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2006 Field Day Abstracts:

*Highlights of Research Progress
featuring Climate Friendly Farming™*

Dedicated to Dr. Robert I. Papendick



**Department of Crop and Soil Sciences
Technical Report 06-2**

*WSU Dryland Research Station,
Lind – June 15, 2006*

*WSU / USDA-ARS Palouse Conservation Farm Field Day,
Pullman – June 22, 2006*

*WSU Wilke Farm Field Day,
Davenport – June 29, 2006*

Welcome to our 2006 Field Days!

As the Chair of the Department of Crop and Soil Sciences, I am proud to introduce the **2006 Field Day Abstracts: Highlights of Research Progress**. This publication has a simple purpose: to introduce you to over 35 research programs conducted in 2006 by WSU faculty and USDA/ARS research scientists working as part of or in cooperation with the Department of Crop and Soil Sciences.

This edition features the research of the Climate Friendly Farming™ team, in conjunction with their symposium on June 21st at the WSU-Pullman campus, and related field day at the Palouse Conservation Field Station on June 22nd. More information can be found on their website, <http://cff.wsu.edu>.

The Department of Crop and Soil Sciences mission states that we will "discover and develop principles of crop and soil sciences through scientific investigation and apply these principles to the development of new crop varieties and new crop, soil and water management practices in agricultural, urban and natural environments; teach principles and applications to undergraduate and graduate students; and disseminate accumulated knowledge through resident instruction, continuing education, extension, publications, and professional contacts."

As you will read in the abstracts, we have exciting new and ongoing research activities. Our 2006 departmental sponsored field days are just one way for us to help you learn more about the latest developments in our research programs.

Sincerely,



*Dr. William L. Pan, Chair
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Cover: *Field monitoring of nitrous oxide (N₂O) emissions.*

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The Climate Friendly Farming Research & Demonstration Project is a project of Washington State University's Center for Sustaining Agriculture and Natural Resources which seeks to understand the interconnections between climate change, greenhouse gas emissions and agriculture in an effort to reduce agricultural emissions of greenhouse gases, improve soil carbon sequestration of carbon dioxide, and develop bioenergy, biofuels and bioproducts from agriculture that offset the combustion of fossil fuel carbon. Funded by the Paul G. Allen Family Foundation.

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Respectfully Dedicated to Dr. Robert I. Papendick



Dr. Robert I. Papendick, Soil Scientist and Research Leader, retired from the USDA-ARS at Pullman, Washington in 1995 after 33 years of federal service. After retirement he was collaborator and consultant with the ARS/WSU Columbia Plateau Wind Erosion/Air Quality Project at Washington State University.

Robert was born at Canistota, SD and grew up on a mixed livestock/small-grain farm nearby. After two years of military service he obtained a BS degree in Agronomy in 1957 and a Ph.D. in Soil Science in 1962, both from South Dakota State University. Following graduation Dr. Papendick was employed as soil physicist with the Tennessee Valley Authority, Wilson Dam, Alabama where he conducted fundamental research on advancing the direct use of anhydrous ammonia as a nitrogen fertilizer over a range of soil and cropping conditions. In 1965, he joined ARS as soil scientist at WSU to conduct research on water conservation/use efficiency and erosion control on regional farmlands. From 1972 until 1995 he served as both supervisory soil scientist and Research Leader of the ARS Land Management and Water Conservation Research Unit at Pullman.

Throughout his career, Dr. Papendick was a far-sighted leader in the fore-front helping to solve a number of agricultural conservation, production and sustainability issues. His ARS Soil and Water unit pioneered no-till research for erosion control in the Pacific Northwest wheatlands beginning in the late 1960s amidst much negative speculation until the concept gained creditability in the late 1970s. He played a leadership role in developing and managing the tri-state STEEP (Solutions to Environmental and Economic Problems) project, in response to grower concerns in the mid 1970s about the need for increasing emphasis on controlling soil erosion and sediment pollution of the region's streams, rivers and lakes. The STEEP research and education program is now acclaimed nationally as a model for multidisciplinary research. This program is still ongoing, and is credited for its successful development and application of conservation technologies that meet USDA program and grower goals for sustaining soil, water, and air quality without impairing farm productivity and profitability.

In 1979 Dr. Papendick chaired a national study team commissioned by Secretary of Agriculture Bergland that published *A Report on Recommendations for Organic Farming in 1980*, a first assessment ever by the USDA on organic farming. The study and report laid the foundation and language for the sustainable agriculture initiatives in the 1985 and 1990 Farm Bills which gave legitimacy and momentum to a strong and healthy organic farming industry in the US today.

Beginning in the late 1980s under Pullman ARS leadership, Dr. Papendick worked with air quality specialists and program managers at the Environmental Protection Agency (EPA), the Washington State Department of Ecology (DOE), WSU, and the U of I, to develop a regional wind erosion/air quality research and education proposal which addressed the sorely neglected farmland dust problem in the Columbia Plateau/Basin and outlying urban centers. The effort resulted in substantial new support from EPA and DOE and initiation of a multidisciplinary erosion/air quality program in 1992. This nationally recognized Columbia Plateau Wind Erosion/Air Quality Project operating since is a direct result of these early activities and has led to new knowledge on the fundamentals of wind erosion and dust emissions, and control methods that have mitigated the dust problem by reducing the number of exceedances of federal air quality standards in the region.

Dr. Papendick was active in the American Society of Agronomy (ASA) and Soil Science Society of America (SSSA) for over 30 years. He was elected ASA Fellow and SSSA Fellow in 1977 and served on numerous boards and committees, and as an associate editor of the SSSA Journal. Dr. Papendick has authorship on over 200 technical publications and has received multiple honors and awards in recognition of superior service and research excellence. Among these publications were two books, one the 1998 Handbook entitled "Farming with the Wind: Best Management Practices for Controlling Wind Erosion and Air Quality on Columbia Plateau Croplands" and the second in 2004 "Farming with the Wind II: Wind Erosion and Air Quality Control on the Columbia Basin". Both have been widely distributed to growers, scientists, agencies, and policymakers.

Currently Dr. Papendick is collaborating with colleagues on researching and documenting the impact of the STEEP program, and the history of farming in the low rainfall areas. Also, he and his wife Ruby are enjoying their children, grandchildren and great-grandchildren as well as gardening and traveling.

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FARM BACKGROUNDS

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 3 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 90-acre watershed using 369 GPS-referenced sites on a nonaligned grid. Maps

are available or being developed from archived samples for soil types and starting weed seed banks, populations of soilborne pathogens, and soil water and nitrogen supplies in the profile. 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 systems (rotations) starting in the fall of 2001. Yield and protein maps were produced for the crops produced in 1999 and 2000.

The 90-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.

History of the 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 has the lowest rainfall of any state or federal facility devoted to dryland research 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. The primary purpose of irrigation on the Dryland Research Station is not to aid in the development of wheats for higher rainfall and irrigated agriculture, but to speed up and aid in the development of better varieties for the low-rainfall dryland region.

Dr. M. A. McCall was the first superintendent at Lind. McCall was a gifted researcher given somewhat to philosophy in his early reports. In a 1920 report he outlined the fundamental reasons for an outlying experiment station. He stated: "A branch station, from the standpoint of efficiency of administration and use of equipment, is justified only by existence of a central station." The Lind station has followed the policy of studying the problems associated with the 8-to 12-inch rainfall area.

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. A pump and irrigation system were installed in 1967. A new seed processing and storage building was completed in 1983 at a cost of \$146,000. The Washington Wheat Commission contributed \$80,000 toward the building, with the remaining \$66,000 coming from the Washington State Department of Agriculture Hay and Grain Fund. A machine storage building was completed in 1985, at a cost of \$65,000, funded by the Washington Wheat Commission.

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. Also in 1996, the state of Washington transferred ownership of 1000 acres of adjoining land 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 was established as one of 10 original erosion experiment stations throughout the United States during the period 1929 to 1933. The station consists of a number of buildings including offices, laboratories, machine shop, a greenhouse, and equipment buildings, as well as a 200-acre research farm. Scientists and engineers from the USDA/ARS and Washington State University utilize the Station 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. Several persons are employed at the Station by both the federal and state cooperators. The Station has a full-time manager who lives on-site and maintains the busy flow of activities which characterize the farm. This includes the day-to-day



routine items, farm upkeep, maintaining the complex planting and harvest schedule to meet the requirements of the various cropping research, and operating the machine shop which fabricates a majority of the equipment used in the research projects. There are also a number of part-time employees, many of whom are graduate students, working on individual projects. Along with the many research projects, a no-till project at the Palouse Conservation Farm was initiated on bulk ground in the fall of 1996. The objective of this project is to determine if it is technologically possible and economically feasible to grow crops in the eastern Palouse under no-till. The ARS Units at Pullman are focusing on technologies and research needed to make no-till farming possible in this region.

History of Spillman Agronomy Farm

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



William J. Spillman, breeding plots at Pullman, 1900

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

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

Facility updates to Spillman Agronomy Farm include: (1) a 100- by 40 foot machine storage addition built in 1981, (2) in 1968, the Washington Wheat Commission provided funds for a sheaf storage facility and at the same time (3) the Washington Dry Pea and Lentil Commission provided \$25,000 to build a similar facility for the pea and lentil materials. The facilities of the Spillman Agronomy Farm now range in value well over a half million dollars.

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

On July 7, 2005, over 330 people attended a special 50th Anniversary Field Day at Spillman Agronomy Farm that included 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 Sate 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. A local family has operated the farm for approximately 60 years. Funding for the work at the Wilke Farm comes from research and extension grants and through the proceeds of the crops grown. Goals for research at the Wilke Farm are centered around the need to develop cropping systems that are economically and environmentally sustainable. Focus is on systems that reduce soil erosion by wind and water, improve the efficiency and net return of farming operations, enhance soil quality, and reduce stubble burning.

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. Wheat is the most profitable crop in the rotation and the wheat-summer fallow rotation has been the most profitable system for a number of years.

The farm is split in half by State Highway 2. The north side has been in continuous winter or spring cereal production for approximately 10 years and being cropped without tillage for the past 5 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. There are three replications of a 4-year rotation (winter wheat, spring cereals, a broadleaf crop, and a warm season grass), and three replications of a 3-year rotation (winter wheat, spring cereals, and a broadleaf crop). Crops grown in the rotation have included barley, winter and spring wheat; canola, peas, safflower, sunflowers, and yellow mustard for broadleaf crops; and proso millet for the warm season grass. Data on soil quality, weed and insect populations, diseases, crop yield, and economics are being collected. The farm provides research, demonstration, education and extension activities to further the adoption of direct-seeding systems in the area. The Wilke Farm is a collaborative approach to develop direct seed systems that include local growers, WSU research and extension faculty, NRCS, agribusiness, Lincoln County Conservation District, and EPA. In addition, the Wilke Farm is used increasingly for small plot research by WSU 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.

Feature: Climate Friendly Farming

The Climate Friendly Farming™ Project: Dryland Farming Systems Research

DAVID HUGGINS¹, DAVID GRANATSTEIN², CHAD KRUGER²
¹USDA-ARS, ²WSU



Human understanding of climate went through major revisions during the last half of the 20th century. Now earth's climate is thought to be much less stable, and potentially very sensitive to small changes that could trigger major shifts in weather over the course of the next few decades. At the beginning of the 21st century, it is largely acknowledged by the scientific community that global warming is a real phenomenon. Furthermore, understanding future climate change and managing associ-

ated uncertainties are not only a challenge to scientists but are also recognized as very complex with major social, economic and political concerns.

Current agricultural practices and management strategies are largely a consequence of human adaptation to historic climatic conditions. In the face of climate change, however, the future viability of current agricultural strategies may be seriously challenged. The Intergovernmental Panel on Climate Change (IPCC, 2003) states that the current rate of global warming is the fastest in recorded history and has already started to disrupt many biological and ecological systems on the planet. Research in the Pacific Northwest indicates that climate change could lead to significant reductions in winter snowpack leading to water shortages, more extreme temperature fluctuations, and increased intensity of pest infestations. Furthermore, there is an increasing expectation that in addition to supplying more food, fiber and fuel, agriculture will also need to provide broad ecosystem services such as clean water and air, wildlife habitat, and long-term conservation of natural resources. Finding agricultural solutions that explicitly recognize agriculture's broadened role in the face of uncertainties associated with climate change is the overall goal of Climate Friendly Farming™. Towards this end, solutions must put into perspective agri-

(Continued on page 12)



This grant to CSANR is the largest grant received by WSU from the Paul G. Allen Family Foundation and the first for agricultural research (\$3.75 million, 5-year project). The "Climate Friendly Farming" research fits nicely with the mission of the Paul G. Allen Family Foundation—to promote the healthy development of populations and to strengthen families and communities in the Pacific Northwest.

THE **PAUL G. ALLEN**
 FAMILY *foundation*

(Continued from page 11)

culture's role in mitigating climate change as well as improving agriculture's performance (e.g. productivity, stability and sustainability) during the 21st century.

Agriculture's role in global change issues has often centered on the potential to store soil carbon through reduced tillage and direct-seeding. That role, however, is now recognized as much larger and includes major climate-friendly strategies for dryland agriculture such as: (1) conservation tillage and associated increases in fuel efficiencies and soil carbon sequestration; (2) intensification and diversification of cropping systems including the use of annual and perennial crops, biofuels and the reduction of fallow; (3) application of precision conservation technologies and systems to increase fertilizer and pesticide use efficiency (particularly N use efficiency); and (4) increasing the use of biomass or dedicated energy crops to produce renewable bioproducts (energy, fuels, chemicals, etc.) which can offset the use of fossil fuels.

Dryland agricultural research activities for the Climate Friendly Farming™ Project include:

1. Establishing field-scale research sites for various alternative agricultural systems (ie. continuous direct-seeding, perennial-based polyculture and low soil disturbance direct-seed organic farming systems).
2. Designing innovative agricultural systems and assessing economic factors, energy cycles and efficiencies, and the cycling and flow of carbon, nitrogen and water.
3. Evaluating alternative agricultural systems for greenhouse gas impacts including carbon sequestration and N₂O emissions.
4. Developing and evaluating Precision Nitrogen management technologies / strategies for reduced N₂O emissions.
5. Evaluating the potential role of biofuel / bioenergy crops in dryland cropping systems.



BioFuel Feedstocks: Agriculture's Opportunity? Sustainable Production of Bioenergy Crops

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Sustainability is a requirement for all new biobased technologies. Sustainability is dependent upon: acceptable environmental impacts of products; economic viability for all participants; and a positive social impact of the product and its production. The Pacific Northwest (PNW) produces excellent yields of wheat, barley, beans, potatoes and alfalfa hay. However growers are faced with problems of low profits, crop surpluses, as well as problems associated with monoculture and limitations and costs of synthetic pesticides and fertilizers. Continuing increases in petroleum costs have increased grower interest in looking at the potential of bioenergy crops to increase net returns in a variety of rotation systems. Oilseeds such as canola/rapeseed/mustard fit well into many crop



Spring mustard.

rotations of the PNW and have been shown to break some pest cycles (weed, insects and diseases) and minimize synthetic chemical usages for such crops as potato, carrots and onions as well as small grains in Washington. In Prosser, we have initiated a series of trials evaluating a six oilseed crops grown to maturity for an emerging biodiesel market: spring and winter rapeseed, mustard, sunflower, safflower and soybean. Other studies involve the evaluation of switchgrasses and crop residues for ethanol production. In Pullman, alternative biofuels including perennial and annual crops are being evaluated for their suitability in the design of sustainable agricultural systems.

Canola & Mustard Variety Trials – Potential for Biodiesel

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

The Pacific Northwest (PNW) has become a center of canola and mustard production in the USA. Canola and mustard are ideal rotational crops when included in crop rotations with small-grain cereals, and wheat yield after these crops can often be significantly increased over monoculture



cereal production. More recent changes in fuel prices have increased interest in alternative fuels and biodiesel has commanded the attention of many groups. Success in biodiesel production will depend on local production of feedstock oils to avoid high transportation costs. Consistent supply of these oils will require greater acreage and stability of canola and mustard production in the region. The primary limiting factors limiting canola and mustard acreage in the PNW is a lack of adapted cultivars. To address this, the University of Idaho has been conducting field evaluation trials of winter and spring canola and mustard. These trials are planted throughout

the potential growing regions of Idaho, Oregon, Washington and western Montana. The aim of these trials are to: (1) screen a range of canola and mustard cultivars for adaptability to different environmental conditions throughout the PNW; (2) identify specific cultivars that show high productivity under specific conditions in the region; and (3) make the farming community aware of the cultivars available for production in the area and their potential performance through field tours and written presentations. Since 1994, we have evaluated 168 different spring canola cultivars from 20 different seed companies, along with 98 winter cultivars from 10 companies. Similarly we have evaluated over 30 different mustard cultivars or advanced breeding lines. Local growers have access to inspect the trials in their region and to review performance data to help determine the most suitable cultivars for their farms. Results are presented at grower meetings, in written reports, and on our website (<http://www.ag.uidaho.edu/brassica/>).



Economics of Spring Canola Production in Dryland Eastern Washington

KATHLEEN PAINTER, WSU CENTER FOR SUSTAINING AGRICULTURE AND NATURAL RESOURCES; HERBERT HINMAN, SCHOOL OF ECONOMIC SCIENCES, WSU; AND DENNIS ROE, USDA NRCS

Demand for oilseed crops promises to be strong due to recent legislative and commercial developments regarding biodiesel production. This study determines the costs of production for spring canola across three rainfall zones in eastern Washington. Typical production practices and machinery complements are based on producer surveys. In addition, this new publication (EB2009E) provides cultural information plus other sources for the producer.

Canola production can provide rotational benefits for dryland grain growers in the Pacific Northwest. Canola producers have a greater choice of herbicides, thus facilitating weed control. Canola can also help loosen hardpan within the soil and break up disease cycles. However, oilseed crops are more difficult to establish and may require more moisture than most other rotational crops. As crop breeding research and variety trials continue, growers can expect varieties that are better suited to this region. Although it can potentially improve yields of the subsequent wheat or barley crop, recent market prices for canola have been too low to cover typical production costs for this crop.

This study calculates break-even crop prices for a range of production levels. The break-even price is the price needed to cover all production costs including land rent and machinery labor but excluding returns to risk and management. In the 12" to 15" rainfall zones, the break-even crop price is \$15.30 per cwt, based on a 1000 lb/ac yield. In the 15" to 20" rainfall zone, the break-even price is \$13.80/cwt, based on a 1300 lb/ac average yield. For the 20" or more rainfall zone, the break-even price is \$11.70/cwt. Current bid prices at this time have been averaging around \$10/cwt.

This Extension Bulletin plus detailed budgets in spreadsheet format are available on the WSU Farm Management website, <http://www.farm-mgmt.wsu.edu>.

Economics of Dryland Winter Canola Production in Eastern Washington and Oregon

KATHLEEN PAINTER, WSU CENTER FOR SUSTAINING AGRICULTURE AND DENNIS ROE, USDA NRCS

Winter canola provides a rotational option for dryland grain growers in the Inland Northwest. Winter canola is typically planted in late August on summer fallow, and harvested the following year in early July. Since canola is more sensitive than wheat to dry seedbed conditions, producers can switch to winter wheat production if conditions are not favorable for canola. Labor for planting and harvesting can be spread out over a longer period if producers are growing both winter wheat and winter canola. Canola has rotational benefits in that it helps clean up grassy weeds, its long taproot penetrates hard pan, and it can break disease cycles.

We have developed budgets for winter canola production based on interviews with producers in the lower rainfall regions of eastern Washington and Oregon: 11" rainfall in Adams County; 14" rainfall in Whitman County; 14" rainfall in Spokane County, and 14" rainfall near Pendleton, OR. Production costs for this crop are similar to those for winter wheat, but yields are more variable and the crop is more difficult to establish. Given the current market price of canola of approximately \$9 per cwt, producers' profits ranged from \$43 to \$107 per acre over variable production costs (excluding fixed costs of machinery and land, land rent, and land taxes). Based on conservative yield data, none of the producers in this study were able to cover their total production costs, with losses ranging from \$24 to \$48 per acre.

As crop breeding research and variety trials continue, growers can expect varieties that are better suited to this region. Yield improvements and/or market price increases are needed to make this crop competitive with winter wheat in the wheat/fallow areas of eastern Washington and Oregon.

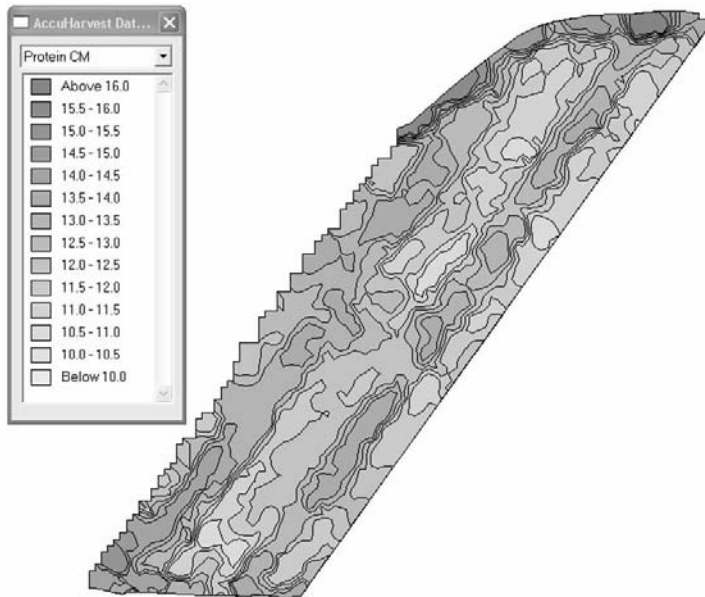
On-Line Sensing of Grain Protein Concentration and Using this Information in Precision Nitrogen Management

DAN LONG, USDA-ARS COLUMBIA PLATEAU CONSERVATION RESEARCH CENTER

The possibility of using on-line sensors to measure grain protein concentration attracts a growing number of growers, millers, and agronomists in their desire to assess grain quality early in the



commodity supply chain. To meet this need, whole grain, near infrared analyzers, widely available in elevator companies and state grain labs, are being adapted for use in the field on a combine or grain auger.



Field map of grain protein concentrations from combine-mounted sensor.

Such an on-line sensing technique would pave the way for growers to determine the quality of the grain as it is being harvested.

The USDA-ARS in Pendleton is assisting in this endeavor by investigating the field performance of optical sensors manufactured by three different firms. An optical sensor determines protein concentration by measuring the amount of near infrared light that is either transmitted through the grain (NIT) or reflected from the grain (NIR). Each

measurement can be referenced to a field location using the Global Positioning System in a fashion that is similar to mapping with a yield monitor.

An initial monitoring test was conducted to measure the protein concentration of flowing grain with near infrared transmittance (NIT) technology. A test stand was constructed from the cross auger, elevator, and grain bin-filling auger of a real combine. A DSquared Development (La Grande, OR) NIT sensor was installed on the grain bin-filling auger and readings from this sensor were compared with protein values measured on 30-lb reference samples. The percent difference in protein concentration between the sensor and reference values was less than 0.5 percent thus suggesting that on-line sensing from an operating combine at harvest is technically feasible. We are determining ways that grain protein maps can be used not only in grain quality segregation, but also precision agriculture applications. Potential uses of this information include identification of nitrogen management units for variable-rate fertilizer application, and estimation of straw yield for the Conservation Security Program. Sensing from a grain auger would also allow growers to segregate low quality- from high quality-wheat as it is being harvested in the field and transferred into a storage bin.

COVER STORY—

Greenhouse Gas Emissions in Pacific Northwest Cropping Systems

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One of the leading environmental issues facing our planet is global climate change, largely driven by increases in atmospheric concentrations of greenhouse gases: carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). Atmospheric concentrations of CO₂, CH₄, N₂O and other greenhouse gases have increased during the last two centuries, primarily as a consequence of human activities (e.g. the combustion of fossil fuels, agriculture and land use changes). Dur-



ing the period from 1750 to 2000, atmospheric concentrations of CO₂ increased 31% (from 280 to 368 ppm); CH₄ increased 151% (700 to 1750 ppb) and N₂O increased 17% (270 to 316 ppb).



Field monitoring of nitrous oxide (N₂O) emissions.

While total N₂O emissions are much lower than CO₂ emissions, N₂O has drawn particular attention because it is a potent greenhouse gas with a global warming potential 296 times that of CO₂. Although N₂O is emitted from both anthropogenic and natural sources, agriculture has been identified by the Intergovernmental Panel on Climate Change (IPCC) as the major contributor to anthropogenic emissions. Nitrogen fertilizer applications are the most important source of anthropogenic N₂O emissions and account for approximately 81% of the anthropogenic emissions of N₂O. Some potential management measures that can help mitigate agricultural N₂O emissions from arable soils include cropping pattern, tillage practice, and nitrogen and

irrigation management practices (including precision N management). The USDA-ARS and Washington State University are conducting greenhouse gas emissions research at the Irrigated Experiment Station at Paterson, WA, and under dryland conditions at the Palouse Conservation Field Station and the WSU Cook Research Farm near Pullman, WA. Our observations both at Pullman and Paterson show transient increases in N₂O emissions from fertilized, relative to unfertilized, research plots. The magnitude of these transient increases varies among cropping systems.



Carbon Sequestration and Carbon Credits

DAVID GRANATSTEIN¹, LYNNE CARPENTER-BOGGS¹, DAVID HUGGINS², CLAUDIO STÖCKLE¹ AND CHAD KRUGER¹
¹WSU, ²USDA ARS

Cropping systems play an important role in atmospheric greenhouse gas status. Duxbury (1994) estimated that agriculture contributed 25% of the historical anthropogenic emission of carbon dioxide (CO₂) into the atmosphere during the past two centuries. Soils store carbon for long periods of time as stable soil organic matter (SOM; about 58% carbon), which reaches a steady-state level in natural systems as determined by climate, soil texture, topography and vegetation. When soils are disturbed by agricultural tillage, fallow, or residue burning, large amounts of CO₂ can be lost to the atmosphere. However, a significant portion of this carbon can be recaptured from the atmosphere and returned to the soil through reduced tillage and improved crop rotations. Tillage and crop rotation are major regulators of SOM cycling, flow and storage in agricultural systems. Tillage controls the availability of



Soil carbon sequestration.

carbon in crop residues and roots as well as decomposition rates. Shifts from high to low disturbance tillage regimes often promote the accumulation of SOM by decreasing its availability to microbial attack and slowing rates of SOM decomposition. Crop rotation determines the amount of carbon in residues and roots that are returned to the soil as well as the quality of the carbon additions that influence SOM decomposition. Studies evaluating the combined influence of crop

and tillage management on SOM often conclude that crop rotation effects are primarily due to differences in carbon additions, while major tillage effects are on SOM decomposition rates and losses via soil erosion. Ongoing research efforts of the Climate Friendly Farming Project at the Palouse Conservation Field Station are evaluating and modeling the potential for combinations of reduced tillage and crop rotation to store carbon in soil. Determining the amount of carbon sequestration that results from various agricultural practices is essential information for future trading of carbon credits to carbon emitters, such as coal fired power plants. Carbon is currently trading in the US for ~\$5.00 / ton CO₂ Equivalent on the Chicago Climate Exchange.

Low Soil Disturbance Organic Cropping System: Lessons Learned During the First Four Years

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Organic systems that include high soil disturbance from tillage-intensive operations are not sustainable in many dryland cropping areas of the Pacific Northwest (PNW). Interest has grown internationally for designing new soil conserving organic systems; however, no low disturbance organic strategies have been developed for the PNW. Another constraint in the dryland cropping region of the PNW is the lack of livestock and sources of manure for supplementing soil fertility. Combining direct-seed technologies with organic production methods is the overall goal of this field study initiated in 2001 within the Agroecosystem Research Trials (ART) at the USDA-ARS Palouse Conservation Field Station near Pullman, WA. Our overall organic cropping system strategy integrates cover crops, forage legumes and spring cash crops into a rotation with 3 phases:



Intercropping Phase



Legume Hay Phase



Spring Cereal Phase

Field-scale trials were initiated during the fall of 2001 with each crop/phase represented every year in three replicates. Seeding operations were accomplished using no-till drill and broadcast methods. Mechanical mowing and undercutting sweeps were used for low disturbance management of cover crops, volunteer grain and weeds. Key elements of the system are as follows.

- Cover cropping: establish winter surface cover for erosion protection; dry surface seed-zone in spring and create "dormant mulch"; suppress weeds; and build soil fertility and tilth.
- Sweep undercutting and mowing: low disturbance management of cover crops, weeds; maintain surface residues, create dormant mulch, and provide soil erosion protection; create soil discontinuity and establish depth of seed-zone water.
- Use spring annual cropping and perennial legumes to control weeds and build soil fertility.
- Legume hay/green manure phase: build N fertility reserves and deplete weed seed bank prior to spring cereal grain.
- No-till and broadcast seed to minimize disturbance and create opportunities for diversifying cover crops, cash crops and intercrops.
- Avoid summer fallow due to excessive soil erosion hazard and degradation.



The organic system design is evolving with agronomic and economic evaluations and is entering a new phase that also includes a livestock component that basically substitutes for the legume hay portion of the rotation.

No-till Cereal-livestock Integration for Diversified Farms

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¹WSU, ²USDA-ARS



Palouse farmers know the current difficulties of wheat production: soaring fuel and fertilizer costs, narrowing profit margins, the threat of suspended crop support programs, new soil conservation and resource management expectations, and more. Are there options to our current dependence on wheat? Our research project, funded by the Western Sustainable Agriculture Research and Education organization (WSARE), proposes that grazing livestock could address key challenges faced by agriculture in the region.

The integration of livestock into cropping systems has the potential to diversify farm income, provide low-risk biological options

for weed and pest control, and to increase the productivity of land. Our research aims to explore the integration of grazing into annual cropping system practices by: (1) comparing integrated livestock-cereal systems; (2) troubleshooting management practices; (3) making economic and natural resource assessments; and (4) working with area farmers to test strategies and explore options.

This research builds on the Agroecosystem Research Trials (ART), initiated in 2001 at the USDA-ARS Palouse Conservation Research Station (PCFS). Recent work at the ART assessed alternative cropping systems and economic potential associated with the organic market. Many challenges prevent these systems from being implemented on a widespread scale, from the basics of fertility and weed management to the complexities of alternative marketing strategies. Our work is exploring the potential for livestock integration to overcome some problems of, among other things, fertility and profitability.

CURRENT ACTIVITY

We are designing the integrated livestock-cereal treatment of our comparison study, which means identifying critical management issues, developing strategies to address them, and working with our producer-researcher group to test and modify our plans. We see three primary areas for integrated farming systems development: (1) pasture establishment (including species selection and initial management plan); (2) pasture performance including livestock, plant and soil dynamics; and (3) the agronomic challenge of transitioning a 4-yr old pasture into wheat without the aid of chemical controls.

Our goals for summer 2006 are to: spring establish a pasture mix consisting of orchardgrass, perennial ryegrass, meadow brome, alfalfa, red clover and a white clover; collect baseline data in research plots for the described treatments; collect baseline data on field from a grower-cooperator farm where we will conduct take out/transition trials; conduct laboratory and field tests monitoring nitrogen cycling; further develop systems design priorities with participating growers; and assemble comparative economic data for the treatments under investigation.



Developing Perennial-based Cropping Systems

JULIE DAWSON¹, STEVE JONES¹ AND DAVE HUGGINS²

¹WSU, ²USDA-ARS

Perennial-based cropping systems have advantages over annual crops in terms of increasing water and nutrient use efficiency, curbing soil erosion and building topsoil. Although many perennial counterparts for our annual cash crops exist, few are currently the focus of breeding programs. In our region, breeding perennial wheat is an innovative program under the leadership



Perennial wheat.

of Drs. Steve Jones and Tim Murray. In comparison to annual wheat, perennial wheat would likely have a more extensive root system, larger leaf area, greater green leaf duration and greater overall biomass production. Evaluating nitrogen use efficiency (NUE) is an active area of research within the breeding program. Breeding plants to invest more resources in roots and vegetative growth could improve NUE if deep root systems and longer duration of photosynthesis are associated with improved nitrogen uptake efficiency. However, it could also result in initial declines in grain yields. Particularly in perennials, the need to reserve resources for the next growing season could reduce the amount of

nitrogen (N) translocated to the grain. Fortunately, lower yields in perennial grains may not be inevitable with the use of advanced breeding methods and well-selected parents. With a long-term breeding program it is possible to make acceptable gains from selection.

At the Palouse Conservation Farm, plantings of perennial wheat, native grasses, spring and winter wheat are being analyzed for N uptake efficiency and effective rooting depth. The study is planted in field-scale strips replicated nine times. It is hypothesized that native grasses will have greater moisture depletion and be more efficient at taking up available nitrogen than perennial stands, which will in turn be more efficient at using water and nitrogen than annuals. Results will be used to identify and characterize variation for N uptake and partitioning efficiency between and within wheat types. This will enable a strategy to be developed for incorporating higher NUE into annual and perennial wheat varieties.



Part I. Breeding, Genetic Improvement, and Variety Evaluation

Winter Wheat Breeding, Genetics and Cytology

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This year at the Lind Research Station, we bulked the seed from each of 111 F₂ breeding lines. Fifty-five of these had an average coleoptile length statistically equal to or greater than Moro. The average coleoptile length of all 55 lines was 101.5 mm compared to Moro (94.3 mm) with a range of 90 mm to 127 mm. This equates to 55% of the crosses having an average coleoptile length 7% greater than Moro. Great strides are being made in developing very aggressive emerging wheats.

Approximately 400 advanced breeding lines were tested in replicated yield trials and nearly 6500 early generation breeding families were field tested for general agronomic traits, stand establishment, disease resistance, and adaptability. All advanced breeding lines were tested under severe natural eyespot foot rot and stripe rust infection at Spillman Agronomy Farm, Pullman, WA. We are very close to releasing high yielding, high rainfall soft white winter wheat.

The two main objectives for the breeding project are: 1) develop new winter wheats with agronomic traits and disease resistance needed for production in Washington and 2) develop winter wheats with quality traits needed for domestic and export markets. Our two latest releases, MDM (HWW) and Bauermeister (HRW) were developed with these objectives in mind and are significant advances in varietal improvement for hard wheats. Both varieties were approved for full release in February 2005 and continually perform well in Variety Testing trials in various Pacific Northwest states. MDM also performed extremely well in the Asian Products Collaborative Project quality evaluations for the 2004 crop year.

Nearly 2000 soft and hard winter wheat crosses were made in the greenhouse during the 2004/2005 crop year and planted in the field in the fall of 2005. Of these, 893 crosses were made specifically for the introgression of traits associated with superior emergence into our locally adapted cultivars.

Improving Spring Wheat Varieties for the Pacific Northwest

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A total of 375 crosses were made in 2005, and 30,824 breeding lines were evaluated in field trials at multiple locations. Nearly 1,100 F₄ lines were selected from the field based on plant type, stripe rust resistance and heading date. Special emphasis was placed on selecting head rows with high temperature adult plant (HTAP) resistance to stripe rust. All early generation selections from the field were evaluated for end-use quality potential using small scale tests designed to assess protein content, protein quality, flour extraction, and noodle color prior to making selections for advancement to 2006 field trials.

In 2005, Hollis replaced nearly all of Scarlet acreage in the low to intermediate rainfall zones, and certified seed of this variety was available for 2006. Louise, released in 2005, has excellent potential as the Zak and Alpowa replacement in the intermediate to high rainfall zones. It has superior HTAP resistance to stripe rust compared to Alpowa, is partially resistant (65%) to the Hessian fly, and has better emergence than both Zak and Alpowa. The grain yields of Louise equaled or exceeded those of Zak and Alpowa in a majority of the dryland field trials conducted from 1999 to 2005. The end-use quality of Louise is superior to Zak, and this variety is a dramatic end-use quality improvement over Alpowa. Louise will be in commercial production for the first time in 2006. Otis, released in 2005, has outstanding grain yields that equaled or exceeded those of Blanca Grande and Idaho 377s across production zones for the last three years. Otis has seedling resistance to stripe rust, as well as adequate HTAP resistance, and is tolerant to Hessian fly. Otis also will be available for commercial production for the first time in 2006.

Application of Biotechnology to Spring Wheat Variety Improvement

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Biotechnology is useful for identifying superior breeding lines in early generations of selection that carry genes that are deemed as being essential for commercial success prior to field evaluation. Our goal is to use marker-assisted breeding (MAB) to introgress target gene(s) into adapted germplasm as quickly as possible. We used this strategy to incorporate *Yr5* and *Yr15*, two seedling resistance genes to stripe rust that have not been circumvented by any race of the pathogen found in North America to date, into Scarlet (HRS), WA7900 (HWS), Zak (SWS) and Alpowa (SWS). Backcrossed-derived lines with these genes will be evaluated in replicated field trials at multiple locations in 2006. A chromosomal segment from a wild relative of wheat that was reported to increase grain protein concentration (GPC) by 1 to 2% has been incorporated into Scarlet, Tara 2002, and the hard red winter line WA7869 using MAB. Several promising derivatives are being tested for a second year in replicated yield trials, and we are conducting a controlled experiment to determine if the expression of this region is influenced by drought and/or disease pressure. By 2007, we expect to identify genotypes with cultivar release potential that have durable stripe rust resistance based on the presence of *Yr5* and *Yr15*, as well as individuals with higher GPC due to introgressing the region on chromosome 6BS that is associated with this trait into these lines. The Hessian fly is one of the most destructive insect pests of spring wheat in the U.S. and most resistant spring wheat cultivars in PNW carry *H3*. We incorporated two novel genes, *H9* and *H13*, into Otis, Macon and Louise using MAB, and 5000 F₄ head rows will be evaluated in the field in 2006. Genetic linkage mapping efforts, including the use of microspore culture for population development, are currently underway for *Rhizoctonia* and *Pythium* root rots.

The Effect of Wheat ABA Hypersensitive Response Mutants on Seed Dormancy and Drought Tolerance

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The plant hormone abscisic acid (ABA) stimulates seed dormancy during embryo maturation, inhibits germination of mature seed, and stimulates stress responses such as stomatal closure in response to drought stress. *Arabidopsis* mutants isolated for ABA hypersensitive (ABH) seed germination showed increased seed dormancy and drought tolerance. ABH crop plants may provide increased resistance to preharvest sprouting (PHS) by increasing seed dormancy, and increased drought tolerance by increasing ABA sensitivity of stomatal closure. Based on this hypothesis, wheat plants hypersensitive to ABA in seed germination were isolated. Fast-neutron mutagenized allohexaploid wheat (cv Chinese Spring) was screened for inability to germinate on a concentration of ABA that is too low to prevent wild type seed germination. In ABA dose-response assays, 12 mutants showed ABA hypersensitivity in seed germination while 13 appeared to have prolonged seed dormancy. Genetic analysis showed that two are the result of a single dominant mutation, whereas three others may be a single semi-dominant (additive) mutation. It is expected that some of the 25 ABH mutants identified will show improved drought tolerance. ABH mutants should close their stomates earlier in response to drought and have slower transpiration. Drought tolerance was evaluated by estimation of transpiration rate, stomatal conductance, and carbon isotope discrimination ($\delta^{13}\text{C}$). Of 11 tested, six ABH showed slower transpiration rate, and one of four mutants showed lower stomatal conductance. In preliminary experiments 5 of 19 mutants appeared to have reduced $\delta^{13}\text{C}$ relative to wild type. Thus far, it does appear that increased ABA sensitivity in seed germination correlates with slower transpiration rate and drought tolerance in young wheat plants. Future work will examine drought tolerance in the field as measured by yield and harvest index.

Barley Improvement Research

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The overall goal of the WSU Barley Improvement Program is to make barley a more profitable crop. Specific objectives are to improve agronomic and grain quality factors and disease and insect resistance for dryland and irrigated production. The emphasis is on spring hulled barley with additional efforts on spring hulless and/or waxy, and winter types. One new two-row spring cultivar each was released in 2001 (Farmington), 2002 (Bob), and 2003 (Radiant in collaboration with D. v. Wettstein). Bob and Radiant have yields similar to Baronesse, while Farmington yields best in med.-high rainfall zones. Based on results through 2005 from across eastern Washington, Farmington (121 loc-yr), Bob (87 loc-yr), and Radiant (83 loc-yr) yielded 96, 97, and 98% of Baronesse, respectively. For most individual nurseries, the yields of these cultivars were statistically equal or greater than Baronesse. Farmington and Bob have partial resistance to barley stripe rust. Two newer two-row breeding lines have performed well agronomically, WA15279-00, and WA10701-99. WA10701-99 has high malting quality, as well, and is being considered for release. A new waxy hulless line, WA9820-98 is also a new release candidate to be directed at food and feed use. A 6-row winter barley is also a release candidate. Current collaboration in the U.S. Barley Genome Project involves mapping dormancy, preharvest sprouting, and malting quality genes and molecular breeding for malting barley improvement. Combining the high yield of Baronesse and high malting quality of Harrington using molecular marker assisted selection has yielded several promising breeding lines. Collaborative projects in evaluating barley for food use and pest resistance are also underway. New breeding lines have been identified with resistance to barley stripe rust, Russian wheat aphid, and Hessian fly. Work on screening for resistance to soil borne pathogens is in progress.

News on Barley Breeding by the R.A. Nilan Distinguished Professorship

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In the 2005 WSU Spring Barley Variety Trial Yu-501-385 has produced over the 12 test stations a mean yield of 4164 LBS/A, Radiant 41012 LBS/A and Baronesse 4044 LBS/A. Highest yields were achieved at Moses Lake by Cebeco 01409 (6363 LBS/A), Radiant (6350 LBS/A) and line WA 8569-99 (6304 LBS/A). Over 5 years averages top yielders at different stations were Baronesse, Radiant, Bob, Xena and Farmington.

Proanthocyanidin-free barley allows the breweries to bottle brilliant clear beer without chill-haze proofing with polyvinyl-polypyrrolidone as is presently practiced to avoid protein precipitation in the bottle and to achieve the required shelf life. The two-row barley Radiant has shown in tests that high quality malt can be obtained with it, when grown under suitable field conditions. Full-scale brewing tests have demonstrated that proanthocyanidin-free malt chill-haze proofs beer better than the technical process and it is thus sufficient to use 50% proanthocyanidin-free malt and 50% proanthocyanidin containing malt in the mash tun. Proanthocyanidin-free barley is however also an excellent feed barley.

Brewers like to use mixtures of two-row and six-row barley for malting because of the higher amount of starch degrading enzymes (diastatic power) in the six-row barley. We have therefore been breeding proanthocyanidin-free six-row barley. Tests in State Uniform Nursery over the last three years have shown that the proanthocyanidin-free six-row lines 2001 NZ392 [16230-95 BA6B-95-8253] and 2001 NZ706 [Pant 643/9130-87 BA6B93-2978] can compete in yield with the Busch Agriculture malting barley varieties Legacy, Robust, Tradition and are superior to Morex. They will form a substitute for Steptoe. But in contrast to Steptoe malting quality is high and reaches quality scores comparable to Legacy, Robust and Tradition. Applications for the release of these two lines are submitted to the WSU barley variety release committee. They will constitute, probably worldwide, the first proanthocyanidin-free six-row malting barley cultivars. They are also excellent feed barley.

Molecular Breeding to Enhance Grain Yield of Premium Malting Quality Barley Cultivars

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High malting quality barley production in the PNW is limited by competition of higher yielding, better adapted, barley for feed cultivars. Baronesse is the leading barley in Washington and Oregon. Baronesse, a two-row feed barley, is well adapted to the diverse production conditions of the PNW. The two-row American malting standard Harrington, an older Canadian cultivar, yields significantly lower than Baronesse. To transfer Baronesse yield and adaptation traits to Harrington while maintaining its premium malting quality, we follow a molecular-marker assisted selection strategy. Preliminary genotyping was done using RFLP (restriction fragment length polymorphism). RFLP are being converted to PCR based markers: CAPS (cleaved amplified polymorphic site), which will be more breeder-friendly for routine screening of germplasm. Advanced lines derived from crosses between Harrington and Baronesse have been tested in the field and genotyped. Primary chromosome fragments carrying yield genes have been detected and are currently being pyramided in individual lines. This was not done previously. Advanced lines carrying 2-3 quantitative trait loci (QTL) have been advanced in the greenhouse and will be tested for yield and quality during the 2006 field season. Several lines from previous genotyping out-performed Baronesse in the field in preliminary tests in 2005. Crosses with high malting quality cultivars Klages and Morex are in progress to also transfer Baronesse grain yield QTL to them. In addition, we are also targeting malting quality chromosome fragments to further select for these traits in early generations and reduce the amount of material being advanced. The final goal of this project is to have premium quality barleys with Baronesse-like grain yield and adaptation to the PNW conditions.

WSU Extension Uniform Cereal Variety Testing Program—2005

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The goal of the WSU Extension Uniform Cereal Variety Testing Program is to provide a uniform replicated testing program that provides comprehensive, objective and readily available information on the performance of both winter and spring types of public and private cereal varieties to Washington growers and wheat and barley breeders. The diversity of growing regions in Eastern Washington for wheat and barley production necessitates using a large number of uniform testing locations that represent all these regions. The Variety Testing Program established 21 soft white winter, 9 hard winter, 18 soft white spring wheat, 18 hard white spring wheat, 18 hard red spring wheat, two winter barley and 15 spring barley nurseries at 22 locations encompassing 12 counties in 2005. A combined total of 198 different wheat and barley varieties/advanced lines were evaluated (103 winter wheat, 46 spring wheat 9 winter barley and 40 spring barley). Approximately 30% of all entries were advanced lines from WSU or USDA/ARS wheat and barley breeding programs at Pullman, WA. Results from these trials supported either pre-release or commercial adoption of 10 winter wheat two spring wheat and one spring barley varieties from both public and private breeding programs. Yield and quality data from all 2005 winter wheat nurseries were made available electronically within 2 days after harvest to enable growers and seed conditioners the opportunity to make fall 2005 planting decisions using on current year data. All data used by the USDA Western Wheat Quality Lab, Pullman, WA to develop wheat quality varietal rankings continued to be derived from harvested samples from the Variety Testing Program trials. The WSU Variety Testing Program web site continues to be one of the most efficient mechanisms to access current and historical information on wheat and barley performance in Washington (<http://variety.wsu.edu>).

Grain Legume Breeding, Genetics and Pathology

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The grain legume breeding program is focused on producing new improved cultivars of dry pea, lentil, chickpea and fall-sown winter-hardy pea and lentil. Emphasis has been placed on development of edible types of winter peas and winter lentils that can be direct-seeded in the fall into cereal stubble or reduced tillage situations. All

types of edible grain legumes must be environmentally adapted, high yielding and market acceptable. The breeding efforts directed at each of the individual legume crops are described below.

Dry peas: The goal of the dry pea breeding program is to develop improved cultivars of green and yellow cotyledon spring and winter peas as well as marrowfat types adapted to all suitable US production regions. The project addresses production constraints including disease resistance, harvestability, agronomic adaptation, yield and quality. Two new dry pea varieties were approved for release in 2006, '**Medora**' (selection PS99102238), an upright green pea and '**Windham**' (selection PS9830S358), a semi-dwarf winter feed pea. '**Specter**' (selection PS9830F009) was released in 2005 and was the first white-flowered, clear-seeded winter feed pea cultivar to be released from the USDA-ARS program.

Lentils: The U.S. lentil industry competes in the world market and must have cultivars with acceptable quality for a variety of market classes. Until very recently, the Palouse region produced only one type of lentil, the so-called Chilean type ('Brewer') with large, yellow cotyledons. The trend has been toward several additional types including: Spanish Brown, Turkish Red, Eston and Richlea. '**Pennell**', a large, yellow cotyledon lentil with uniformly green seed coats, was released to the industry and has good standing ability and higher yields when compared to Brewer. '**Merrit**', another large-seeded yellow lentil, was also released and is expected to be a replacement for Brewer. A new large green (yellow cotyledon) lentil selection, LC860616L, has performed well in field trials and was approved for release in 2006 as '**Riveland**'. The release of '**Morton**', a red cotyledon, winter-hardy lentil, is the first of its kind and has provided improved yields when compared to commonly grown spring cultivars and offers producers a viable fall-sown legume rotation crop for use in direct seed situations.

Chickpea: Ascochyta blight is a devastating disease of chickpea in the Palouse area and has caused serious crop loss. Several blight resistant cultivars have been released, but most recently, '**Sierra**' was released with greater resistance to Ascochyta blight, larger seeds and improved yields and quality. '**Dylan**' (selection CA9990I604C), a Café type chickpea with fern leaf morphology and improved blight resistance, was released in 2005. '**Troy**' (selection CA9990I875W), a large-seeded Spanish White type chickpea with fern leaf morphology and improved resistance to Ascochyta blight, was approved for release in 2006.

For more information, please refer to the Grain Legume Research Unit website at: <http://pwa.ars.usda.gov/pullman/glgp/>.

2005 Dry Bean Performance Evaluation in Washington

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As coordinator of the Dry Bean Nursery Program, all bean lines were planted on Shano silt loam soil at Othello Research Farm, WSU on May 24, 2005 to test the adaptability of all new dry bean lines in central Washington. This is part of the W-1150 multistate project: Exotic Germplasm Conversion and Breeding Common Bean for Resistance to Abiotic and Biotic Stresses and to Enhance Nutritional Value. In 2005, there were 38 lines of all market classes (black, navy, pink, pinto, great northern Flor-de mayo, small red, yellow and kidney) including 4 commercial cultivars using as check. Fertilizers were adjusted to 100 lbs N and 80 lbs P per acre. Eptam (2 qt/a) and Sonalan (1 qt/a) were preplant incorporated into the top 4" to control weed. All seedlings grew well under irrigated central Washington. Seedling vigor of all lines was very good. Days to maturity varies from 86 (some pinto and kidney lines) to 99 days after planting (Canyon pinto). Black and Navy are normally considered as full season bean and they required 90 to 96 days in 2005. No insects nor diseases were observed in the field therefore no pesticides were applied during the growing season. Ten plants of each line from each plot were gathered, weighed and threshed for harvest index and plant biomass and seed yield efficiency. Yields ranged from 1410 lbs/a (Mogul dark red kidney) to 4960 lbs/a (115 M black bean). Detailed information about performance, yield, rust resistance and canning quality is available at <http://www.prosser.wsu.edu/Documents/2005cdbnreport2906.pdf>.

Part 2. Pathology and Entomology

Strawbreaker Foot Rot, Cephalosporium Stripe, and Snow Mold Diseases of Winter Wheat

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Strawbreaker foot rot (eyespot) and Cephalosporium stripe are two of the most important diseases of winter wheat in the Inland Pacific Northwest, where they occur on 1.3 to 1.8 million acres in Washington State. These diseases are important to all of the market classes of wheat grown in the state with potential loss in grain yield up to 50% in fields where strawbreaker is important and up to 80% or more in fields where Cephalosporium stripe is severe. Both of these diseases are most common in areas with more than 18" annual precipitation, but can cause significant losses in the lower rainfall areas too. Early-seeded winter wheat has the greatest risk of being affected by these diseases, especially when planted following summer fallow.

The snow mold diseases occur in the northernmost wheat-producing areas of Lincoln, Douglas, and Grant Counties and southern Okanogan County, where snow cover can persist for 100 days or more. These diseases can cause complete loss in years when they are severe, although growing disease resistant varieties has effectively limited losses.

Application of fungicides in the spring prior to jointing and/or planting a resistant variety like Madsen, have been the main control measures for eyespot. Currently Tilt and Topsin-M are the only fungicides registered for eyespot. Disease-resistant varieties remain the most desirable and least expensive method for controlling eyespot and several varieties with resistance are available (Table 1). Varieties with true resistance to Cephalosporium stripe are not available. Collaborative research in our program and Dr. Stephen Jones' winter wheat breeding program has resulted in transfer of resistance from wheatgrass into wheat; varieties with very effective resistance to Cephalosporium stripe and eyespot should be available in the next few years. Disease resistant varieties and early seeding are the best control methods for the snow mold diseases. Bruehl and Eltan are currently the most popular varieties in areas where snow mold is of concern.

In cooperation with the WSU winter wheat breeding program, we screen winter wheat cultivars and breeding lines for resistance to Cephalosporium stripe and eyespot every year at the Spillman Agronomy Farm, Palouse Conservation Field Station and Plant Pathology Farm. Screening for snow mold resistance occurs in grower fields located near Mansfield and Waterville, WA. As a result, potential new varieties with effective resistance to these diseases have been identified and released (e.g., Bruehl) or are in the final stages of testing. This work is part of our long-term goal to improve the resistance of winter wheat varieties to these important diseases and thereby reduce yield losses and external inputs for Washington State wheat growers.

Table 1. Winter wheat varieties adapted to the Pacific Northwest United States with resistance to eyespot.

| Variety | Eyespot reaction ¹ | Market Class ² | Release date |
|--------------|-------------------------------|---------------------------|--------------|
| Chukar* | R | SW Club | 2001 |
| Coda* | R | SW Club | 1998 |
| Temple# | MR | SW Club | 1998 |
| Finch* | R | SW | 2001 |
| Foote# | R | SW | 1998 |
| Madsen* | R | SW | 1988 |
| MJ-4* | R | SW | 2000 |
| Mohler* | R | SW | 2002 |
| ORCF-101# | R | SW | 2003 |
| ORCF-102# | R | SW | 2004 |
| Tubbs* | R | SW | 2001 |
| Weatherford# | R | SW | 1998 |
| Residence* | MR | HR | 1994 |

¹ R=resistant; MR=moderately resistant. Ratings are based on variety descriptions published by the Washington State Crop Improvement Association (*) or descriptions published by the breeder releasing the variety (#).

² SW=soft white wheat; HR=hard red wheat.

*Control of Stripe Rusts of Wheat and Barley

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In 2005, stripe rust of wheat was the most widespread in the U.S. and also occurred unusually early and severe in the PNW. Barley stripe rust occurred in the western U.S. and was severe in some fields grown with susceptible cultivars. Stripe rusts of wheat and barley were accurately predicted. Fungicide application was implemented to control stripe rust on both winter and spring wheat crops, which prevented major losses. A total of 27 races of the wheat stripe rust pathogen and 15 races of the barley stripe rust pathogen were detected, of which six and two races were new for the wheat and barley stripe rust pathogens, respectively. PST-100 was the most predominant race of the wheat stripe rust pathogen in the PNW and throughout the country. Wheat stripe rust races PST-115 and PST-116 were increasing in frequency, which rendered several previously resistant cultivars to become susceptible. More than 16,000 wheat and 5,000 barley entries were evaluated for stripe rust resistance, from which new germplasm and advanced breeding lines with stripe rust resistance were identified. The information was provided to breeding programs for developing and releasing new cultivars with adequate resistance. Molecular markers were identified for genes conferring HTAP resistance in Alpowa wheat and Bancroft barley, which are useful for developing resistant cultivars. Genes that are important for rust development, survival, and virulences were identified in the wheat stripe rust pathogen, which leads to a better understanding of the pathogen. These genes were used to design primers for identifying markers for studying the distribution, migration, population structures, and virulence variations of the stripe rust pathogen. New effective fungicides were tested for control of stripe rust. Profitability of fungicide application on various cultivars of wheat and barley without and with different level of stripe rust resistance was determined.

Application of Real-time PCR for Quantification of *Pythium* Species in Soils from Dryland Cereal-based Cropping Systems

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At least ten species of *Pythium* commonly occur in agricultural soils in eastern Washington. The cropping systems in these dryland areas are based on cereals, with rotation crops including several legumes and brassicas. Given the complex and diverse *Pythium* species composition, variation in species prevalence at different locations may depend on host crop and environment. A replicated field trial with cereals and five different rotation crops was sampled at monthly intervals beginning at planting. In a separate study, a survey of *Pythium* species present in soils from grower fields was conducted, with a variety of host crops represented. In both studies, soils were collected and real-time PCR was used to quantify ten species of *Pythium*. In the replicated trial, *P. abappressorium*, *P. irregulare* group IV and *P. rostratifingens* were the most commonly identified, with DNA concentrations of *P. irregulare* group IV 5- to 10-fold higher than the other species. *Pythium* populations were similar with regard to host, except for reduced populations of *P. rostratifingens* with lentil or fallow soil. The highest DNA concentrations of *P. irregulare* group IV were observed in chickpea plots. This species of *Pythium* was also associated with damping-off of chickpea early in the growing season. In the survey of grower fields, up to nine species of *Pythium* were found at a single location. *P. irregulare* group IV and *P. abappressorium* were observed most frequently (greater than 75% of locations), while more virulent species such as *P. irregulare* group I and *P. ultimum* occurred in fewer than 40% of the sites. *P. irregulare* group I was found only in wheat and lentil soils. Future development and testing of this technique may lead to a useful tool for identifying the *Pythium* species as well as other soilborne fungi present in a soil prior to planting.

Research on Grain Legume Diseases

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Grain legumes (dry peas, chickpeas and lentils) are important rotation crops in cereal-based production systems. Diseases of grain legumes have been a major constraint to the yield and quality, and consequently to the profitability of grain legume production. Our research program is focusing on several important diseases of grain legumes. Research from our field experiments is summarized here.

Ascochyta blight of chickpea: Ascochyta blight of chickpea is a devastating disease caused by the fungal pathogen *Ascochyta rabiei*. Management of Ascochyta blight is mainly through use of resistant cultivars and judicious application of fungicides. Identifying resistance sources and determining pathogenic variation of the pathogen is important in developing new resistant cultivars. We have found that the pathogen population can be divided into two pathotypes, and currently the dominant pathotype in the Palouse region is pathotype II which is pathogenic on resistant cultivars. Greenhouse and field evaluations have identified several chickpea germplasm lines that are highly resistant to the pathotype II and are being used for resistance breeding. Fungicide trials conducted at Pullman and Genesee from 2002 to 2005 showed that Headline and Quadris are effective in reducing disease severity of Ascochyta blight. A new fungicide Proline (available soon) is also very effective. Applications of these fungicides increased yield significantly on susceptible cultivars, but their effect on yield of resistant cultivars was evident only in certain cases. Resistant cultivars such as 'Dwelley' and the recently released 'Sierra' are tolerant to Ascochyta blight. That means they can still yield comparably even with certain levels of disease infection.

White mold of lentils and peas: White mold is caused by the fungal pathogen *Sclerotinia sclerotiorum*. White mold can be a serious disease under conditions conducive to the disease (cold and moist weather, and excessive vegetative growth). Research is being conducted to identify resistance/tolerance sources in the pea and lentil germplasm lines. Several lines of lentils showed tolerance to the disease and pea cultivars also showed differential response to white mold. Mapping populations have been developed using these tolerance sources and are used to identify tolerance genes or quantitative trait loci that will help resistance breeding. The pathogen populations in lentil fields near Colton and Spangle were extensively sampled and studied for genetic variation through mycelial compatibility groups. Considerable genetic variation was found in the pathogen populations, which has been taken into consideration in developing screening procedures in breeding programs.

Funding from the Cool Season Food Legume Research Program will allow us to initiate a study on **powdery mildew of pea**. Research will focus on management practices and genetics of resistance aiming at developing resistant pea cultivars adapted for US production.

For more information and our last year's progress report, please refer to the Grain Legume Research Unit website at: <http://pwa.ars.usda.gov/pullman/glgp/>.

Part 3. Quality Evaluation

Soft White and Club Wheat Characteristics Related to Sugar-Snap Cookie Diameter and Japanese Sponge Cake Volume

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We determined physical and chemical properties of club and soft white wheat genotypes and related those attributes to the quality of sugar-snap cookie and Japanese sponge cake quality for the purpose of developing an efficient and accurate evaluation method of club and soft white wheat quality. Winter club and soft white spring (SWS) wheat produced softer kernel than spring club and soft white winter (SWW) wheat. Accordingly, SWW yielded less break flour and more flour particles larger than 63 μ m. The mean SDS sedimentation volume, as an index of protein strength, was ≥ 99.9 mL in SWS and SWW and ≤ 63.6 mL in soft white spring and winter club wheat. SWW wheat produced smaller sugar snap cookie and Japanese sponge cake than SWS and club wheat on

average. Kernel hardness, break flour yield, proportion of flour particles larger than 63 μ m, protein content and sucrose solvent retention capacity correlated with sugar snap cookie diameter and Japanese sponge cake volume. In wheat flour of less than 9.0% protein, however, sugar snap cookie diameter correlated only with kernel hardness, break flour yield and sucrose solvent retention capacity, and Japanese sponge cake volume with proportion of flour particles larger than 63 μ m and protein content. This indicates that the influence of protein content and quality on sugar snap cookie and Japanese sponge cake quality seems to diminish as flour protein content decreases. Sucrose solvent retention capacity and proportion of flour particles larger than 63 μ m may effectively estimate flour quality for making sugar snap cookie and Japanese sponge cake better than other wheat flour quality parameters.

We in the WSU Wheat Quality Program also provide end-use quality testing of early and advanced generation breeding lines to assist wheat breeders at WSU in the development of superior wheat varieties. End-use quality evaluation of breeding lines is conducted based on milling performance and functional properties (processing and baking quality) of wheat grains. Each year we test 1000 to 2000 breeding lines of soft white, hard red and hard white spring wheat.

USDA Western Wheat Quality Laboratory

CRAIG F. MORRIS, DIRECTOR

The twofold mission of the WWQL is to 1) cooperatively develop new wheat varieties for the PNW by evaluating grain, milling and baking qualities of breeding lines, and 2) conduct research on wheat grain quality and utilization. In cooperation with the WSU winter wheat program we have released Rod (1992) and Masami (2004) Soft White Winter; Finley (1996) and Bauermeister (2005) Hard Red Winter; and Hiller (1998), Edwin (1998) and Bruehl (1999) Club wheat varieties. A Hard White variety, MDM, was cooperatively released in 2005. Like MDM, Bauermeister is a back-cross derivative of Eltan and has the low PPO associated with Eltan. However preliminary results indicate that MDM PPO levels are significantly higher than Baurermeister (0.65 vs. 0.55). In cooperation with the WSU spring wheat program we have released Alpowa (1993), Wawawai (1994), Zak (1999) and Louise (2004) Soft White Spring; Scarlet (1998), Tara 2002 and Hollis (2003) Hard Red Spring; and Eden (2002) Club wheat varieties. The Hard White varieties, Macon and Ottis, were released in 2002 and 2004, respectively. In cooperation with the ARS program, we have released Finch Soft White Winter wheat in 2001; and Coda (1998) and Chukar (2001) Club wheat varieties; winter Club line ARS97135 was approved for pre-release in 2006. Over the last 6 years, we have cooperatively released 49 wheat varieties and germ plasm lines, including:

Morris & Konzak. 2000. Registration of D-null 'Bai Huo' waxy wheat germplasm. *Crop Sci.* 40:304-305.

Morris & Allan. 2001. Registration of hard and soft near-isogenic lines of hexaploid wheat genetic stocks. *Crop Sci.* 41:935-936.

Morris & Konzak. 2001. Registration of hard and soft homozygous waxy wheat germplasm. *Crop Sci.* 41:934-935.

Morris & King. 2002. Registration of soft and hard red winter wheat near-isogenic sister lines of 'Weston'. *Crop Sci.* 42:2218-2219.

Part 4. Agronomics, Alternate Crops and Systems

Winter Wheat Seedling Emergence as Affected by Soil Crusting

W.F. SCHILLINGER, H.L. SCHAFER, T.A. SMITH, AND S.E. SCHOFSTOLL, DEPT. OF CROP AND SOIL SCIENCES, WSU

Rain showers that occur after planting winter wheat into summer fallow cause surface soil crusting. The emerging coleoptile or first leaf often cannot penetrate such crusts. Information is needed on the interrelationship among quantity of rain on soil crusting and winter wheat emergence as affected by surface residue cover.

Methods. In a laboratory experiment, a portable rainfall simulator was used to deliver rainfall at two different rates through two booms to newly-planted winter wheat in pots. The rainfall simulator delivered 0.05 inch/hour of rain through one boom and 0.1 inch/hour through the second boom. Twenty-five seeds each of Edwin and Eltan winter wheat were planted one-inch deep in pots containing 3 inches of wet (i.e., 15% soil moisture) soil. The wet soil was covered with four inches of dry soil immediately after planting. Beginning one day after planting, the rainfall simulator was used to apply 0.05 inch/hr for 3 hours (total = 0.15 inch) or 0.10 inch/hr for 2 hours (total = 0.2 inch). Rainfall simulation was repeated on the third and fifth days after planting. A total of 84 pots were required for each replication (i.e., run) of this 5-factor factorial experiment. Factorial treatments for the experiment were:

1. Two winter wheat varieties (Edwin and Eltan).
2. Two rainfall intensities and durations (as described above).
3. Three rainfall timings (1, 3, and 5 days after planting).
4. Three surface residue conditions (bare soil, 750 lb/ac of straw, and 1500 lb/ac of straw).
5. Two heat factors (50% of pots put under a heat lamp at 85°F air temperature for 9 hr/day, the remaining 50% of pots kept at room temperature with no additional heat).

Results. To date, we have completed three runs (i.e., replications) of this labor-intensive and complex experiment. Statistical results for main effects are shown below:

Analysis of variance by single factors:

1. Two winter wheat varieties (Edwin and Eltan). $P < 0.10$.
2. Two rainfall intensities (0.05" / hr, 0.10" / hour) + check (no rain). $P < 0.10$.
3. Three rainfall timings (1, 3, and 5 days after planting) + check. $P < 0.0001$.
4. Three surface residue loads (bare soil, 750 lb/ac straw, and 1500 lb/ac straw). $P < 0.05$.
5. Two heat factors (85°F air temperature for 9 hr / day vs. room temperature). NS

Initial results show that timing of rainfall may be the most important of the factors examined affecting winter wheat stand establishment in summer fallow. Wheat seedling emergence was much more adversely affected by rain occurring 5 days after planting versus 3 days after planting versus 1 day after planting. In other words, the worst situation is to have rain occur just before winter wheat seedlings are due to emerge from the soil. We plan to conduct three more runs of this experiment and report detailed results at a later date.

Optimizing Seeding Rate and Phosphorus Fertility to Enhance the Yield of Recrop, Late-Seeded Winter Wheat

RICH KOENIG AND ERIC HARWOOD, DEPT. OF CROP AND SOIL SCIENCES, WSU; AND AARON ESSER, GRANT/ADAMS COUNTY EXTENSION

Field studies were initiated in Fall 2004 at four locations in the low to intermediate rainfall zones of eastern Washington. Three of the locations were recrop winter wheat (Lind, Ralston, and Harrington) seeded in October, while the fourth (Ritzville) was winter wheat after chemical fallow seeded in September and October. Each study involved a factorial combination of two seeding rates (40 and 70 lb/acre) and five phosphorus (P) rates (0, 20, 40, 60 and 80 lb P₂O₅/acre) applied as fluid ammonium polyphosphate in a deep band placed 2 to 3 inches below the seed row at planting. Emergence, early season dry matter accumulation, final grain yield, grain yield components, and straw and grain P uptake were determined. Under conditions of low seed zone moisture (September planting in chemical fallow), higher rates of P placed in a deep band reduced winter wheat stand density. Negative effects of P on stand density were not observed with late seeded wheat, presumably due to more favorable seed zone moisture conditions and a lower potential for fertilizer salt injury. Phosphorus increased vegetative-stage dry matter accumulation with late seeded wheat at two of the four locations, and with early-seeded wheat at the chemical fallow site. There was also a small linear relationship between P rate and grain yield (1.6 to 3.6 lb grain per lb P₂O₅ applied) at the Lind and Ralston recrop locations, and a 9.7 bu/acre response with 20 lb P₂O₅/acre at the Ritzville chemical fallow location. Preliminary results indicate that improved phosphorus nutrition can

increase early season dry matter production and final grain yield of late-seeded winter wheat in recrop and chemical fallow situations. However, based on this one year of data the response to phosphorus may be relatively small and not economical in recrop situations due to the low overall yield potential. Studies were repeated in 2005-06 at three of the four locations (Lind, Ralston and Ritzville) with P rates of 0, 10, 20, 40 and 60 lb P₂O₅/acre.

Chloride Response of Pacific Northwest Winter Wheat Cultivars

RICH KOENIG AND JOHN BURNS, DEPT. OF CROP AND SOIL SCIENCES, WSU; KIM CAMPBELL, USDA-ARS WHEAT GENETICS, QUALITY, PHYSIOLOGY AND DISEASE RESEARCH UNIT

Chloride (Cl) deficiency symptoms are expressed by certain winter wheat cultivars grown in the Pacific Northwest. Studies were conducted to evaluate the response of five winter wheat cultivars (Tubbs, ORCF 101, Finch, Madsen, Falcon) to Cl source (ammonium chloride or potassium chloride) and application timing (fall vs. spring) at a rate of 30 lb Cl/acre. Trials were conducted at the Spillman Farm and near Farmington, WA in 2004-05, and are being repeated in 2005-06. Whole plant samples were collected at early head emergence for tissue Cl determination and flag leaves were imaged with a flatbed scanner to quantify percent leaf spot severity. Grain yield was measured at maturity. The Farmington site inadvertently received an aerial application of Cl in 2004-05. At Spillman, Cl application resulted in higher tissue Cl concentration at early head emergence in all cultivars, but there was no difference between Cl sources or application timing. Leaf spot was most severe with Tubbs, Madsen and ORCF 101. Symptoms in Falcon were masked by severe stripe rust. Falcon, Finch and ORCF 101 did not respond to Cl fertilization, while the yield of Madsen and Tubbs was 11.5 and 15.9 bu/acre higher, respectively, with ammonium Cl applied in the fall compared to the 0 Cl treatment. There was no statistically significant difference in yield between ammonium Cl and potassium Cl sources. On average, fall application resulted in slightly higher yields (2 bu/acre) than spring application. Madsen and Tubbs were the two cultivars with the most severe leaf spot symptoms, suggesting that leaf spot severity is a good indicator of cultivar responsiveness to Cl. Preliminary data indicate few differences between ammonium or potassium Cl sources and that spring application produced slightly higher yields than fall application with responsive cultivars Madsen and Tubbs.

Alternative Nitrogen Sources for Grass Seed Production in the Post-Ammonium Nitrate Era

RICH KOENIG AND BILL JOHNSTON, DEPT. OF CROP AND SOIL SCIENCES, WSU; RICHARD SHUMWAY, SCHOOL OF ECONOMIC SCIENCES, WSU

Due to domestic terrorism concerns and impending regulations, U.S. fertilizer companies have agreed to voluntarily discontinue the production and importation of dry ammonium nitrate (34-0-0) fertilizer. For grass seed producers accustomed to broadcast applications of dry fertilizer, urea (46-0-0) is the main alternative to ammonium nitrate. Fluid urea ammonium nitrate (UAN, 32-0-0) is another viable alternative for those equipped to handle fluid fertilizers. Once applied, urea undergoes an enzyme (*urease*)-mediated breakdown process referred to as hydrolysis. This process is rapid and normally complete within 5 to 7 days after application. The products of urea hydrolysis are ammonia and carbon dioxide. The ammonia formed from urea will react in much the same way as ammonia from anhydrous or aqua fertilizers. If there is insufficient moisture to transport urea or its breakdown product (ammonia) into the soil, significant loss of gaseous ammonia can occur. Research has shown that, under ideal conditions, volatile ammonia losses can exceed 50% of the total nitrogen applied as urea. Unfortunately, many of the conditions that promote ammonia volatilization are the same as those under which nitrogen is managed in grass seed cropping systems. Ammonia volatilization from urea broadcast on grass seed stands after burning (i.e., some fields in Idaho) may also be higher than on fields where residue is baled, since ash is an alkaline material and high pH enhances ammonia volatilization from urea-based nitrogen sources. Research was initiated in 2005 to assess the relative effectiveness of dry urea and fluid urea ammonium nitrate compared to dry ammonium nitrate on plant nitrogen recovery and grass seed yield, to evaluate the effect of timing of urea application and placement of fluid urea ammonium nitrate on nitrogen recovery and grass seed yield, and to evaluate the economics of the alternative nitrogen management practices. Preliminary results will be available in 2006.

Effect of N Fertilizer Source, Rate, Placement and Application Timing on Hard Red Winter Wheat Yield and N Use Efficiency

MATTHEW S. STOWE, RICHARD T. KOENIG AND JOHN P. REGANOLD, DEPT. OF CROP AND SOIL SCIENCES, WSU; D. R. HUGGINS, USDA-ARS

The development of management strategies to improve nitrogen use efficiency (NUE) of wheat is required to reduce cost of fertilizer inputs and N pollution. Our main objective was to assess the effects of N source, rate, placement and timing on grain yield, grain protein and NUE of hard red winter wheat in field experiments conducted at the Palouse Conservation Field Station in southeastern Washington during 2004-05 and 2005-06. Treatments included: (1) controlled release (CR) and conventional urea fertilizer applied at rates of 0 to 250 lb N/acre; (2) select CR and urea N placement (broadcast or banded beneath or with the seed); and (3) urea application timing (at planting, late fall, spring, and fall-spring combinations) at 150 lb N/acre. Grain yield and plant and soil N were measured to assess NUE components. Preliminary yield results indicate no significant differences between conventional urea and CR throughout the range of N application rates. There was also no significant difference in yield among N timings. The CR deep band treatment produced 1,214 lb/acre (20 bu/acre) higher grain yield than CR broadcast. Second year results and a complete evaluation of NUE components are pending.

*Relationship between Available Water and Wheat Grain Yield

W.F. SCHILLINGER, S.E. SCHOFSTOLL, H.L. SCHAFFER, AND T.A. SMITH, DEPT. OF CROP AND SOIL SCIENCES, WSU

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In the years 1953 – 1957, Dr. G.E. Leggett, extension soil scientist at Washington State University, conducted a series of experiments in Eastern Washington to determine optimum nitrogen fertility for dryland wheat based on available water in the soil profile in late winter / early spring plus growing season (i.e., late March / April, May, and June) precipitation. All spring rainfall was considered “available”. With 90 replicated treatments, Leggett’s data showed 4.0 inches of available water was required just for vegetative growth of wheat (i.e., before grain production begins) and, for every additional inch of water, 5.6 bushels of wheat per acre could be expected (Fig. 1, dotted line). Using multiple regression, Leggett found that each inch of water stored in the soil over the winter (beyond the baseline of 4.0 inches) resulted in 5.3 bushels of grain per acre, and that for each inch of rain in the spring, 6.9 bushels of grain would be produced.

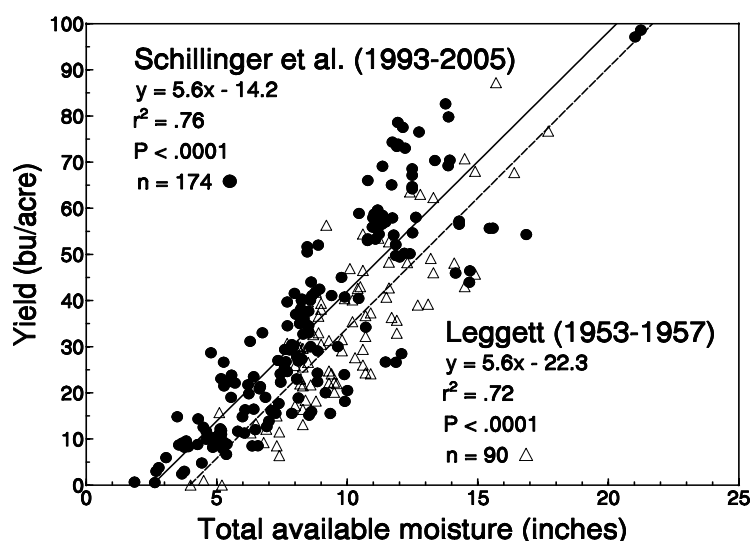


Fig. 1. The relationship between available soil water and grain yield of dryland wheat in Eastern Washington. Data were collected by G.E. Leggett (open triangles, dotted line) from 1953-1957 and by W.F. Schillinger et al. (filled circles, solid line) from 1993 – 2005.

From 1993 – 2005, W.F. Schillinger et al. conducted a series of dryland wheat-related experiments involving 174 replicated treatments where soil water content in early spring, annual precipitation, and wheat grain yield were measured. These data show that wheat requires 2.5 inches of available water just for vegetative growth. For every inch of available soil water above the 2.5-inch baseline, one inch of stored soil water provided 5.4 bushels of grain per acre and one inch of spring rainfall provided 6.9 bushels of grain per acre (Fig 1). Predicted grain yield differences between the two models may likely be due to the ability of modern wheat varieties to begin grain production with less available water compared to wheat varieties in the 1950's. The interpretation of these data on the relationship of available water and wheat grain yield is still in the preliminary stage. Data will be further evaluated and reported at a later date.

*A Pilot Study of Yield, Protein, and N Information for Dryland Spring Wheat Classes in Eastern Washington Using Variety Testing Data

DOUGLAS YOUNG, RICHARD KOENIG, JOHN BURNS AND RAPHAEL KARUAIHE, SCHOOL OF ECONOMIC SCIENCES AND DEPT. OF CROP AND SOIL SCIENCES, WSU

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This project is funded by the Washington Wheat Commission. The objective of this pilot study was to utilize data from Washington State University's Uniform Cereal Variety Testing Program from 2002-2005 to summarize information on yield (bu/ac), grain protein (%), test weight (lbs/bu), total N (applied N plus soil N in lbs/ac), available soil moisture at planting time (inches), and soil organic matter (%).

Consistent with expectations, mean yields, test weights, soil organic matter, and soil moisture increase with precipitation for hard red, hard white, and soft white spring wheat classes. Yield of HRS, for example, average 37 bu/ac in the low precipitation zone to 76 bu/ac in the high precipitation zone. Also consistent with expectations, protein levels descend with higher precipitation. For example for HRS, mean protein drops from 15.3% in the low precipitation region to 13.5% in the high precipitation region. Data also suggest that yield variability increases with precipitation zone, while grain protein concentration is not consistently more variable in higher rainfall environments. The range of soil residual N values coupled with the importance of total (soil + fertilizer) N supply in achieving hard wheat protein goals highlight the importance of soil testing to accurately assess residual soil N levels before fertilizing and planting. With recent increases in the price of N fertilizer, soil testing is even more important to quantify N reserves.

Additional interpretations of these variety testing N response data are forthcoming. Data will also be combined with information from ongoing winter and spring N fertility studies. The ultimate goal is to develop fertilizer N recommendations for eastern Washington dryland wheat production regions that are sensitive to changing wheat and fertilizer prices.

Soil Quality and Direct Seeding in Dryland Systems

ANN C. KENNEDY, USDA-ARS PULLMAN, WA; WILLIAM F. SCHILLINGER AND TAMI L. STUBBS, DEPT. OF CROP AND SOIL SCIENCES, WSU

Soil quality parameters were assessed at several long-term dryland cropping systems research sites in eastern Washington to further define management practices that are soil building rather than degrading. The objective was to characterize soil quality changes over time as affected by tillage and cropping management systems at sites near Pullman, Colfax, Dusty, Ritzville, and Lind, WA. Over the past several years we have found that soil quality changes during the transition to no-till are less dramatic and more variable in the low precipitation zones (150- to 300- mm annually) compared to the higher precipitation zones (300- to 550- mm annually). With direct seeding, the lower disturbance has more of an impact on soil quality measurements than surface residue management or crop rotation. Soil organic carbon slowly increased in long-term no-till and approached or exceeded that of nearby undisturbed sites. Long-term no-till also increased the proportion of aggregates in the larger sized soil fractions. Also, no-till stored a greater proportion of the carbon in the larger size aggregates thus protecting more of the carbon from loss due to wind erosion. We also continue to see that long-term no-till results in changes in microbial communities and an increase in the fungal:bacterial ratio. Data from these long-term experiments will allow us to better assess the productivity and quality of soils in the dryland cropping region of the Inland Pacific Northwest. This information will allow the identification of soil quality parameters that can be used in the development of best management practices for conserving soil quality and enhancing crop production.

Soil Quality and Water Intake in Traditional-Till vs. No-Till Paired Farms in Washington's Palouse Region

ANN C. KENNEDY, WILLIAM F. SCHILLINGER, TAMI L. STUBBS, AND STEVEN E. SCHOFSTOLL, USDA-ARS AND DEPT. OF CROP AND SOIL SCIENCES, WSU

Many farmers in the steeply-sloped Palouse region of eastern Washington and northern Idaho practice no-till farming. Soil quality and water intake parameters were assessed in standing wheat stubble along summit, side, and toe slope positions in a 2-year study at three paired-farm sites located between LaCrosse and Colfax in Whitman County using traditional tillage vs. no-till management. Paired sites had similar south-facing aspect, slopes ranged from 29 to 45%, and no-till fields had not been tilled from 2 to 20 years. Soil aggregates greater than 1000 μm were 5 to 10 % higher in no-till compared to traditional tillage. Soil organic carbon in no-till was 30% greater than in traditional tillage at the toe slope position. Dehydrogenase enzyme activity was higher in traditional tillage, mainly due to the exposed calcium carbonate layer at the side-slope position and higher pH of traditional tillage. Phospholipid fatty acid methyl ester analysis showed that fungal biomarkers were higher and Gram positive and Gram negative biomarkers were lower in no-till.

There were no differences in over-winter soil water storage or ponded water infiltration rate in undisturbed standing wheat stubble between traditional tillage and no-till, indicating soils that produce high wheat grain yield of 70 bushels per acre or more have similar water intake regardless of tillage history as long as the stubble is left standing over winter. Results show long-term cumulative benefits of no-till versus traditional tillage on soil quality in the intermediate-to-high precipitation zone, but no differences in soil water intake when stubble is left standing over winter, possibly due to the high quantity of wheat root channels produced in both systems.

Appreciation is extended to John and Cory Aeschliman of Colfax, Washington, for their enthusiastic endorsement of the research and their donation of time and land.

Evaluation of Wildflower Refuge Plantings for Integrated Weed and Insect Pest Control

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The Palouse prairie ecosystem has been intensely degraded since the conversion to agriculture. This destruction may greatly reduce source populations of beneficial insects useful for agriculture, as well as removing refuge habitat for birds and other native wildlife. The margins of agricultural fields can also be a haven for noxious weeds. As a consequence, some farmers will cultivate these areas, limiting their ecological buffering capacity. Rather than trying to maintain a plant-free zone at the edge of fields, an alternative strategy might be to plant field borders with native plants, to both out-compete weeds and serve as a refuge for beneficial arthropods and other wildlife. To accomplish the integration of these two goals, we are evaluating refuge boarder plantings, with emphasis on indigenous Palouse prairie plantings. Thus, our plantings have

the potential to increase biodiversity regionally, if widely adopted by local growers.

The central question of our research is to investigate the optimal combination of indigenous prairie species that can be used to both support a beneficial arthropod community and simultaneously displace weeds. This research addresses the following specific questions:

1. Which species of wildflower are most attractive to beneficial arthropods?
2. Which species of wildflower are most effective at competitively displacing weeds?

3. Is a wildflower blend more effective than single species planted in monoculture for attracting beneficial insects, while at the same time successful at suppressing crop weeds?

In 2005 small test plots, the Palouse Prairie mix attracted the greatest amount of beneficial insects when compared to an alfalfa/clover mix, a "western wildflower" mix, and indigenous prairie flowers planted in monoculture. A commercially available "western wildflower" blend that had been established in 2002 was able to best displace weeds, though we cannot determine if this was due to it being in its third year of establishment. We will be able to determine in successive years if the Palouse Prairie mix increases in its ability to suppress weeds.

Can Dry Bean be Grown in Marginal Soil?

AN. N. HANG, DEPT. OF CROP AND SOIL SCIENCES, WSU-PROSSER

An experiment was conducted using cv. 'Othello' pinto and cv. 'Merlot' small red dry bean to study the effect of inoculants on dry bean production on Shano silt loam soil. Soil analysis was done to get the base line fertilizer and organic matter in the soil. Field was pre-irrigated, Eptam (2 qt/a) and Sonalan (1 qt/a) were pre-plant incorporated into the top 4" to control weed. Field was low in organic matter (1.24%) and nitrogen (15 ppm nitrate N). No fertilizers of any kind were added to the soil at seed bed preparation. Seven inoculation products and a control were applied to the seed at planting prior to seeding. All plots were managed as used in a standard procedure for bean production in the area. The purpose of this study is to define the effect of rhizobium on plant population at 6 weeks after planting, plant vigor at 6 weeks after planting and at mid season, nodule count at early and mid flowering, disease incidence and yield.

There is no difference in plant populations and plant vigor. Nodule count is somewhat higher at mid bloom and there is higher number when bean was inoculated at planting. Pinto and small red bean responded to inoculant by increase the yield. Merlot is slightly produced higher yield than Othello pinto. Highest yields were 3500 lbs/a for Othello and 3,800 lbs/a for Merlot. Hundred seed weight did not change with different inoculant. With less N growers can lower their input while reducing nitrate contamination to the environment.

Part 5. Economics and Sustainability

*Economics of No-Till Annual Cropping Rotations at Ritzville, 1997-2004

DOUGLAS YOUNG, ELIZABETH NAIL, AND WILLIAM SCHILLINGER, SCHOOL OF ECONOMIC SCIENCES AND DEPT. OF CROP AND SOIL SCIENCES, WSU

More on the Web During 2005 the economic analysis of the full 8-year no-till annual cropping experiment at Ritzville was completed. This experiment compared several no-till annual cropping rotations to the region's dominant rotation of tilled winter wheat-fallow (WW-SF).

No-till annual rotations are clearly an environmental success. Engineers' have predicted that no-till continuous spring grains can reduce dust emissions by 94% during severe wind events compared to tilled WW-SF. But the full 1997-2004 experimental results at Ritzville have shown that the continuous no-till annual cropping systems significantly lagged conventional tillage winter wheat/fallow in profitability. Continuous no-till soft white spring wheat (SWS) and SWS-spring barley (SB) were compared economically to the results of growers within a five-mile radius of the experiment who grew winter wheat after fallow under conventional tillage. Eight-year average net returns for the two no-till systems lagged conventional WW/SF net returns by \$24 to \$29 per rotational acre. Furthermore, the spring cropping systems exhibited significantly more economic downside risk in dry years. During the drought years of 2001 to 2004, the no-till rotations incurred substantial losses every year, but WW-SF did so only in 2001.

Some farmers might be able to trim the cost of production for no-till annual cropping, but closing the entire profitability gap is not likely. Other research has shown significant public valuation for higher levels of air

quality provided by soil conserving cropping systems. No-till cropping systems might provide a cost effective alternative to large government conservation programs like the Conservation Reserve Program (CRP). However, political support for CRP could continue as growers might perceive it to provide a higher and completely stable return relative to cropping.

Comparing Plateau and Conventional Nitrogen Response Functions for Crop Yield and Quality

RAPHAEL N. KARUAIHE AND DOUGLAS L. YOUNG, SCHOOL OF ECONOMIC SCIENCES, WSU

Comparison of nitrogen response statistical functions with maximum yield horizontal plateaus to conventional non-plateau functions showed mixed results. The plateau functions had better goodness of fit for hard red spring wheat protein and yield data in eastern Washington and for yield in Coastal Bermuda Grass hay in Alabama. However non-plateau functions provided a better fit for Alberta, Canada hard red spring wheat yield and protein. These and earlier results suggest that some crops may conform to a plateau pattern for a considerable range. There was also statistical support that protein response to nitrogen in hard red spring wheat may exhibit a finite-plateau in one data set.

These results, which introduce fertilizer response plateau properties for crop quality, as well as crop yield, justify exploration of these functions for a broader set of crops and regions. The findings that plateau functions, when ranked higher, imply lower nitrogen rates has important implications for both private and public decision makers. If these plateau functions accurately describe the nitrogen response process for some crops, decreased fertilizer rates will also help protect water from nitrogen leaching and runoff.

Future research should extend comparisons of plateau and non-plateau yield and quality nitrogen response functions to other crops and regions. These analyses could also broaden the scope of mathematical functional forms utilized. Finally, future work should seek formal statistical tests including possible generalized log likelihood ratios for comparing the type of functions used in this study.

Broadleaf Incorporation into an Intense Direct Seeded Cereal Rotation

AARON ESSER, WSU LINCOLN-ADAMS AREA EXTENSION, MARK SHEFFELS, LINCOLN COUNTY PRODUCER COOPERATOR



A series of on-farm tests were carried out over a 4-year period near Wilbur, Washington in a 12-inch precipitation zone. Tests were designed to better understand the value of mustard as an alternative crop in an intense cereal grain cropping rotation under direct seed conditions in the dryland cropping region of eastern Washington. The two treatments: spring barley and yellow mustard, were seeded with a Flexi-Coil 5000 direct seed drill on 12-inch row spacing on ground that had an intense cereal grain history. The treatments were harvested and the yield and market price was collected. Subsequent spring cereal crops (wheat or barley) in the study were direct seeded with the same drill. Cereal crops following each treatment were harvested and the yield; grain quality, and market price were collected. The trial is a randomized complete block design with 4 replications.

Mustard yielded less than barley averaging 647 lb/ac compared to 1,640 lb/ac. Mustard as the previous crop had 82% less weeds, and had greater amounts of nitrogen remained in the top 1-foot. Little difference was detected in the subsequent cereal crop production following either barley or mustard. Cereal following barley produced the greatest yield at 1,854 lb/ac compared to 1,625 lb/ac following mustard. However, the yield differential varied over duration of the study. Mustard followed by cereal had the highest 2-year total return at \$186/ac compared to

only \$175/ac for barley followed by cereal; however these differences varied among years. In conclusion mustard has value as alternative crop in an intense cereal grain cropping rotation in the dryland cropping region of eastern Washington. Over the duration of this study, mustard in rotation produced \$11/ac more gross economic return than barley included in rotation. However gross economic return is both a function of crop production and market price.

*Glyphosate and Diesel Price Changes Benefit Conservation Tillage

ELIZABETH NAIL, DOUGLAS YOUNG, AND WILLIAM SCHILLINGER, SCHOOL OF ECONOMIC SCIENCES AND DEPT. OF CROP AND SOIL SCIENCES, WSU

More on the Web Using 2005 versus 1998 input prices for the economic analysis of a winter wheat-summer fallow (WW-SF) tillage system experiment at Lind strengthened the relative profitability of two conservation tillage systems compared to traditional tillage. Sharp increases in diesel prices by 2005 penalized the traditional tillage (TT) WW-SF system due to more diesel consumption. However, all three WW-SF systems in this experiment used fairly similar quantities of diesel. In areas where zero-tillage direct-seeding is feasible, relative cost savings would be even greater. The conservation tillage systems consumed more glyphosate herbicide, but that cost was cushioned by a decline in glyphosate prices. Use of aqueous $\text{NH}_3\text{-N}$ instead of anhydrous $\text{NH}_3\text{-N}$ also favored the conservation tillage systems as aqueous $\text{NH}_3\text{-N}$ experienced a more moderate price increase between 1998 and 2005. Using the same N fertilizer source for all three tillage systems would have narrowed the profitability advantage for the conservation tillage systems, but they would have still remained significantly more profitable than TT. The updated economic results in this comparison provide strong evidence for the relative profitability of conservation tillage, such as those using the undercutter implement, for winter wheat-summer fallow farming in low precipitation regions of eastern Washington under current economic conditions.

*How Do Government Crop Subsidies and Crop Insurance Influence the Profitability of Conservation Cropping Systems?

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More on the Web The purpose of this research was to examine the effects of government subsidies and crop insurance on the relative profitability of conservation and conventional dryland cropping systems in arid eastern Washington. Special attention is devoted to the direct payments, countercyclical payments, and loan deficiency payments (LDP's) included in the 2002 Farm Bill. Even with the inclusion of government subsidies and crop insurance, none of the six annual no-till crop rotations in the low-precipitation Phase II (2001-2004) of a Ritzville experiment generated sufficient returns to cover total costs, nor did any approach the profitability of the winter wheat-summer fallow (WW-SF) which averaged \$16.93 per rotational acre with subsidies and insurance. During 2001-2004, subsidies and insurance boosted the highest ranked annual no-till crop rotation, soft white spring wheat-spring barley (SWS-SB), by \$24 per rotational acre, increased the lowest ranked soft white winter wheat (SWW)-SB-yellow mustard (YM)-SWS rotation by \$17.26 per rotational acre, but also lifted the traditional WW-SF system by \$16.88 per rotational acre. These results reflect the proverb that "a rising tide raises all ships." A similar comparison for an experiment in the Horse Heaven Hills of Benton County also showed no reversals of rankings between annual no-till hard red spring wheat and traditional WW-SF with and without subsidies and crop insurance.

If Congress reverts to subsidies that are coupled to current production, inclusion of such subsidies would be an essential part of accurate economic comparisons of cropping systems. But present World Trade Organization rules discourage coupled payments. Also, where specific environmental "green payments" are available from state or federal agencies for conservation farming systems, their inclusion in economic assessments would be needed for valid private profitability comparisons. To date, however, most federal farm programs enacted by Congress have been tied to historic or current crop production rather than to environmental practices.

Spillman Agronomy Farm Endowment Fund

The Spillman Agronomy Farm is located on 382 acres five miles southeast of Pullman, WA in the midst of the rich Palouse soils. 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.

"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 improvement. I spoke at the Spillman Farm Field Day in July of 1996, the year I retired. I said then the farm was operating on a shoestring. Well, it is still being held together by the same shoestring. It is urgent after 50 years this facility receive the support it deserves." —Bob Allan, retired USDA-ARS Wheat Geneticist

Cook Agronomy Farm Endowment Fund

Located in Whitman County, five miles Northeast of Pullman, WA, the 140-acre Cook Agronomy Farm (formerly referred to as 'Cunningham Farm') includes soils and topography representative of the Annual Cropping Regions of Washington State. WSU and USDA-ARS research scientists are conducting collaborative programs to develop and implement a coordinated research programs designed to meet the needs of direct-seed cropping systems in this higher precipitation region of the Inland Northwest.

Lind Dryland Research Station Endowment Fund

The WSU Dryland Research Station comprises 320 acres that was deeded to WSU in 1915 to "promote the betterment of dryland farming" in the 8-12 inch rainfall area of eastern Washington. The Lind station is approximately five miles north of Lind, WA and has the lowest rainfall of any state of federal facility to dryland research in the United States. For over 100 years, the Lind Station has maintained a policy of studying the problems associated with the 8-12 inch rainfall area.

Wilke Research Farm Endowment Fund

The Wilke Research and Extension Farm is location on the east edge of Davenport, WA 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, followed by summer fallow. The 320-acre farm was bequeathed to WSU in 1982 by Beulah W. Wilke for use as an agricultural research facility. WSU partnered with farmers and the agricultural industry to create a demonstration farm devoted to developing new farming systems based on annual cropping, alternative crop rotations using no till systems that are suitable for the soils and climate of the intermediate rainfall system.

These endowment funds have been established to secure the future of agronomic cropping systems including cereal and pulse crop research and development by your tax deductible charitable gifts.

Mail to:
CAHNRS Alumni and Development Office
PO Box 646228
Pullman, WA 99164-6228

For additional support or information on estate planning, please contact Patrick Kramer. (509) 335-2243, kramerp@wsu.edu.



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This grant to CSANR is the largest grant received by WSU from the Paul G. Allen Family Foundation and the first for agricultural research (\$3.75 million, 5-year project). The “**Climate Friendly Farming**” research fits nicely with the mission of the **Paul G. Allen Family Foundation**—to promote the healthy development of populations and to strengthen families and communities in the Pacific Northwest.