great Plains double-disk drill into spring barley (first year only) or hard red winter wheat residue (8 years). Seeded and harvested strips were approximately five acres. Planting dates ranged from as early as March 26 to as late as May 12 and were dependent on spring weather and soil conditions. Seeding rates were initially high (8-10 lbs/acre) but were reduced after the first three years to 6 lbs/acre.

The average yield of spring canola from 2001-2009 was 1880 lbs/acre. Yield of broadcast spring canola was similar to no-till, indicating the potential of early spring seeding into winter wheat residue. With the exception of one year (2005), spring canola

yield decreased 43 lbs/acre for every day seeding was delayed after April 12th. Economic analyses show that while spring canola had negative net returns, other rotational crops were also unprofitable. Given current market prices for canola, the economic analyses would change dramatically, as it is at more than double the average price of \$12.80 per 100 lbs during the study period.



Spring canola planting date effects on seed yield at the WSU Cook Agronomy Farm.



Relationship between spring canola planting date and September through April precipitation at the WSU Cook Agronomy Farm.

Is Spring Canola Viable in North Central Washington?

FRANK YOUNG¹, DENNIS ROE², LARRY MCGREW¹, DALE WHALEY², CHASITY WATT³;

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Very little spring canola research has been conducted in the wheat/fallow region with the exception of irrigated systems and one year when spring canola was planted in lieu of a failed winter canola crop with this research team. There has been sporadic canola production in north central WA during the last several years. We initiated this study in 2011 to determine the optimum row spacing for spring canola, and if there were any particular varieties that performed well in this environment.

In the spring of 2011, two glyphosate tolerant spring canola varieties (early and late maturity) and one glufosinate tolerant variety were planted in 7- and 14-inch row spacing at the same plants/A population. Data collected include crop population, yield, and oil quality. When averaged over row spacing, Invigor (glufosinate tolerant) canola yielded 935 lbs/A compared to the glyphosate tolerant DKL late maturing (1,120 lbs/A) and early maturing (1045 lbs/A) varieties. Yields were slightly higher in the 7-inch spacing for both the Invigor and late maturing DKL variety compared to the 14-inch spacing. Both glufosinate and glyphosate controlled all annual grass weeds and broadleaves such as Russian thistle, kochia, mustards, and prickly lettuce. Oil quality analysis is pending.

We have seeded spring canola again this year with the same methodology described above. We believe spring canola is an 'opportunity' crop for both irrigated and dryland production in this region. If soil moisture is sufficient in the spring for germination a grower may opt to seed spring canola, or it can be seeded in the event of a failed winter canola crop the previous fall. After data collection this year we would like to begin the process to procure crop insurance for spring canola in Okanogan and Douglas counties as we did for winter canola several years ago.



Spring canola row spacing study.

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