COOPERATIVE EXTENSION
Washington State University
Department of Crop and Soil Sciences

Technical Report 00-1

Dedicated to Dr. Roland Line

2000 Field Day Proceedings: Highlights of Research Progress

Dryland Research Station, Lind
June 15, 2000

WSU/USDA, Pullman
June 29, 2000

Stephen Dofing and Roger Veseth, Editors

Contributing agencies; Washington State University, U.S. Department of Agriculture and Department of Crop and Soil Sciences
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Dedication to ROLAND F. LINE

Dr. Roland F. Line, Research Plant Pathologist, retired from the USDA-ARS, Department of Plant Pathology, Washington State University in December 1999, after 36 years of federal service. Dr. Line continues to share his expertise in cereal disease as an ARS collaborator and faculty member in the Dept. of Plant Pathology, WSU.

Roland Line was born in Winona, MN, and received his early education in Cromwell, MN. He received a B.S. degree in agricultural education (1956) and his M.S. (1959) and Ph.D (1962) degrees in plant pathology and genetics from the University of Minnesota. His early research was on potato diseases, but for more than 40 years he has been a cereal pathologist. As a research associate at the University of Minnesota (1959
1963) he was responsible for research on the ecological potential and survival of stem rust.

From 1963 to 1968 Dr. Line led a cooperative U.S. Army, USDA, and experiment station project on stem rust epidemiology and loss assessment at central U.S. sites from Oklahoma to North Dakota. In 1968, Dr. Line assumed leadership of the ARS research program on control of rusts and smuts at Washington State University, Pullman, WA. Dr. Line implemented a control program that reduced flag smut to a minor disease and saved farmers millions of dollars. He developed a rust monitoring program that provided early warning to breeders and growers to enable them to take action to prevent major losses.

Since 1979 he has used predictive models and monitoring data to forecast wheat stripe, leaf, and stem rust, and more recently, barley stripe rust. His computerized expert systems for predicting and managing wheat and barley diseases (MoreCrop for wheat and MoreCrop for barley) are available on the internet (http://pnw-ag.wsu.edu/morecrop/) and are used by both growers and scientists. Dr. Line with co-workers identified 60 wheat stripe rust races and almost as many barley stripe rust races and used virulence data and DNA techniques to develop concepts on the evolution, origin, distribution, and relationships among stripe rust forms and races. His rust research program resulted in identification of several unique types of stripe rust resistance, the most important being durable, high-temperature, adult-plant resistance.

Dr. Line has contributed to the release of over 50 wheat cultivars with rust resistance, which has prevented multi-million dollar losses to the wheat industry. Dr. Line and co-workers have identified more than 40 wheat genes and 30 barley genes for stripe rust resistance, determined the chromosomal location of many of the genes, and recently identified molecular markers to aid in breeding for resistance.

Dr. Line has published more than 350 technical publications, papers, and book chapters. Committee service includes National Wheat Improvement, Wheat Crop Advisory/Germplasm, Western Wheat Workers, Cereal Disease, and numerous American Phytopathological Society committees. He was a member of the USDA TCK Team that provided the biological justification for removing the Chinese import barrier to Pacific Northwest wheat. In recognition of his contributions to wheat and barley research, he has received the O.A. Vogel Crop Improvement Award, USDA Certificates of Merit, and was recognized in 1999 as a Fellow of the American Phytopathological Society.

Valuable support for Dr. Line's cereal disease research in Washington has been provided by the Washington Wheat Commission and Washington Barley Commission, in partnership with USDA-ARS and Washington State University.

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ACKNOWLEDGEMENT OF CONTRIBUTORS IN SUPPORT OF 1999-00 RESEARCH

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

Fertilizer, Seed and Amendments

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Latah Co. Growers	Whitman Co. Growers	Wilbur-Ellis
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McKiernan Bros.	Palouse Welding	WA Wheat Commission
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Field Day Contributors
Lind Dryland Research Station, Spillman Farm and Palouse Conservation Field Station

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McGregor Company	Whitman County Wheat Growers

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Russ Zenner	Genesee ID

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". For 83 years, 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. This year marks the 83rd field day. Visitors are welcome at any time, and your suggestions are appreciated.

HISTORY OF SPILLMAN FARM

In the fall of 1955, 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. The dedication of the new facility took place at the Cereal Field Day July 10, 1957. In 1961 the Agronomy Farm was named Spillman Farm after the distinguished geneticist and plant breeder at Washington State University in the late 1880s.

Through the dedicated efforts of many local people and the initiative of Dr. Orville Vogel, 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 Wheat Commission and Washington State University. The newly acquired 160 acres were fenced and the wetland drained; it became an integral part of the Agronomy Farm, now consisting of 382 acres.

The headquarters building, which is 140 feet long and 40 feet wide, was completed in 1956. A 100 by 40 feet addition was built in 1981. In 1957 a well that produced 340 gallons per minute was developed. In 1968 the Washington Wheat Commission provided funds for a sheaf storage facility that was necessitated by the increased research program on the farm. At the same time 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.

The Spillman Agronomy Farm was developed with proper land use in mind. A conservation farm plan which includes roads, terraces, steep slope plantings, roadside seedings, and a conservation crop rotation including alfalfa and grass has been in use since the farm was purchased.

Dick Hoffman was appointed farm manager in 1994.

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 60 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 in 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.

Breeding and Genetic Studies to Increase Winter Hardiness

Kay Simmons and Todd Linscott

Goal: Increase winter hardiness of Pacific Northwest wheat varieties.

Field breeding for increased cold hardiness can only be conducted in the winter and progress has been slow because of mild and variable Washington winters. The new WSU Plant Growth Wheat Research Center with temperature-controlled growth rooms enables us to freeze test wheat lines year around.

Approach: Identification of current varieties that are not cold hardy. Development of more cold hardy club and common winter wheats through incorporation of more cold hardy parents in breeding programs and early generation testing for cold hardiness.

Accomplishments:

Conducted freeze testing on multiple breeding lines and large numbers of plants.

We have developed a simulated freezing test for the purpose of identifying wheat lines that are freezing tolerant in Washington. This 10-week test includes planting, seedling cold acclimation, freezing over a range of cold temperatures, and crown grow out for survival rating. Breeders require large numbers of lines be tested, so we optimized procedures to evaluate large numbers of plants in the same test. During the past year we have used these improved methods to determine freezing tolerance of Pacific Northwest varieties, advanced breeding lines, and special genetic collections. Over 37,000 plants were evaluated. The greenhouse and growth room facilities in the new WSU Plant Growth and Wheat Research Facility have been essential for this project.

Expanded cold hardiness testing of PNW winter wheat varieties. Using the scaled up tests we determined relative cold hardiness levels for winter varieties in each market class: clubs, soft common white, and hard red. Results were incorporated into the Certified Seed Buying Guide in cooperation with the Washington State Crop Improvement Association.

Tested all advanced and elite lines in the ARS Wheat Genetics Breeding Program (K. Campbell) - Conducted freeze tests on all advanced and elite lines and determined the relative levels of cold hardiness. Kim Campbell used the results in two different ways. First, Dr. Campbell incorporated the cold hardiness results as a selection criteria into her breeding program and, second, Dr. Campbell used the most cold hardy clubs as parents for new club wheat breeding crosses.

Tested lines selected by the WSU Winter Wheat Breeding Program (S. Jones) - Conducted freeze tests on selected winter wheat breeding lines and determined that several lines were very cold hardy.

5. **Determined the effect of four vernalization genes on cold hardiness** - Near-isogenic lines differing in four vernalization genes (developed by R.E. Allan) were freeze tested. This enabled us to assess the relationship between vernalization genes and freezing tolerance.

Acknowledgments: This project is funded by the Washington Wheat Commission in partnership with USDA-ARS and Washington State University. We thank Dan Dreesmann and the WSU College of Agriculture and Home Economics for support of the plant growth facilities and temperature-controlled growth chambers.

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Progress within the Grain Legume Breeding Program

F.J. Muehlbauer, K.E. McPhee, R.W. Short, J.C. Coker and S.L. Willett

The grain legume breeding program is focussed on producing improved cultivars of dry pea, lentil, chickpea and Austrian winter pea. Industry is demanding a wide range of types within each crop. These types must be environmentally adapted, disease resistant, high yielding, and market acceptable. To meet these demands we have accelerated the breeding process. An increased use of greenhouse screening techniques for early generation breeding material coupled with intense field screening of selected material has dramatically reduced the overall time from parental selection and cross pollinations through to cultivar release. The breeding efforts directed at each of these crops are described below.

Dry peas:

Dry peas are an important rotational crop to the cereals in the Palouse region of eastern Washington and northern Idaho. The crop provides an alternative to the cereal grains and is considered necessary in order to break disease cycles, improve weed control and fertility status of the soils. The crop is attacked by a number of diseases of which root rots, wilts, viruses and powdery mildew can be of epidemic proportions. Currently, the dry pea crop is made up of 80% smooth, round-seeded green types (typical of "Alaska" peas). The remainder is made up of smaller-seeded green types ("small sieves") and large yellow-seeded types. The principal quality factor for the smooth green types is good color retention and resistance to seed bleaching. Cultivars are needed which will retain their dark green cotyledon color even though moist conditions known to be conducive to seed bleaching may occur. Progress has been made under previous industry supported projects in the development of dry pea varieties with multiple disease resistance, particularly to root rot, wilt, powdery mildew and viruses (mainly bean leaf roll and pea enation mosaic).

Progress is also being made in developing cultivars with greater resistance to seed bleaching and darker seed coats. The method currently used involves greenhouse and laboratory tests to identify durable color quality and is working exceptionally well. Selections made using this technique have shown marked improvement in color quality. Current selections and additional selections to be identified using this screening procedure, will provide the industry the quality and disease resistance needed to remain competitive in world markets.

Market exploration for the marrowfat type pea indicates that this type of pea could soon play an important role in the Pacific Northwest. Marrowfat peas are green in color and approximately twice the size of the traditional smooth green peas (35-40 vs. 18-22 gm/100 seed). They are oblong and have an irregular or dimpled seed surface. They are used in soups in the United Kingdom and as snack foods East Asia. Snack processing includes soaking the seed and frying it in hot vegetable oil until crunchy and then adding seasonings to the seed surface for flavor. The first priority within the market is extremely large seed size and then durable dark green color. Integrity of the seed coat is also important and must be protected during harvest and seed handling.

The dry pea breeding program has recently been expanded to include the orange or red cotyledon types. This type is not grown extensively at this time, but has great potential in the marketplace as an ingredient in soup mixes much like the 'Redchief' lentil. The first crosses were made in the fall of 1998 and segregating populations are being grown in the field.

In 1997, three new cultivars were released, 'Shawnee', 'Fallon' and 'Joel'. Shawnee was released as a replacement for 'Umatilla', Fallon was the first semi-leafless type released from the program and Joel was released as a replacement for 'Columbian', but has not been readily accepted by the industry as yet. In 1999, two additional varieties were approved for release. Names have not been assigned to these selections yet and are designated PS510718 and PS510737. They are both higher yielding than either Joel or Columbian and have durable dark green cotyledon color. Both are semi-dwarf types and have normal leaf type resulting in a tendency to lodge near the end of the season. PS510737 has exceptionally dark green color and maintains that color during soaking and cooking. Over the past four to five years the "afila" leaf trait has been incorporated into many of the breeding lines to confer an upright growth habit conducive to direct harvesting with a wheat header. Numerous selections are being evaluated in field trials this year.

Lentils:

The lentil industry of the U.S. competes in the world market and must have cultivars that produce acceptable quality of the various market classes. For that reason, cultivars with improved yields and seed quality are essential to maintaining and improving competitiveness. Until very recently, the Palouse region produced only one type of lentil, the so-called Chilean type ('Brewer') with large, yellow cotyledons. Indications are that several types can be produced and sold in various markets both domestically and worldwide. Several other types are now being produced including "Spanish Browns", and red cotyledon types, both small and large seeded. An exceptionally large yellow-seeded lentil with uniformly green seed coats is needed by the industry to compete in markets in the Mediterranean region. In addition to a large yellow lentil cultivar, the industry would benefit from a small Turkish red type of lentil.

Crimson was released in 1990 as a Turkish red type. 'Mason' a large yellow cotyledon type, was released in 1997 and has exceptionally large seed size and is higher yielding than Brewer. It also produces large amounts of residue that is beneficial for soil conservation. Two advanced selections, LC460197 and LC460266, were approved for preliminary increase of breeder seed in 1999. LC460197 is a large seeded selection (similar to the 'Laird' variety in Canada) with an upright plant habit and even maturity. LC460266 is similar to 'Brewer' but with somewhat larger seeds, a taller and more upright growth habit and even maturity. It is anticipated that the former will compete with the Laird lentil from Canada, while the latter will be a replacement for the Brewer lentil. Names for these two selections have not been decided. Approximately 1.5 acres of each selection are being grown this year. It is projected that seed of these new varieties will be available to growers in 2001. Both selections have improved standing ability, higher yields and leave increased amounts of residues when compared to Mason and other varieties currently being grown. The upright growth habit and more even maturity may allow these varieties to be harvested directly without swathing.

Chickpea (Garbanzo beans):

Ascochyta blight is a devastating disease of chickpea in the Palouse area and has caused serious problems with the production of the crop. Success in the early 1990s led to the development of cultivars such as 'Dwelley', 'Sanford' and 'Myles'. These cultivars made it possible to grow the crop with some assurance that the disease would not be as devastating. In 1997, 'Evans' was also released as an earlier flowering and maturing variety with resistance to ascochyta blight. These three cultivars are the only large-seeded kabuli types with resistance to ascochyta blight available for production. Recent market information indicates that there is an increasing demand for the so-called 'Spanish White' type which is characterized by exceptionally large white seeds. Numerous crosses were made to incorporate ascochyta blight resistance into the Spanish White type. During the 1998-99 winter season, lines of the Spanish White type were winter increased at Yuma, Arizona to provide additional seed for yield testing and also to gain a year in development time. Based on the 1999 trial data, two selections, one Spanish White type (CA9783007) and one cream colored Dwelley type (CA9783152), were proposed and approved for preliminary increase of breeder seed. These increases were grown at Brawley, California and an additional seed increase is currently being grown under irrigation near Walla Walla, WA. These two new varieties could be available to growers in 2001 if additional seed increases are made in the winter of 2000-2001.

In addition to the work on the Spanish White type, there is a need to improve on the resistance to blight in Sanford and Dwelley. Those cultivars need to have better resistance to the pod infection phase of the disease. Germplasm has been identified in the blight screening nursery with good resistance to pod infection. Resistance to pod infection in regular cream colored and Spanish White cultivars cultivar is needed for future long-term control of the disease and prevention of spread through infected seed.

Winter Peas:

Two types of winter peas are being developed including the regular Austrian winter pea and winter hardy white-flowered, clear-seeded selections that can either be used as feed peas or food peas. Production of the crop has declined over the past 10 years due to a serious problem with aphanomyces root rot and infestations of ascochyta blight and sclerotinia white mold. These foliar disease problems appear to be solvable through the use of plant types that keep the canopy upright during most of the growing season increasing air movement thereby reducing humidity in the lower canopy. The root disease problem is somewhat more difficult. However, we have established root disease screening nurseries that have the potential of identifying genetic material with tolerance to the most important root rotting pathogens. The development of multiple disease resistant cultivars is needed if this crop is to continue as an integral part of the cropping system used in the Camas prairie. The most urgent need is to develop cultivars with resistance to these diseases and with sufficient winterhardiness to be grown over a wide area.

'Granger' is the most recently released Austrian winter pea cultivar. It has been widely accepted by the industry and has been grown on a large number of acres in northern Idaho and also in Washington and other states. Granger is long-vined and has the semi-leafless trait allowing it to stand more upright and reduce the severity of foliar disease during the season.

In 1999, the winter pea nursery at Spillman Farm was severely damaged by winter killing and the least hardy lines were eliminated from the program. This development has made it possible to concentrate on the hardiest selections. In addition to the elimination of less hardy selections, we were able to make additional crosses designed to introduce disease resistance into the hardiest lines. The most recent winter season, 1999-2000, was very mild and little or no elimination of selections could be made.

The Pea and Lentil Commission has eliminated funding for the winter pea project.

<u>Winter lentil:</u>

A breeding program for winter lentil has been established and many breeding lines have been identified with excellent winter hardiness. At the present time it appears that small seeded red and yellow cotyledon types of winter hardy lentils have the most potential for production in the Palouse region. We have selections available in these two categories that can be fall sown into standing wheat or barley stubble where they can survive the winter and resume growth in the very early spring. Several winter lentil selections are currently being tested in direct seed systems. Based on results of trials this season, we may have selections to propose for increase of Breeder seed in anticipation of variety releases. It continues to be difficult to combine high yield and winter hardiness into the large-seeded types.

BARLEY IMPROVEMENT RESEARCH

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C.I. Krugerand M.C. Ferguson

Collaborators: A. Kleinhofs, D. von Wettstein, S.M. Dofing, P.E. Reisenauer, J.A. Froseth, R.J. Cook, and R.L. Line

Cultivar Development/Variety Testing

The overall goal of the WSU Barley Improvement Program is to make barley a more profitable or valuable crop. Specific objectives are to improve agronomic and grain quality factors and pest (disease and insect) resistance for dryland and irrigated production. The emphasis is on two-row spring barley with additional efforts on six-row spring, spring hulless &/or waxy, and winter types.

The latest releases from the Barley Improvement Program were two new spring barley cultivars in 1997; 'Bear', a two-row hulless type and 'Washford,' a six-row hooded (beardless) hay type. A spring two-row line, WA9504-94, was approved for preliminary seed increase with a probable decision for release in February 2001.

Bear -- A New Two-Row Spring Hulless Barley. Bear yields well relative to other hulless cultivars in eastern Washington and northern and southern Idaho. The test weight of Bear has ranged from 57 to 60 lb/bu. Nutritional quality of Bear is very good based on starter pig, mobile nylon bag technique, and *in vitro* trials. It is expected to be used for livestock feed and potentially for human food.

Washford – A New Six-Row Spring Forage (hooded) Barley. Harvested at the grain soft-dough stage, Washford produced 15%) more hay and 22% more seed than the old standard, Belford . Washford is shorter than Belford by 8% and has greater lodging resistance. All agronomic data are averages over 6 years of tests at Pullman. Washford had the highest hay yield at four of the eight 1996 Montana/Wyoming locations and was equal to the highest yielder at two additional locations. Few disease symptoms have been noted on the forage barleys. However, Washford has shown some susceptibility to loose smut and it is susceptible to barley stripe rust. There is limited quality data, but appears to be comparable to Belford in feed value. Washford is expected to be used primarily for hay, but also other forage uses for ruminant livestock. It should supplant Belford.

WA9504-94 – A New Two-row Spring Feed/Malting Barley. This semi-dwarf line has shown wide adaptation in eastern Washington, high malting quality, and a moderate level of resistance to barley stripe rust (BSR). It is expected to compete better in eastern Washington than other BSR resistant cultivars recently released compared to the high yielding BSR susceptible feed cultivars such as Baronesse.

For spring barley in 1999, approxmately150 crosses were made. In 1999, heads were selected from 170 segregating F_4 populations (~100/population). In addition, there were ~100 F_2 single seed descent populations in the greenhouse. Lines were selected from approximately 10,000 head rows. There were approximately 1,200 single replication evaluation plots planted at Spillman Farm and Ritzville or Royal Slope this year; the entries of which mostly came from 1998 head/plant rows. The more advanced lines are tested in 20 30- to 48-entry major yield trials at Spillman Farm and throughout eastern Washington including a 48 entry preliminary state yield trial at three locations – Pullman, Fairfield, and Ritzville – and the state uniform trial of 39 entries planted at 14 locations (eight extension/Dofing and Reisenauer). Barley performance in 1999 was presented in the Nov. 6, 1999 *Green Sheet* and in the Jan. 2000 *Wheat Life*. Several 2-row lines show good agronomic and quality promise. There were six grower-conducted on-farm tests with seven entries in three counties in 1999 coordinated by Kevin Anderson of Great Western Malting Company and Roland Schirman and John Burns, area/county extension agents in Columbia and Whitman county, respectively.

Grain quality evaluations of breeding lines and cultivars are conducted on field-grown samples. Basic kernel quality characteristics, such as test weight and kernel plump-thin percentages, are measured in our laboratory. Malting quality is evaluated at the USDA-ARS Cereal Crops Research Unit at Madison, Wisconsin. Feed quality evaluations have been conducted in the Department of Animal Sciences primarily by John Froseth.

Disease and Insect Resistance. While yield and grain quality are always important selection criteria, pest resistance is moving up in priority. Crossing, screening and selection for Russian wheat aphid, barley stripe rust, soil borne pathogen, and Hessian fly resistance is underway. The **Russia wheat aphid** is a relatively new pest in the Pacific Northwest (PNW) and has the potential to inflict serious damage to the barley crop. Reaction screening is carried out at the USDA-ARS Insect Laboratory at Stillwater, Oklahoma. RWA resistant lines were first grown in field tests in 1998. **Barley stripe rust** (BSR) is a new disease to the PNW and little resistance exists in currently grown barley cultivars. Rollie Line is collaborating on monitoring and testing for this disease. We have had germplasm screened for barley strip rust reaction the past several years in Bolivia, Texas, Colorado, and Washington. Expanded field testing of resistant lives began in 1997. There appears to be good resistance in a relatively large number of WSU breeding lines including WA9504-94 described above. **Soil borne pathogens** probably affect barley production more than we realize. A new effort was initiation in 1994 through Vadim Jitkov's M.S. research project in collaboration with Jim Cook to screen for reaction to soil borne pathogens in the field and growth chamber. Barley cultivars and breeding lines may have been identified with resistance to ***Rhizoctonia solani*** for the first time. Relatively simple inheritance of resistance is indicated which should facilitate breeding for resistance to this soil borne pathogen. Field testing for soil borne pathogen reaction has been expanding over the past few years with nurseries planted at Spillman Farm, Dusty, Ralston, Ritzville, and Bickelton. Carolyn Kruger, a new M.S. student is developing her thesis research around direct-seeded barley and soil borne disease reactions in the field and greenhouse. Backcross breeding projects are underway for Russian wheat aphid, barley stripe rust, and *Rhizoctonia* resistance. Backcross progeny are being screened with molecular markers linked to the stripe rust resistance genes. New collaboration was begun in 1999 for screening barley germplasm for **Hessian fly** resistance at the USDA-ARS Insect Laboratory at Purdue University, West Lafayette, IN. The first set of cultivars and breeding lines are currently being tested. Hessian fly in barley seems to be a persistent and growing pest problem as reduced tillage production gains in popularity.

Application of Biotechnology

Collaboration in the North American Barley Genome Mapping Project involves work on several fronts with Andy Kleinhofs, Janet Clancy, and Wenxiang Gao, graduate student. The first comprehensive map developed from Steptoe/Morex is being applied to quantitative trait locus

(QTL) analysis and molecular marker assisted selection relevant to cultivar development. We are verifying QTL identified and developing molecular marker assisted selection strategies for use in the breeding program. Initially, we are concentrating on the dormancy trait and yield from Steptoe, several malting quality traits from Morex, *Rhizoctonia* resistance from identified germplasm sources, and barley stripe rust resistance from several sources. Mapping populations from the Harrington/TR306 and Harrington/Morex crosses are also being evaluated. The incorporation of yield QTL from Baronesse and barley stripe rust QTL from Orca into Harrington and the incorporation of Steptoe yield QTL into Morex are collaborative projects with Andy Kleinhofs, Dave Kudrna, and Deric Schmierer, M.S. student. The availability of a detailed genome map allows us to begin to understand the genetics of complex economically important agronomic (yield, lodging, maturity) and quality (feed, kernel, malting) traits through QTL analysis. With the identification and location of specific genes, marker-assisted selection strategies can be developed for more directed breeding.

Collaboration in breeding proanthocyanidin-free barley and transformation of barley with a heat-stable beta-glucanase (brewing and feed quality traits) is underway with Diter von Wettstein and Judy Cochran. The transformation project will see transformed plants in the field for the fifth year in 2000. The proanthocyanidin-free barley project has been a long-time collaboration. A boost to the project occurred with the induction and incorporation of pigmented "pant" mutants (vs anthocyaninin-free types), which have improved adapted and quality.

1999 Variety Testing Program - Spring Barley

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Overview

The 1999 state spring trial consisted of 39 varieties grown at 14 locations. Trials at Fairfield, Pullman, Pomeroy, Ritzville, Lind, and Royal Slope were grown cooperatively with the spring barley breeding program. The trial at Royal Slope was irrigated, and the remaining trials were dryland.

Seven varieties were 6-row, and 32 were 2-row. Two hulless varieties, Bear and Condor, were also included.

Growing Conditions

In general, growing conditions during 1999 produced barley yields that were somewhat below average. Spring soil moisture was sub-optimal at many locations, although timely rainfall during the summer resulted in soil moisture that was generally adequate at many locations. Spring temperatures tended to be lower than average. Kernel quality was generally good in 1999, and strip rust was virtually non-existent.

Results

Grain yield and test weight of the varieties grown in the trials are presented in the following tables. Across all locations, Baronesse was again the highest yielding variety, with an average yield of 3895 lbs/A. The second highest yielding entry was Xena, with a yield of 3856 lbs/A. Steptoe was the highest yielding 6-row variety, with an average yield of 3547 lbs/A.

Test weights were generally high in 1999, with an overall average of 50.1 lbs/bu. Test weights of all 2-row varieties were over 48 lbs/bu. With the exception of Morex, all 6-row varieties had test weights less than 48 lbs/bu.

Acknowledgments

This work was made possible by funding provided by the Washington Barley Commission, WSU College of Agriculture and Home Economics, Washington State Crop Improvement Association, fees paid by private companies, and the generous contribution of cooperators who provided land and other assistance required to grow these trials.

1999 WSU SPRING BARLEY VARIETY TRIAL SUMMARY

October 27, 1999

YIELD (LBS/A)

VARIETY NAME	LIND FALLOW	BICKLETON	POMEROY	ASOTIN	DUSTY	RITZVILLE	DAYTON	FAIRFIELD	LAMONT	PULLMAN	REARDAN	ST. JOHN	FARMINGTON	ROYAL SLOPE	VARIETY MEAN
2-ROW															
BANCROFT	1262	1577	1976	2133	2441	2453	3266	2629	3853	3987	4696	4990	5162	6327	3339
BARONESSE	1387	1993	2178	2156	2971	2425	3345	3568	4502	4399	5052	5741	6591	8228	3895
BCD 44	1202	1075	1549	1855	1844	2114	2526	3217	3594	4156	3655	4743	5355	7497	3170
BCD 47	1005	1061	1950	2007	1952	2056	2671	2347	3618	3357	3783	4935	5595	6214	3039
CA 108702	1223	908	1515	1844	1988	2215	2900	3478	3907	3037	4666	4866	5814	7482	3274
CA 803208	1199	1639	2159	2055	2464	2259	2930	3425	4095	3259	4443	5036	5840	7224	3430
CA 803803	1361	1232	1766	2163	1983	2220	2787	3014	3880	4202	4783	4634	6120	7833	3427
CA 808505	1291	941	1747	1705	2243	2199	2656	2800	4025	3789	4289	4803	5491	6856	3202
CA 905711	1212	1097	1721	1454	2119	2296	3080	3142	3966	3852	4432	5070	5550	7141	3295
CAMELOT	1277	1366	2301	2081	2812	2262	2619	3186	4145	4877	4360	5422	5771	6738	3515
CDC STRATUS	1226	1134	2173	2222	2002	2363	3144	3071	4006	3560	4465	4996	5271	7024	3333
CEB 938	1326	1226	1966	2129	2153	2370	3106	3150	3915	4547	4700	5507	6273	7283	3546
CHARMANT	1328	1035	1649	1698	2327	2203	2793	3157	4078	3590	4742	5041	5832	6600	3291
CREST	1391	1507	1814	2365	2168	2131	2991	3137	3705	3253	4338	5105	4996	6966	3276
GALLATIN	1279	1495	2192	2437	2505	2458	3051	3278	3948	4332	4387	5187	5444	6713	3479
HARRINGTON	1117	1442	1874	1917	2347	2277	2396	3473	3792	3255	4450	5074	5308	6830	3254
MELTAN	1231	1727	2107	2312	1982	2204	3395	3073	3861	4616	4494	5187	5747	7080	3501
ORCA	1207	1814	1962	2225	2070	2259	2541	3150	3272	3462	3452	4604	5554	6626	3157
PONGO	1523	1102	2001	1908	2182	2471	3110	2983	4142	5222	5032	5789	6201	7486	3654
SG 188	1241	1184	1847	2202	2288	2229	2699	2866	3833	3533	3942	4952	5786	6927	3252
SG 220	1519	1142	1813	2108	1766	2296	3029	3610	4002	4798	4429	5163	6198	7215	3506
TOFTA	1363	1367	1617	1788	2321	2517	3229	3160	4431	4629	4849	5418	6113	7010	3558
WA 11801-95	1355	1252	1990	2214	2720	2463	2781	3235	4139	4694	4462	5508	5685	7420	3566
WA 11825-95	1381	1108	2037	2021	2374	2518	3090	2791	4285	3918	4681	5511	6102	7409	3516
WA 11832-95	1290	1498	2189	2349	2687	2608	3027	3163	4467	4435	4739	5396	6221	7137	3658
WA 12223-95	1184	1312	1779	2051	2318	2201	3219	2561	4119	4448	4849	5178	5753	7662	3474
WA 12953-95	1106	1134	2091	2264	2286	2488	3449	2843	4208	3835	4874	5315	6042	6598	3467
WA 16641-93	887	806	1532	1185	2021	2015	2672	2510	3588	3977	4541	4767	5705	6105	3022
WA 7642-92	1343	1174	2095	2396	2432	2584	3072	3121	4342	4216	4767	5655	5793	7414	3600
WA 9504-94	1397	1762	1971	1772	2469	2255	2859	3869	3935	4349	4921	5117	6164	7230	3576
WA 9508-94	1234	936	1957	2203	2463	2300	2626	3135	3679	3958	4098	5085	5469	7393	3324
XENA	1434	1570	2216	2412	2163	2266	2927	2359	4304	4664	5317	5591	6299	8178	3693
6-ROW															
MOREX	819	1589	2076	1974	1856	2176	2291	2123	3484	2958	3790	4566	4881	3244	2702
STEPTOE	1096	1741	2354	2296	2576	2221	2598	2848	2881	4319	4587	5495	6370	8271	3547
TANGO	804	1687	1863	2041	1663	2058	2386	2090	2714	2954	4039	4687	5808	6980	2984
WA 18009-94	1182	1200	1663	1758	2021	2300	2135	2218	3276	3007	4565	4533	5861	6851	3041
WA 18060-94	1097	1249	1842	1413	1917	2119	2535	2390	3588	2846	4201	4229	5737	6780	2996
HULLESS															
BEAR	1163	478	1462	1520	1944	1988	2376	3032	3519	3333	3511	4416	4343	5619	2765
CONDOR	986	1070	1585	1881	1870	1947	2217	2380	3516	3609	4029	4434	5317	6201	2932
NURSERY MEAN	1229	1298	1912	2013	2223	2277	2834	2964	3862	3929	4447	5070	5732	6969	3340
LSD @ .10	195	600	185	294	279	195	405	617	312	677	365	399	419	728	117
CV %	13.5	39.4	8.2	12.5	10.7	7.3	12.2	17.8	6.9	14.7	7.0	6.7	6.2	8.9	11.3

1999 WSU SPRING BARLEY VARIETY TRIAL SUMMARY

October 27, 1999

TEST WEIGHT (LBS/BU)

VARIETY NAME	LIND FALLOW	BICKLETON	POMEROY	ASOTIN	DUSTY	RITZVILLE	DAYTON	FAIRFIELD	LAMONT	PULLMAN	REARDAN	ST. JOHN	FARMINGTON	ROYAL SLOPE	VARIETY MEAN
2-ROW															
BANCROFT	53.4	46.0	46.5	44.7	50.8	50.9	50.0	50.3	48.3	50.0	50.2	48.7	47.9	53.7	49.6
BARONESSE	51.8	46.9	46.9	45.6	53.2	51.6	51.3	51.3	49.6	50.7	51.1	49.8	51.1	55.6	50.7
BCD 44	53.7	45.2	48.2	46.2	52.1	51.9	50.0	50.4	49.3	50.3	50.5	49.4	48.8	54.2	50.3
BCD 47	53.4	47.7	50.0	44.9	53.2	53.1	50.5	52.2	50.3	50.6	52.0	50.5	48.9	53.2	50.9
CA 108702	52.3	44.0	47.5	45.8	51.7	50.0	49.1	50.7	48.4	49.5	49.3	48.7	46.5	54.1	49.4
CA 803208	54.3	48.4	49.9	46.0	54.1	53.6	51.2	51.9	51.4	51.4	52.5	52.0	50.3	54.5	51.7
CA 803803	53.4	47.0	48.2	45.0	52.6	52.4	50.2	51.0	49.2	50.3	51.6	49.9	51.0	55.3	50.7
CA 808505	53.8	44.8	48.2	47.3	51.5	51.7	51.2	51.4	49.9	51.0	50.4	50.0	47.7	54.3	50.6
CA 905711	53.2	46.4	47.5	47.7	50.2	50.6	49.5	50.5	46.8	49.8	48.6	48.1	46.7	53.9	49.4
CAMELOT	53.0	48.8	50.0	46.8	53.9	52.7	51.8	52.0	50.8	51.7	51.8	51.9	51.6	54.9	51.7
CDC STRATUS	52.9	45.4	46.5	44.4	51.2	52.0	49.5	50.3	48.6	49.7	49.6	48.1	49.1	54.7	49.7
CEB 938	53.7	45.6	48.9	46.4	52.8	52.6	51.5	51.9	50.2	50.2	51.5	50.9	51.0	54.1	51.1
CHARMANT	52.5	45.8	47.0	44.9	51.2	50.9	49.6	50.5	49.2	49.7	50.5	49.2	49.0	53.1	49.7
CREST	52.8	47.6	47.0	46.5	53.4	51.7	50.8	51.6	50.1	50.1	52.3	50.5	50.2	54.7	50.9
GALLATIN	52.8	48.0	49.1	46.4	51.9	52.0	51.2	51.8	50.0	51.7	52.2	51.5	51.7	55.4	51.3
HARRINGTON	52.6	44.2	46.3	45.3	51.5	51.7	50.7	51.9	50.1	50.2	50.3	48.8	47.7	54.5	50.0
MELTAN	54.4	50.2	49.5	45.7	53.8	53.0	51.4	51.4	50.6	50.9	52.7	50.9	50.2	54.4	51.4
ORCA	51.7	49.1	46.4	42.2	52.6	51.5	49.4	50.0	47.3	48.2	49.1	48.5	50.0	54.4	49.3
PONGO	51.1	42.6	46.0	45.0	50.9	49.7	48.9	49.6	48.1	48.5	49.5	47.7	45.7	52.4	48.6
SG 188	53.8	48.6	50.1	48.4	53.3	52.9	51.7	50.6	50.0	50.4	51.1	51.2	51.2	54.6	51.4
SG 220	54.3	49.2	50.2	48.4	54.5	53.9	52.4	52.4	51.3	52.7	52.8	52.3	53.1	56.3	52.6
TOFTA	51.8	44.0	46.2	44.2	52.0	50.9	50.2	50.5	49.6	49.9	50.0	48.1	47.6	53.5	49.5
WA 11801-95	52.7	45.1	47.6	45.9	52.2	51.5	51.0	51.6	50.0	50.9	50.6	50.6	49.1	55.3	50.6
WA 11825-95	52.2	48.8	46.8	43.0	52.3	50.0	49.6	50.1	49.0	50.1	50.3	48.8	49.3	55.4	49.8
WA 11832-95	52.6	46.8	47.6	44.2	52.1	51.4	50.0	50.5	49.5	49.9	51.0	49.8	48.8	55.0	50.1
WA 12223-95	53.7	45.1	47.9	44.1	51.7	51.5	50.4	51.9	50.0	50.2	51.0	49.8	47.5	54.3	50.2
WA 12953-95	52.5	42.8	45.6	44.1	51.6	49.4	47.9	49.7	48.2	49.3	49.1	47.7	47.9	53.7	48.9
WA 16641-93	51.8	45.4	47.5	46.4	50.8	50.9	50.1	51.5	48.4	50.6	49.8	49.3	47.3	54.0	49.8
WA 7642-92	52.6	45.1	48.1	46.4	52.4	51.4	51.1	51.8	50.0	50.6	51.5	50.7	50.6	55.4	50.9
WA 9504-94	53.3	46.5	47.9	45.3	51.7	51.3	50.2	51.4	48.6	50.5	50.2	49.6	49.2	54.4	50.2
WA 9508-94	52.3	44.1	47.4	45.0	51.4	51.2	50.1	50.0	49.2	49.5	50.8	49.7	49.1	54.1	49.9
XENA	52.4	46.3	48.0	45.9	53.7	51.8	51.4	49.9	50.5	50.3	51.9	50.8	51.1	55.3	50.9
6-ROW															
MOREX	51.7	47.2	45.9	42.2	50.9	51.5	47.9	48.1	46.8	48.4	49.2	48.1	48.9	52.6	48.6
STEPTOE	50.8	44.6	43.8	39.2	48.7	49.1	45.7	46.3	41.4	46.4	46.9	45.2	46.0	51.2	46.2
TANGO	49.4	45.4	43.0	40.5	48.3	48.0	44.5	45.0	40.9	45.7	45.3	43.1	45.5	51.2	45.4
WA 18009-94	50.8	44.5	42.7	36.6	47.7	48.1	44.5	46.1	43.6	45.1	45.7	42.2	44.1	51.1	45.3
WA 18060-94	47.6	44.1	42.0	37.4	47.0	48.4	45.2	45.4	43.5	45.4	44.7	42.7	45.6	50.4	45.0
HULLESS															
BEAR	59.3	52.2	53.1	50.9	58.4	59.4	56.2	57.9	54.1	59.2	56.2	54.3	54.6	61.2	56.4
CONDOR	58.5	49.9	53.5	52.3	58.3	58.4	56.3	57.3	56.0	55.6	55.3	53.8	55.9	62.5	56.3
NURSERY MEAN	52.9	46.4	47.6	45.1	52.1	51.7	50.1	50.8	49.0	50.2	50.5	49.3	49.2	54.4	50.1
LSD @ .10	0.8	*	1.0	1.3	0.6	0.7	0.7	1.1	0.6	0.8	0.9	0.8	0.7	0.8	0.2
CV %	1.2	*	1.8	2.5	1.0	1.1	1.3	1.8	1.0	1.3	1.6	1.4	1.3	1.2	1.4

Winter Wheat Breeding and Genetics
1999 Progress Report

Steven R. Lyon, Research Technician Supervisor
Stephen S. Jones, Breeder

Advanced yield trials were conducted at 23 locations statewide. This large number of field trial locations allow us to be very successful in screening our advanced lines, as the incidence of various diseases was high at some locations and nonexistent at others.

Lines with Cephalosporium resistance (transferred from wild species into popular soft white common varieties) have been entered into advanced yield trials.

This year we again evaluated performance of advanced snowmold resistant lines in northern Douglas County without the incidence of severe snowmold pressure. Consequently, Dr. Tim Murray tested these lines in the greenhouse snowmold project.

Edwin (WA7834) was approved for release in 1998. This year it was in foundation seed and it continues to outperform Moro. Edwin is expected to be grown on significant acreage in the coming years.

Bruehl (WA7833), a soft white club was approved for release in 1999. Although Bruehl has shown wide adaptation in intermediate and high rainfall zones, it was primarily released for the areas of the Pacific Northwest that have severe snowmold problems. It has improved tolerance to local strains of the speckled snow mold pathogen, excellent straw strength and matures earlier than other local snowmold resistant varieties. Bruehl also has superior yield potential and excellent club wheat end-use quality. This past year it had a statewide yield in our 8 club nursery locations of 63.6 bu/a, compared to Hiller (60.9), Rely (59.2), Eltan (69.4) and Madsen (56.3). Northern Douglas County had severe snowmold present in 1996 and 1997, and Bruehl has consistently outscored Eltan and Sprague on snowmold regrowth ratings. The data for Bruehl indicate it has good emergence, rust resistance and matures several days earlier than Eltan. Bruehl will be available as Foundation seed this fall and already, the WSCIA has had more foundation seed of Bruehl requested than any other variety in their history.

We have several promising soft white common numbered lines that will be advanced to preliminary release consideration if end-use quality remains high.

Development of a hard white and hard red Eltan is proceeding as planned. Ninety hard white selections were field tested this past year and first year quality tests show that 70% have a better noodle color score than Eltan and 25 % have better loaf volume, confirming the dual purpose nature of these wheats. The hard red Eltan selections are also being screened for quality and other agronomic characteristics.

We established a nursery at the Lind Field Station exclusively for screening for fusarium dryland footrot. All of our advanced and preliminary yield lines are evaluated for susceptibility/ tolerance to this disease.

Hard red selections are being evaluated for snowmold resistance in Douglas County. Those that are shorter and have all other desirable agronomic and quality characteristics are being advanced for possible release for this area. We also planted the Winter Wheat Eastern European Regional Yield Trial (WWEERYT) nursery in Douglas County to screen the hard red lines for quality and adaptability.

1999 Hard Red Varietal Performance in Low Rainfall Breeding Nurseries

Variety	Mkt Class	Connell			Finley			Horse Heaven			Average			Rank
		bu/a	lbs/bu	prot.	bu/a	lbs/bu	prot.	bu/a	lbs/bu	prot.	bu/a	lbs/bu	prot.	by yield
Eltan	SWCom	35.1	59.9	13.9	68.9	63.2	11.2	33.6	61.5	14.2	45.9	61.5	13.1	1
Hatton	HRW	37.0	61.9	13.5	66.2	63.4	12.8	25.9	64.4	12.3	43.0	63.2	12.9	2
Finley	HRW	37.1	62.2	13.2	55.5	63.2	12.5	34.1	62.7	12.8	42.2	62.7	12.8	3
Q. H. 542	HRW	34.2	61.1	13.0	49.2	63.2	12.1	20.0	62.0	13.6	34.5	62.1	12.9	4
Buchanan	HRW	27.8	60.6	12.8	50.7	61.8	12.0	21.1	62.3	12.1	33.2	61.6	12.3	5
Symphony	HRW	27.0	57.2	14.1	55.1	60.4	12.6	12.5	56.6	14.3	31.5	58.1	13.7	6
Weston	HRW	24.5	61.8	14.5	50.0	63.4	14.3	16.3	62.5	14.7	30.3	62.6	14.5	7
Estica	HRW	22.8	53.5	12.5	48.3	56.6	11.4	16.5	52.9	13.3	29.2	54.3	12.4	8

1999 Soft White Common Varietal Performance (bu/a)

	High rainfall			Intermediate rainfall			
Variety	**Colton**	**Pullman**	**Walla Walla**	**Coulee City**	**Harrington**	**Pomeroy**	**Ritzville**
Sprague	73.8	106.7	69.5	57.4	64.0	55.9	44.0
Daws	106.0	92.0	96.7	51.7	59.0	60.0	63.1
Stephens	109.2	104.9	107.3	44.7	54.2	98.6	61.6
Lewjain	106.9	84.7	95.0	46.9	62.4	75.6	56.6
Eltan	97.0	94.9	91.8	66.8	65.7	60.8	63.9
Rod	116.1	111.7	102.5	53.5	68.6	72.3	64.3
Madsen	117.3	100.8	120.9	49.7	62.1	106.6	71.4

	Int. rainfall	Low rainfall			
Variety	**Waterville**	**Connell**	**Finley**	**Horse Heaven**	**Lind**
Sprague	36.9	29.8	51.8	36.6	51.7
Daws	37.9	37.9	53.2	44.3	61.6
Stephens	24.6	34.3	61.0	54.0	68.0
Lewjain	50.4	41.2	54.2	47.8	48.2
Eltan	63.5	37.6	51.3	50.2	60.2
Rod	46.2	38.4	52.9	51.5	65.9
Madsen	40.2	50.4	56.5	52.6	70.0

1999 Soft White Club Varietal Performance (bu/a)

	High rainfall	Intermediate rainfall				
Variety	Pullman	Coulee City	Harrington	Pomeroy	Ritzville	Waterville
Moro	58.8	47.7	69.3	55.0	51.0	39.3
Tres	72.9	47.5	50.0	64.5	64.4	50.2
Rohde	90.2	42.9	57.3	74.5	61.7	48.4
Hyak	90.8	49.5	60.1	74.2	61.3	42.9
Rely	94.2	47.2	64.4	69.5	75.0	48.8
Hiller	102.1	47.6	63.9	65.5	70.7	48.0
Bruehl	107.8	59.5	77.4	74.3	78.9	62.0
WA7871	101.5	51.8	62.5	65.2	68.8	45.6
Edwin	80.8	46.2	63.0	58.2	71.0	48.2

	Low rainfall	
Variety	Connell	Lind
Moro	21.5	54.8
Tres	32.5	54.3
Rohde	36.2	59.3
Hyak	44.0	55.8
Rely	35.3	73.1
Hiller	39.8	73.0
Bruehl	43.1	64.3
WA7871	51.9	66.6
Edwin	31.5	66.4

Winter Wheat Breeding Personnel

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1999 Variety Testing Program - Winter Wheat

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Overview

The 1999 state winter wheat trial consisted of 35 varieties grown at 18 locations. The trial at Moses Lake mistakenly cut by a custom combine, and subsequently that trial was lost. Trials at Ritzville, Bickleton, Lind, and Coulee City were grown cooperatively with the winter wheat project and the trial at Pomeroy was grown cooperatively with the club wheat breeding project.

Entries consisted of 29 soft white common, 5 soft white club, and 1 hard red common types. Three of the soft white common entries were seed mixtures. Varieties in the trial consisted of all named varieties grown on significant acreage in the state, promising varieties from the WSU wheat breeding program, and varieties submitted by private companies on a fee-for-entry basis. In order to obtain a uniform set of comparisons, all entries were grown at all locations.

Growing Conditions

1999 growing conditions were generally good for winter wheat production, although lack of precipitation limited yield at several locations. Soil moisture at planting time was low at many locations, although late fall and early winter precipitation resulted in good emergence and early growth. No significant winter injury was observed at any of the locations. Cool temperatures in the spring resulted in slow growth. Incidence of foliar disease was minimal in 1999.

Results

Grain yield, test weight, and protein, of varieties in the trials are presented in the following tables. Across all locations, Rod was the highest yielding variety, with an average yield of 96.8 bu/A, followed by Eltan at 95.7 bu/A. Hiller was the highest yielding soft white club. Test weights were generally below normal, with an average test weight across all locations of 59.5 lbs/bu.

Acknowledgments

This work was made possible by funding provided by the Washington Wheat Commission, WSU College of Agriculture and Home Economics, Washington State Crop Improvement Association, fees paid by private companies, and the generous contribution of cooperators who provided land and other assistance required to grow these trials.

1999 WSU WINTER WHEAT VARIETY TRIAL SUMMARY

September 24, 1999

YIELD (BU/A)

VARIETY NAME	RITZVILLE	COULEE CITY	BICKLETON	ASOTIN	FAIRFIELD	MAYVIEW	POMEROY	LIND DRY	DUSTY	FARMINGTON	REARDAN	CRESTON	ST. JOHN	WALLA WALLA	LAMONT	DAYTON	PULLMAN	VARIETY MEAN
Soft White Common																		
ALBION	59.5	53.0	58.4	58.8	59.5	65.5	72.8	84.2	86.7	75.3	100.6	110.2	128.4	109.5	114.8	120.3	138.1	88.1
BU6W93-477	27.0	39.3	53.2	76.4	77.9	56.8	69.6	66.9	77.2	71.1	67.9	103.2	107.5	135.7	121.8	130.7	136.9	83.4
BU6W93-481	20.8	28.4	35.5	62.1	56.8	45.4	65.2	66.6	65.5	50.8	26.5	76.4	81.2	106.5	101.9	129.9	133.2	67.8
CASHUP	50.3	58.0	45.0	73.2	74.7	77.1	74.0	74.8	81.9	89.6	112.6	95.0	141.8	111.1	115.0	143.6	147.3	92.6
ELTAN	62.5	70.7	65.6	76.7	79.7	88.4	79.1	84.5	84.0	97.8	120.3	117.9	130.1	111.4	108.5	120.3	126.4	95.7
ELTAN-MADSEN	53.8	63.0	59.1	74.8	78.1	77.2	76.1	74.2	85.5	90.8	99.2	108.4	133.3	112.9	124.6	129.8	121.3	92.3
HILL 81	38.7	52.8	44.3	64.9	78.1	68.9	70.7	59.0	74.8	86.2	78.0	100.0	127.1	104.6	125.2	116.3	137.4	84.0
ID 10085-5	21.2	41.6	40.5	57.6	55.7	59.0	53.1	56.9	64.4	50.0	54.0	96.1	104.7	92.0	106.0	102.5	119.2	69.4
ID10420A	40.0	49.9	52.8	66.7	75.3	77.7	49.8	67.3	74.1	76.6	77.9	103.3	119.3	133.8	144.6	117.0	128.1	85.2
LAMBERT	43.1	48.0	55.2	68.6	54.1	69.6	66.5	58.5	73.8	72.0	92.2	107.8	122.2	119.2	123.3	112.0	115.2	82.6
LEWJAIN	51.5	57.1	42.6	53.1	63.2	61.1	75.5	77.5	70.0	77.6	97.9	101.3	100.0	108.8	121.1	96.4	130.5	81.6
MACVICAR	30.3	37.5	35.1	66.4	71.5	59.9	70.3	68.5	79.2	53.5	61.3	105.1	107.0	98.3	125.1	106.4	127.4	76.9
MADSEN	33.0	47.8	59.6	63.0	80.3	71.5	84.1	71.5	77.1	91.0	66.7	103.4	129.0	112.1	133.3	127.0	140.9	87.6
MADSEN .75X#/A	35.9	51.9	48.2	62.3	73.6	67.2	76.2	70.7	65.8	80.9	70.5	103.1	107.1	138.1	112.4	128.4	116.6	81.7
MADSEN 1.5X#/A	44.0	46.8	57.8	75.3	83.8	71.0	69.3	65.7	72.2	92.5	73.4	101.0	136.6	130.7	131.8	135.4	130.2	89.3
MADSEN-ROD	51.0	51.6	60.5	75.9	72.9	82.2	72.5	74.8	79.9	82.3	90.7	107.5	112.4	122.6	128.1	130.8	111.8	88.7
MADSEN-STEPHENS	34.9	39.3	50.7	70.7	77.0	53.4	68.4	68.1	76.7	77.5	62.3	93.4	109.9	120.3	111.1	127.4	134.4	81.7
MJ-4	45.2	45.9	47.5	77.0	69.1	78.6	69.8	87.6	66.9	84.0	77.7	100.4	125.9	111.9	120.5	140.5	137.6	87.7
OR939528	28.8	35.7	43.6	63.6	65.1	53.0	78.5	62.8	70.6	65.5	53.1	100.5	85.7	113.1	108.4	118.5	124.2	74.7
Q. HYBRID 7817	44.6	52.2	54.9	71.6	71.7	62.6	56.0	74.7	76.9	76.9	88.8	97.6	117.5	137.4	121.4	115.1	144.8	85.9
Q. HYBRID 95021	21.0	33.0	20.4	53.2	24.8	30.9	66.5	50.8	50.9	53.6	40.2	52.3	74.6	128.9	85.8	108.8	127.6	59.3
ROD	56.9	55.9	67.0	76.8	72.5	78.5	86.2	89.0	85.4	78.8	106.0	108.0	139.2	125.2	137.1	127.2	152.7	96.8
STEPHENS	27.8	39.2	43.9	57.1	58.1	55.6	75.4	65.5	67.3	51.3	48.7	91.4	109.4	105.5	113.8	110.8	115.0	72.2
WA7813	41.3	49.8	49.9	66.5	71.9	88.1	77.1	75.1	67.6	80.9	84.1	93.7	121.4	120.5	128.1	97.4	129.1	84.8
WA7832	38.2	45.6	55.7	66.5	72.2	77.6	67.5	65.4	72.3	81.3	86.6	85.2	123.9	129.5	117.8	126.7	125.8	84.5
WA7853	49.8	57.7	62.6	68.9	61.8	63.2	78.3	80.2	75.9	80.3	83.4	99.8	103.6	102.7	109.7	118.6	142.9	84.8
WA7870	56.8	55.4	58.7	70.6	79.2	66.4	59.7	79.9	77.0	75.1	97.8	105.8	116.2	127.0	123.3	114.1	140.4	88.4
WEATHERFORD	32.4	39.1	41.7	65.8	72.4	68.8	71.8	78.9	66.0	78.1	57.7	90.7	114.3	102.5	122.0	132.2	118.7	79.5
WESTBRED 470	53.1	38.7	60.4	67.5	44.3	65.4	66.9	68.6	79.7	71.1	89.1	90.1	120.3	136.1	101.5	121.7	134.9	83.0
Soft White Club																		
CODA	40.3	43.7	57.6	70.1	78.3	77.3	71.0	71.4	81.4	85.4	105.9	109.2	124.1	124.1	130.9	125.5	109.7	88.7
HILLER	50.2	51.9	56.9	72.6	72.2	78.0	74.2	75.7	73.8	82.9	99.8	114.0	140.4	108.2	137.0	124.5	134.7	91.3
RELY	47.8	50.4	63.6	65.6	79.6	75.0	58.9	72.5	77.1	84.6	105.1	103.2	114.6	119.7	112.1	104.9	110.4	85.0
ROHDE	47.7	39.3	56.6	58.5	49.1	58.3	61.1	66.3	68.4	78.7	98.2	96.2	120.2	125.3	119.3	109.4	100.1	79.5
TEMPLE	41.1	60.4	65.4	67.2	69.1	81.6	77.5	70.0	77.0	89.0	113.3	104.3	127.4	125.9	122.8	116.0	134.8	90.9
Hard Red Common																		
ESTICA	47.6	59.8	52.7	77.2	54.4	69.4	84.1	74.6	83.0	83.3	82.4	99.0	147.2	132.0	123.5	134.9	140.9	90.8
NURSERY MEAN	42.0	48.3	52.1	67.5	68.0	68.0	70.7	71.4	74.5	77.0	82.0	99.3	117.8	118.7	119.5	120.6	129.1	83.9
LSD @ .10	6.0	8.3	11.6	8.8	10.0	10.5	14.7	7.4	7.4	14.3	9.5	10.2	16.9	26.9	16.8	13.2	25.7	3.3
CV %	12.1	12.6	19.0	11.1	12.5	13.2	16.3	8.8	8.5	15.8	9.9	8.8	12.2	15.7	12.0	9.3	16.9	13.5

1999 WSU WINTER WHEAT VARIETY TRIAL SUMMARY

September 24, 1999

TEST WEIGHT (LB/BU)

VARIETY NAME	RITZVILLE	COULEE CITY	BICKLETON	ASOTIN	FAIRFIELD	MAYVIEW	POMEROY	LIND DRY	DUSTY	FARMINGTON	REARDAN	CRESTON	ST. JOHN	WALLA WALLA	LAMONT	DAYTON	PULLMAN	VARIETY MEAN
Soft White Common																		
ALBION	60.4	60.7	59.7	56.9	57.6	56.0	59.4	60.2	60.4	56.5	58.2	61.3	58.9	60.1	59.4	58.0	57.8	58.9
BU6W93-477	58.2	59.7	59.6	58.3	58.9	57.7	61.4	61.6	61.8	55.1	56.0	61.8	59.8	62.6	60.8	59.9	58.9	59.6
BU6W93-481	58.5	59.6	58.7	58.4	59.8	58.4	61.3	61.8	60.9	54.5	55.5	62.1	59.2	61.9	61.3	60.1	59.1	59.5
CASHUP	62.4	62.3	61.4	58.2	60.0	58.7	62.1	62.0	62.9	57.1	61.0	62.5	61.3	62.2	61.4	59.3	58.7	60.7
ELTAN	62.2	62.3	60.5	58.8	59.6	58.1	59.9	61.6	62.3	58.0	59.3	61.4	60.4	60.2	59.3	59.0	58.9	60.1
ELTAN-MADSEN	61.0	62.5	59.0	57.9	59.0	57.6	60.8	61.4	62.0	56.1	59.2	61.7	59.9	61.0	60.8	59.4	58.5	59.9
HILL 81	59.5	62.1	60.3	58.3	59.6	58.6	61.5	60.9	61.8	56.5	57.5	62.3	60.5	61.4	60.8	60.0	58.6	59.9
ID 10085-5	58.8	60.1	58.8	57.1	58.7	57.3	60.4	61.0	60.9	54.8	55.3	61.3	60.2	61.5	60.5	58.8	57.9	59.0
ID10420A	60.4	62.4	60.6	57.6	59.7	58.4	61.9	61.1	62.3	57.4	57.4	61.6	60.4	61.5	60.3	59.3	58.3	60.0
LAMBERT	60.1	59.6	60.0	57.4	58.7	57.1	60.5	60.9	60.6	56.0	57.0	60.6	60.0	61.3	60.0	58.9	58.3	59.2
LEWJAIN	61.7	62.8	62.5	59.3	59.4	59.1	61.5	62.3	62.3	57.8	59.0	62.6	59.7	61.0	61.0	58.2	59.5	60.5
MACVICAR	58.3	59.5	59.1	57.1	59.5	57.1	61.5	60.9	61.8	55.0	55.4	61.8	60.0	61.4	60.3	58.8	58.6	59.2
MADSEN	58.0	60.6	59.9	57.9	58.7	58.1	61.2	60.7	62.0	55.2	55.7	62.0	60.0	60.8	60.0	59.9	58.5	59.3
MADSEN .75X#/A	58.8	61.0	60.2	58.4	58.4	58.4	61.2	60.3	61.3	54.6	55.5	62.2	59.3	60.1	60.3	60.2	58.3	59.3
MADSEN 1.5X#/A	58.9	61.0	60.1	57.9	58.7	58.2	61.1	60.4	61.4	54.3	56.4	61.8	60.1	60.6	60.1	59.8	58.3	59.3
MADSEN-ROD	59.5	61.1	59.7	57.1	58.4	57.9	60.7	60.1	61.0	54.5	57.0	61.8	59.4	60.7	59.7	59.3	58.0	59.1
MADSEN-STEPHENS	58.2	59.8	59.9	57.1	58.5	57.6	61.0	61.3	61.0	55.0	56.9	61.7	59.2	60.3	60.3	59.1	58.0	59.1
MJ-4	56.8	58.7	58.2	57.9	57.7	58.3	59.9	60.5	59.7	55.1	54.5	60.6	59.5	58.6	59.3	58.9	58.8	58.4
OR939528	57.9	60.2	58.6	56.5	57.5	56.5	60.6	60.0	61.0	54.4	55.1	61.9	57.6	60.4	59.6	58.9	57.5	58.4
Q. HYBRID 7817	57.7	60.9	58.7	57.1	58.1	56.2	60.3	60.4	60.8	53.5	55.9	60.1	57.8	61.1	59.1	57.9	58.0	58.4
Q. HYBRID 95021	56.3	58.9	57.8	57.5	56.4	57.0	60.5	60.5	60.3	54.0	55.2	60.0	57.9	60.8	60.0	58.3	57.0	58.1
ROD	59.7	61.3	59.8	56.8	57.7	57.7	60.4	60.1	60.8	53.3	57.4	61.3	58.9	59.4	58.9	57.7	58.2	58.8
STEPHENS	56.9	60.6	58.1	56.4	58.5	57.6	59.5	61.5	60.0	52.8	54.6	61.5	60.1	60.9	59.9	58.6	57.1	58.4
WA7813	61.9	62.8	61.7	57.8	59.9	58.3	62.1	62.4	63.0	57.5	58.9	62.6	61.7	61.9	60.7	59.5	59.0	60.7
WA7832	58.0	60.7	59.1	57.8	59.0	57.7	60.7	60.6	60.7	55.2	57.9	61.7	61.4	61.1	60.0	60.0	59.2	59.5
WA7853	60.5	62.7	61.9	59.9	58.8	58.4	62.3	63.0	62.7	57.6	58.8	63.3	60.4	61.4	61.4	60.6	59.9	60.8
WA7870	61.2	61.9	61.3	58.0	59.6	58.2	62.0	62.0	62.2	57.0	58.1	62.6	60.4	60.8	59.6	59.0	59.6	60.2
WEATHERFORD	58.0	60.5	59.0	57.1	58.6	57.5	60.7	60.8	61.0	55.0	55.8	62.1	59.4	60.6	60.2	59.6	58.8	59.1
WESTBRED 470	62.8	63.6	63.1	60.2	60.8	61.1	63.3	63.4	64.1	59.1	61.5	64.4	63.3	63.8	62.2	61.8	60.6	62.2
Soft White Club																		
CODA	60.6	62.7	61.3	58.4	61.2	59.4	62.8	61.6	62.8	58.1	59.7	63.1	61.3	61.4	61.7	60.3	59.7	60.9
HILLER	58.3	59.9	56.4	58.0	58.8	57.9	59.9	61.2	60.6	54.8	56.2	58.7	58.9	59.8	60.0	58.2	57.1	58.5
RELY	59.6	62.0	59.2	57.6	60.0	58.4	61.0	61.7	62.1	56.8	58.1	61.0	60.2	61.2	61.1	60.0	58.4	59.9
ROHDE	61.7	62.1	61.2	58.8	59.7	59.7	61.7	63.4	63.4	58.4	59.3	62.3	61.4	62.3	61.7	60.3	58.9	61.0
TEMPLE	59.3	61.2	59.7	58.2	60.0	59.8	60.7	61.8	62.1	56.1	59.1	61.8	61.7	62.3	61.6	60.5	58.8	60.2
Hard Red Common																		
ESTICA	55.8	58.3	57.6	53.5	54.1	54.3	59.5	58.2	59.0	50.4	52.7	59.8	57.8	59.2	57.3	57.0	54.5	56.3
NURSERY MEAN	59.4	61.0	59.8	57.8	58.9	58.0	61.0	61.2	61.5	55.7	57.2	61.7	60.0	61.0	60.3	59.3	58.4	59.5
LSD @ .10	0.9	1.1	0.9	0.6	0.5	0.5	1.2	0.7	0.4	1.3	1.0	0.7	0.9	1.0	0.6	0.6	0.6	0.2
CV %	1.2	1.3	1.3	0.8	0.8	0.8	1.5	1.0	0.6	2.0	1.5	0.9	1.3	1.1	0.8	0.8	0.8	1.1

1999 WSU WINTER WHEAT VARIETY TRIAL SUMMARY

September 24, 1999

PROTEIN (%)

VARIETY NAME	RITZVILLE	COULEE CITY	BICKLETON	ASOTIN	FAIRFIELD	MAYVIEW	POMEROY	LIND DRY	DUSTY	FARMINGTON	REARDAN	CRESTON	ST. JOHN	WALLA WALLA	LAMONT	DAYTON	PULLMAN	VARIETY MEAN
Soft White Common																		
ALBION	11.4	10.4	9.4	11.2	11.4	10.6	12.2	12.2	11.0	11.4	9.9	8.2	10.2	12.6	11.1	9.5	8.4	10.6
BU6W93-477	12.8	10.6	8.2	9.8	10.9	10.2	10.9	12.9	10.9	11.7	11.6	7.9	10.7	11.6	11.5	9.3	8.4	10.6
BU6W93-481	12.6	11.3	9.4	10.4	11.0	10.4	10.4	12.4	11.2	12.7	12.8	8.6	11.7	11.9	11.5	9.8	8.6	10.9
CASHUP	12.7	10.6	9.7	10.1	10.7	10.4	11.9	12.3	11.8	11.1	10.3	8.7	11.4	12.1	11.5	9.7	8.6	10.8
ELTAN	11.7	10.0	8.5	9.8	10.5	10.1	9.7	11.5	10.9	11.2	10.6	8.1	10.2	13.0	12.0	9.6	8.2	10.3
ELTAN-MADSEN	12.7	10.0	8.0	10.4	10.4	10.5	11.3	12.4	10.9	10.9	8.8	7.9	11.4	12.6	11.3	9.6	8.4	10.5
HILL 81	12.9	10.4	9.2	10.6	10.7	10.9	10.9	12.8	11.5	12.0	10.9	8.6	11.2	13.0	11.1	9.9	8.5	10.9
ID 10085-5	13.8	11.9	10.0	10.4	11.5	10.5	11.7	13.5	12.4	12.6	11.5	8.6	11.2	13.0	11.7	10.8	8.9	11.4
ID10420A	13.9	11.9	8.6	10.5	10.7	10.6	11.6	12.9	11.6	11.6	10.9	8.7	10.7	12.9	11.3	9.8	8.6	11.0
LAMBERT	12.3	10.8	8.9	9.9	11.0	9.9	10.6	12.7	11.5	12.1	10.5	7.8	9.8	12.1	10.7	9.8	8.7	10.5
LEWJAIN	12.3	11.1	10.2	10.7	11.4	10.5	11.5	12.3	11.7	12.5	10.7	8.4	9.5	12.6	11.8	10.9	8.4	11.0
MACVICAR	12.8	11.1	9.1	10.6	10.8	10.2	10.4	12.8	11.1	12.7	11.4	8.5	9.9	11.4	11.1	9.9	8.1	10.7
MADSEN	13.7	12.0	9.0	10.1	10.8	10.8	10.3	12.8	11.2	12.0	12.2	8.8	11.5	11.8	11.5	10.5	8.6	11.0
MADSEN .75X#/A	13.7	10.8	10.2	10.4	10.8	10.8	10.4	13.2	11.8	12.2	12.0	8.6	11.7	12.0	11.9	9.9	8.6	11.1
MADSEN 1.5X#/A	12.3	10.8	8.3	10.1	10.6	10.8	10.9	13.3	11.5	11.8	11.2	8.1	10.5	11.4	11.4	10.4	8.7	10.7
MADSEN-ROD	12.1	11.0	8.9	10.1	10.6	10.4	10.5	12.6	11.1	11.5	10.8	8.2	10.9	12.1	11.4	9.8	8.0	10.6
MADSEN-STEPHENS	12.6	11.3	9.5	10.8	11.2	10.7	10.3	13.1	11.3	12.2	11.2	8.2	11.1	12.7	11.4	10.0	8.3	10.9
MJ-4	13.0	11.3	9.0	10.3	10.9	10.5	11.6	11.9	11.3	11.2	11.2	7.4	10.0	11.8	11.4	10.0	8.7	10.7
OR939528	13.2	11.4	9.2	10.8	10.9	10.5	11.2	12.8	11.8	12.3	11.8	8.5	10.6	12.1	11.5	10.1	8.5	11.0
Q. HYBRID 7817	11.5	10.2	7.9	10.4	10.7	10.4	10.5	11.4	11.2	11.8	10.6	7.3	9.6	11.4	10.9	9.8	9.0	10.3
Q. HYBRID 95021	12.9	11.6	10.0	11.4	11.6	10.4	10.8	12.1	11.5	11.9	12.8	9.7	11.8	11.8	11.6	9.6	8.5	11.2
ROD	12.0	9.9	7.9	9.4	10.8	10.4	10.9	11.7	10.8	11.4	10.1	7.7	10.2	11.5	11.0	9.4	8.2	10.2
STEPHENS	12.9	9.8	9.2	10.3	10.9	10.4	11.5	12.7	12.0	12.4	12.5	8.2	11.4	13.0	11.4	9.9	8.7	11.0
WA7813	13.2	12.1	8.5	10.0	11.4	10.7	10.8	13.0	11.8	11.9	11.0	8.6	11.8	12.6	11.4	10.2	8.5	11.0
WA7832	13.0	11.5	9.5	10.8	11.4	10.9	11.0	13.8	12.4	12.4	11.3	7.6	10.6	13.0	11.3	10.7	9.5	11.2
WA7853	12.4	10.6	8.6	10.3	11.2	10.7	10.2	11.5	11.0	11.6	10.5	8.0	10.8	12.5	11.2	9.6	8.4	10.6
WA7870	11.8	11.0	8.6	9.3	10.8	10.5	10.4	11.9	11.2	11.8	10.7	7.4	10.4	11.6	10.6	9.8	8.1	10.4
WEATHERFORD	13.6	11.4	8.9	11.3	11.3	10.9	10.6	12.6	11.9	12.1	12.2	8.2	11.9	13.0	12.0	10.3	8.9	11.2
WESTBRED 470	12.5	12.9	9.9	11.7	12.4	11.3	12.3	14.7	11.9	12.7	11.1	9.3	11.8	12.8	13.0	10.5	9.1	11.7
Soft White Club																		
CODA	12.9	10.5	9.1	10.5	10.6	10.1	11.0	13.3	11.2	11.6	11.1	8.2	10.8	12.1	11.9	9.5	8.9	10.8
HILLER	11.2	10.3	8.1	9.2	10.1	9.4	10.1	11.7	11.3	11.4	9.8	7.0	10.5	11.9	10.2	9.4	8.2	10.0
RELY	11.5	10.6	8.6	9.3	11.0	9.7	10.1	11.9	10.9	11.6	10.1	7.7	10.3	11.9	10.8	9.3	8.2	10.2
ROHDE	12.4	11.7	9.3	10.9	11.2	10.3	11.0	13.1	12.1	11.7	11.2	7.8	11.4	12.8	11.2	10.2	9.0	11.0
TEMPLE	12.3	10.5	8.1	9.4	11.3	9.6	11.2	12.9	11.3	11.7	9.8	8.4	10.8	12.1	10.8	9.8	8.5	10.5
Hard Red Common																		
ESTICA	12.2	10.1	9.0	10.5	12.0	11.1	10.0	11.9	10.7	12.3	11.7	8.1	10.2	11.9	11.3	10.2	9.3	10.7
NURSERY MEAN	12.6	11.0	9.0	10.3	11.0	10.5	10.8	12.6	11.4	11.9	11.1	8.2	10.8	12.3	11.4	9.9	8.6	10.8
LSD @ .10	0.8	1.2	1.2	0.6	0.5	0.3	1.0	0.6	0.5	0.6	0.8	0.7	1.1	0.9	0.5	0.7	0.6	0.2
CV %	5.3	8.0	11.0	5.2	3.6	2.1	7.3	3.8	4.0	4.0	6.2	7.2	8.5	5.3	3.4	5.9	5.7	5.9

1999 WSU HARD RED WINTER WHEAT VARIETY TRIAL SUMMARY

October 29, 1999

YIELD (BU/A)

VARIETY NAME	HORSE HEAVEN	CONNELL	BICKLETON	COULEE CITY	DUSTY	PULLMAN LATE	VARIETY MEAN
Hard Red Common							
BLIZZARD	16.0	34.8	50.2	56.7	74.8	83.1	54.2
BOUNDARY	16.6	21.2	60.2	63.2	82.5	92.4	57.7
BUCHANAN	21.2	27.8	54.2	54.6	70.8	80.6	52.8
ESTICA	16.5	22.8	48.0	47.3	89.0	106.1	56.6
FINLEY	23.4	37.1	49.3	54.0	69.5	77.3	53.0
HARD 13	20.9	31.5	51.4	63.2	75.0	87.3	56.4
HARD 5	19.0	19.9	38.9	39.9	66.2	84.8	45.9
HATTON	22.2	34.0	55.0	54.1	83.5	74.5	55.3
N9500603	18.4	27.3	52.8	65.1	92.9	110.5	63.0
N9502901	17.2	20.3	48.1	47.5	71.2	74.6	47.8
N9504001	18.3	23.1	55.7	42.4	67.2	85.9	50.1
N9504301	16.8	27.5	60.9	52.6	84.9	84.4	56.1
N9504306	18.5	24.4	63.1	57.6	80.5	89.5	57.2
N9602702	20.5	33.4	50.4	60.6	67.0	92.7	55.6
Q. HYB. 542	20.0	34.2	54.6	61.9	86.7	98.1	61.0
Q. HYB. 7424	17.2	20.0	49.2	50.3	72.5	112.6	55.2
Q. HYB. 7510	16.2	20.2	48.2	50.8	78.9	106.6	55.1
SYMPHONY	12.5	27.0	49.8	57.2	91.5	101.7	58.5
TX91D-6913	10.5	16.8	38.3	52.4	74.9	94.0	49.4
WA7868	18.4	29.8	52.4	59.3	81.7	90.5	57.0
WA7869	23.2	27.0	51.8	55.1	63.2	83.5	51.8
WANSER	17.7	26.6	49.5	49.2	65.7	77.1	48.9
WESTON	16.3	24.6	49.6	52.5	68.9	70.9	48.5
WPB 703	10.1	15.6	36.6	25.4	62.7	56.9	35.6
Soft White Common							
ELTAN	20.3	30.4	47.9	66.8	95.8	99.6	61.9
NURSERY MEAN	17.9	26.3	50.6	53.6	76.7	88.6	53.8
LSD @ .10	6.1	5.1	12.5	6.7	12.6	6.9	3.7
CV %	24.7	16.0	20.9	10.6	13.9	6.6	14.1

1999 WSU HARD RED WINTER WHEAT VARIETY TRIAL SUMMARY

October 29, 1999

TEST WEIGHT (LB/BU)

VARIETY NAME	HORSE HEAVEN	CONNELL	BICKLETON	COULEE CITY	DUSTY	PULLMAN LATE	VARIETY MEAN
Hard Red Common							
BLIZZARD	62.5	61.2	61.9	63.9	60.4	59.2	61.4
BOUNDARY	58.9	58.2	60.9	62.5	60.2	60.1	60.6
BUCHANAN	62.3	60.6	59.6	62.8	59.3	58.5	60.2
ESTICA	52.9	53.5	55.9	56.9	54.8	55.5	55.5
FINLEY	62.7	62.2	62.1	64.2	61.8	60.3	62.1
HARD 13	58.8	60.3	62.3	63.9	60.1	59.4	61.2
HARD 5	61.7	59.4	62.1	62.3	60.4	59.6	61.0
HATTON	64.4	61.9	63.8	64.5	62.3	60.8	62.9
N9500603	60.1	60.4	59.5	61.6	59.3	59.1	59.9
N9502901	60.5	59.2	59.9	63.1	60.3	60.8	60.9
N9504001	63.6	62.2	64.0	64.5	62.0	59.4	62.5
N9504301	61.0	60.5	62.3	63.9	60.6	60.0	61.6
N9504306	61.0	60.0	61.9	64.1	60.4	60.4	61.6
N9602702	60.3	61.2	61.7	63.0	59.9	60.6	61.3
Q. HYB. 542	62.0	61.1	62.4	62.9	60.9	60.4	61.7
Q. HYB. 7424	62.1	58.9	60.7	61.5	59.6	59.6	60.4
Q. HYB. 7510	62.7	61.0	62.9	62.7	60.2	60.4	61.6
SYMPHONY	56.6	57.2	60.4	61.5	60.3	59.3	60.0
TX91D-6913	61.2	58.7	61.3	61.6	60.7	59.6	60.7
WA7868	60.6	59.0	60.5	62.4	59.6	57.9	60.1
WA7869	60.5	60.1	61.2	62.4	58.7	58.2	60.2
WANSER	62.6	60.6	62.9	63.5	60.3	58.6	61.4
WESTON	62.5	61.8	61.8	64.1	61.6	61.5	62.2
WPB 703	57.4	59.1	59.5	58.9	59.1	58.3	58.9
Soft White Common							
ELTAN	61.5	59.9	60.0	62.1	58.9	59.1	60.1
NURSERY MEAN	60.8	59.9	61.3	62.6	60.1	59.5	60.8
LSD @ .10	*	*	1.0	0.7	0.9	0.6	0.4
CV %	*	*	1.3	1.0	1.2	0.8	1.1

1999 WSU HARD RED WINTER WHEAT VARIETY TRIAL SUMMARY

October 29, 1999

PROTEIN (%)

VARIETY NAME	HORSE HEAVEN	CONNELL	BICKLETON	COULEE CITY	DUSTY	PULLMAN LATE	VARIETY MEAN
Hard Red Common							
BLIZZARD	13.4	12.7	9.1	11.4	12.7	12.0	11.5
BOUNDARY	13.4	13.4	7.7	11.0	12.5	11.2	10.9
BUCHANAN	12.1	12.8	7.5	10.9	11.7	10.7	10.5
ESTICA	13.3	12.5	7.8	10.6	10.9	10.4	10.3
FINLEY	12.8	13.2	8.5	10.7	11.9	11.8	11.0
HARD 13	13.3	12.4	9.1	11.0	12.3	10.8	11.1
HARD 5	14.7	14.4	9.7	14.0	14.9	12.2	12.9
HATTON	12.3	13.5	8.5	11.6	12.4	11.8	11.3
N9500603	12.6	12.7	8.5	10.9	11.9	11.0	10.8
N9502901	13.0	13.8	8.4	12.2	12.3	11.6	11.4
N9504001	13.6	14.6	8.0	12.7	11.9	11.3	11.3
N9504301	13.2	12.4	7.8	11.2	11.2	11.2	10.6
N9504306	13.1	12.4	7.2	10.7	11.9	11.2	10.6
N9602702	12.7	11.2	7.5	11.3	11.5	10.6	10.4
Q. HYB. 542	13.6	13.0	9.7	11.6	12.7	11.2	11.5
Q. HYB. 7424	13.9	13.3	8.8	11.2	12.0	10.8	11.0
Q. HYB. 7510	14.9	15.3	8.8	12.4	13.7	11.2	11.9
SYMPHONY	14.3	14.1	9.6	11.4	11.6	11.5	11.4
TX91D-6913	14.4	14.8	9.1	11.4	12.8	10.2	11.3
WA7868	13.0	12.3	7.4	11.0	12.4	11.3	10.8
WA7869	12.1	13.1	8.7	11.8	13.2	11.4	11.4
WANSER	13.2	13.7	9.0	11.9	12.1	11.5	11.4
WESTON	14.7	14.5	8.4	12.1	13.9	12.8	12.1
WPB 703	15.7	14.8	11.5	14.1	13.8	13.7	13.5
Soft White Common							
ELTAN	14.2	13.9	8.2	10.7	10.6	10.8	10.5
NURSERY MEAN	13.5	13.4	8.6	11.6	12.4	11.4	11.3
LSD @ .10	*	*	12.0	0.9	1.0	0.4	0.4
CV %	*	*	11.7	6.7	6.8	3.0	6.9

Spring Wheat Breeding and Genetics

K. Kidwell, G. Shelton, V. DeMacon, B. Barrett, J. Smith and M. Bayram

The overall goal of wheat breeding efforts at WSU is to enhance the economic and environmental health of wheat production in the Pacific Northwest by releasing genetically superior varieties for commercial production. Traditional breeding methods and molecular genetic technologies are combined to improve the efficiency and effectiveness of variety improvement efforts. Progress has been made towards developing DNA tags for genes associated with Russian wheat aphid resistance, spring growth habit (*Vrn*-B1) and a chromosomal segment from *Triticum diccoides* that is associated with a 1 to 2 % increase in grain protein content. Research efforts to identify potential gene donors for Rhizoctonia resistance among *T. tauschii* accessions and other wild relatives of wheat have been initiated.

Variety Development

Over 500 crosses were made in 1999, and more than 30,000 soft white, hard red, hard white or spring club experimental breeding lines and released varieties were evaluated in field trials at 1 to 15 locations in Eastern Washington, depending on seed availability. F_1 seed from 508 lines was increased to generate segregating progenies for use in conventional breeding strategies, marker-assisted selection and gene linkage analyses. Approximately 288 F_2 and 368 F_3 families were advanced to the next generation, and 3,243 entries among 29,170 F_4 and 1,010 F_5 head rows were selected, based on stripe rust reaction and phenotype, for early generation end-use quality assessment. Following phenotypic selection, grain from selected head rows (2,834) was visually evaluated for plumpness. Selections with sound grain were separated by market class, and then entries from each market class were subjected to a specific assessment strategies depending on end-use goals. Grain protein content and grain hardness was determined on whole grain flour using the Technicon (NIR). Microsedimentation (microsed) and flour swelling volume (FSV) were used to assess protein and starch quality, respectively, of selected lines. Polyphenol oxidase levels also were determined for soft white and hard white material to assess noodle color potential before selecting lines to advanced to 2000 field trials. Grain samples from 812 experimental lines with superior agronomic performance were sent to the USDA-ARS Western Wheat Quality Laboratory (Pullman, WA) for milling and baking evaluations.

Hessian Fly (HF) Resistance

Six novel (H5, H11, H13, H22, H25, H26) HF resistance genes have been transferred into adapted spring wheat germplasm. Following field evaluation of 127 resistant lines in single plot yield trials in Pullman in 1999, 76 (20 soft; 56 hard) high yielding lines were submitted to the WWQL for end-use quality assessment. Entries with superior end-use quality will be evaluated in replicated, multi-location yield trials in 2000.

Russian Wheat Aphid (RWA)

Five unique RWA resistance genes have been incorporated into elite spring wheat germplasm from the PNW. Over 600 resistant head rows were evaluated in the field in Pullman in 1999. Based on phenotypic selection for plant type, maturity and stripe rust reaction, 115 were selected for advancement to single plot yield trials in the year 2000.

Hard White

All hard white breeding material was prescreened for protein quality, starch quality and noodle color potential prior to field evaluation. Fifty-one advanced lines were evaluated in replicated, multi-location field trials in 1999. Three high yielding lines (WA7899 (HW000021), WA7900 (HW000034), WA7901 (HW000098)) were sent to New Zealand in September, 1999 for preliminary increases to generate enough seed to: a) enter lines into multi-location variety testing and breeding nurseries in 2000; b) conduct strip trials in high and low rainfall zones to obtain enough grain for large scale end-use quality assessment by the Wheat Marketing Center in 2000; and c) initiate the certified seed increase process. All of these lines have superior milling, baking and noodle color properties compared to Idaho377s. WA7899 is resistant to the Hessian fly.

Spring Club

Nine advanced generation spring club lines were evaluated in replicated field trials in 1999. All spring club material was pre-selected for protein quality and head type prior to yield testing. Two of these lines (WA7902 (S9700431) and WA7903 (S9700459)), both intermediate in height) have outstanding grain yield potential and end-use quality properties compared to Calorwa. S97000431 also is early maturing and is resistant to stripe rust. Both lines will be evaluated in breeding and variety testing trails in 2000, and the best entry of the two will be proposed for variety release in 2001. Thirteen advanced tall club lines with potential for variety release also will be tested in multi-location, replicated field trials in 2000.

Variety Releases

Scarlet

Registered seed of 'Scarlet' hard red spring wheat will be increased during the 2000 crop year, therefore, certified seed will be available for commercial production in 2001. Although this variety was specifically released for the semi-arid region as a replacement for 'Butte 86' based on its superior yield potential, Scarlet has responded well in fertility trials conducted by S. Reinertsen and B. Palmer at the McGregor Research Station in Mockonema, WA. The target production region for Scarlet may expand into the intermediate rainfall zone if appropriate fertility management strategies are used to maximize yield potential and grain protein content.

Zak

The soft white experimental line, WA7850, named 'Zak', was approved for variety release as the Wawawai and/or Alpowa replacement. Zak has excellent grain yield potential and its end-use quality properties are outstanding. It is stripe rust resistant, and has been rated as tolerant to the Hessian fly. Although Zak's test weight is lower than those of Alpowa and Wawawai are, it has a significantly higher test weight than Vanna and Edwall. Foundation seed of Zak will be produced in 2000. Nabisco has expressed an interest in using Zak in their Portland, OR facility.

Tara

The experimental line, WA7824, tentatively named 'Tara' was approved for variety release as the replacement for Westbred 926. Tara is a high yielding, Hessian fly resistant line with exceptional gluten strength. This variety is well adapted to production in direct seed systems. Breeder's seed of Tara will be produced in 2000. Pendleton Flour Mills and Fisher Mills have expressed an interest in using Tara on an identify preserved basis.

Marker-Assisted Backcross (MAB) Breeding to Increase Grain Protein Content

A rapid plant advancement protocol was developed by which plants are forced to go from seed to seed within a 10 to 12 week period in the greenhouse. This allows us to advance progeny of a single cross through 4 to 5 generations per year, which greatly accelerates the breeding process. A DNA marker associated with gene that confers a 1-2% grain protein content (GPC) increase was identified, and then a strategy was developed to rapidly move this gene into adapted germplasm through MAB breeding. Initial crosses between the protein segment donor parents and the adapted hard red varieties Scarlet and Tara were made in 1998. The goal is to recover lines nearly identical to Scarlet and Tara with the addition of the increased GPC segment from the donor parents. BC_4 lines containing 97% of the genes from the WSU lines and 3% of the genes from the donor parents, including the high protein segment, have been developed using this strategy. Initial field evaluations of these materials will begin in 2000.

Gene Discovery

Rhizoctonia root rot, caused by *R. solani* AG-8, is a prominent disease of spring cereal grains in direct seed management systems. To date, genetic resistance to this disease has not been identified in cultivated wheat or barley. The objectives of this study are to: 1) determine whether current spring wheat and spring barley cultivars vary in their levels of susceptibility to *R. solani* AG-8; and 2) to identify potential gene donors among wild relatives of wheat for use in cultivar improvement. Fifteen spring wheat cultivars, twelve spring barley cultivars, ten *Dasypyrum villosum* accessions, *D. villosum*/durum amphiploids, *Agropyron* amphiploids, and *D. villosum* addition lines were evaluated for disease reaction to *R. solani* AG-8 in growth chamber analyses. Although variation in disease reaction was detected, all current spring wheat and spring barley varieties are susceptible to Rhizoctonia root rot. However, *D. villosum* appears to be a viable source of genetic resistance to R. solani AG-8.

Gene Tagging

Wheat microsatellite and AFLP markers linked within 1.1 to 20.6 cM of the spring growth-habit gene *Vrn*-B1 were identified in reciprocal mapping populations generated by crossing near-isogenic lines carrying the recessive winter (*vrn*-B1) and dominant spring (*Vrn*-B1) growth habit alleles. This demonstrates the effectiveness of using these types of populations to identify DNA markers closely associated with genes of interest. These DNA tags will be used in marker-assisted selection strategies to combine *Vrn*-B1 with other spring growth habit genes into single varieties in an attempt to enhance grain yield potential.

1999 Variety Testing Program - Spring Wheat

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Overview

The 1999 state spring wheat trial consisted of 39 varieties grown in 15 trials at a total of 14 locations. Varieties consisted of 17 soft white common, 1 soft white club, 17 hard red common, and 4 hard white common wheats. Both a summer fallow and annual cropping trial were grown at Lind. Trials at Fairfield, Pullman, Pomeroy, Ritzville, Lind, and Royal Slope were grown cooperatively with the spring wheat breeding program. The trial at Royal Slope was irrigated, and the remaining trials were dryland. Ten additional varieties were grown at the irrigated Royal Slope site. With the exception of varieties grown at Horse Heaven and Connell, hard red and hard white varieties received additional post-emergence fertility to more closely match the practices of growers attempting to achieve higher grain protein in these market classes.

Growing Conditions

All trials were planted in a timely manner into soil moisture that was generally adequate. Cooler than average soil temperatures delayed emergence and growth at many sites. Precipitation during March, April, and May was generally well below average. For example, precipitation at Pullman during these three months was 3.3 inches below average. The lack of moisture reduced yields at most locations. At some locations, lack of spring rainfall may have reduced the movement of surface-applied nitrogen fertilizer into the soil profile. Damage due to diseases and Hessian fly was minimal in 1999.

Results

Grain yield, test weight, and protein of the varieties in the trials are presented in the following tables. Across all locations, ID526 was the highest yielding soft white variety, Spillman the highest yielding hard red variety, and ID377S the highest yielding hard white variety. Test weights were generally acceptable in 1999, although moisture stress reduced test weight at some locations. Average test weight across locations was 60.8 lbs/bu. With the exception of the unadapted variety Kulm, highest protein of hard red spring varieties was achieved by Conan and Laura, both with proteins of 14.0 %

Acknowledgments

This work was made possible by funding provided by the Washington Wheat Commission, WSU College of Agriculture and Home Economics, Washington State Crop Improvement Association, fees paid by private companies, and the generous contribution of cooperators who provided land and other assistance required to grow these trials.

1999 WSU SPRING WHEAT VARIETY TRIAL SUMMARY

October 28, 1999

YIELD (BU/A)

VARIETY NAME	BICKLETON	HORSE HEAVEN	LIND ANNUAL	POMEROY	LIND FALLOW	DAYTON	RITZVILLE	DUSTY	LAMONT	REARDAN	FAIRFIELD	ST. JOHN	FARMINGTON	PULLMAN	ROYAL SLOPE	VARIETY MEAN
Soft White Common																
ALPOWA	11.1	20.6	21.4	26.4	27.1	31.5	45.7	44.6	55.2	68.9	80.9	87.5	79.9	90.7	136.5	55.2
BZ 692-108	8.6	18.7	19.8	25.8	30.5	35.5	48.3	47.0	64.4	70.1	79.5	84.4	80.8	90.5	131.5	55.7
EDWALL	14.5	17.6	22.8	23.5	29.2	33.0	46.9	45.9	57.4	72.1	79.8	85.9	86.2	88.7	123.2	55.1
FIELDER	14.3	18.9	21.3	25.7	26.4	35.7	42.5	40.6	59.9	67.1	71.1	79.8	74.2	81.7	117.0	51.7
ID506	11.5	19.3	23.7	23.8	25.8	39.7	41.1	40.8	59.9	67.8	71.5	79.3	77.4	88.8	130.3	53.4
ID525	13.1	18.7	18.5	20.1	25.5	40.6	43.2	38.2	54.7	64.6	67.7	71.7	77.1	84.6	118.6	50.5
ID526	10.9	19.3	21.7	22.8	31.9	42.9	49.5	48.8	62.0	74.3	78.4	86.9	82.9	95.5	121.8	56.6
ML037,(C6-2)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	134.3	134.3
OR942845	10.4	17.3	21.2	18.1	27.0	41.3	41.2	38.8	60.0	70.9	71.7	79.3	79.7	88.3	114.9	52.0
PENAWAWA	13.3	16.6	22.4	19.4	26.6	36.3	40.9	38.8	57.2	69.7	70.3	80.8	82.4	81.5	125.5	52.1
VANNA	10.2	18.4	23.6	27.7	28.9	40.3	47.3	45.0	61.7	67.7	78.8	82.4	78.3	86.3	129.6	55.1
WA7850	9.0	21.0	23.2	20.0	28.8	38.6	45.1	43.6	59.5	71.6	81.1	79.9	86.4	90.5	134.5	55.5
WA7863	8.4	18.6	20.3	19.6	26.4	32.8	44.1	39.3	58.5	70.1	80.8	84.7	78.3	88.2	122.9	52.9
WA7864	10.7	16.9	22.5	23.1	27.5	33.0	42.3	44.4	63.4	68.7	75.3	77.7	86.3	90.2	108.1	52.7
WA7867	11.9	22.1	22.8	27.9	28.9	37.0	43.0	42.7	62.4	73.3	73.5	79.1	83.4	88.9	119.4	54.4
WA7877	13.0	17.7	24.6	22.8	26.8	41.7	42.0	45.3	66.4	73.2	79.5	76.2	88.9	89.5	129.4	55.8
WAKANZ	12.4	20.9	22.7	21.6	26.4	40.6	44.8	42.7	61.7	67.2	83.4	86.9	77.1	90.6	134.8	55.6
WAWAWAI	11.7	18.7	22.8	27.2	26.4	37.6	44.1	42.3	54.3	70.6	80.8	80.3	88.2	88.2	127.5	54.7
Soft White Club																
CALORWA	9.3	16.6	23.5	24.7	28.0	36.5	42.9	37.6	50.6	67.5	68.9	77.1	77.2	84.4	103.5	49.9
Hard Red Common																
96W51402	.	.	.	.	.	.	.	.	.	.	.	.	.	.	126.4	126.4
96W51505	.	.	.	.	.	.	.	.	.	.	.	.	.	.	118.3	118.3
BONUS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	117.2	117.2
BUTTE 86	8.0	19.3	18.3	21.7	20.4	37.6	31.8	40.3	48.8	53.0	48.4	69.1	73.3	69.3	111.5	44.7
BZ 992-322	15.7	18.3	18.2	23.4	24.1	44.6	38.8	43.1	61.4	64.4	65.3	75.8	83.4	84.7	126.6	52.5
CONAN	10.6	18.3	17.2	16.7	19.2	36.9	31.0	34.7	44.4	53.6	54.9	64.4	68.3	62.9	106.9	42.7
EXPRESS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	123.3	123.3
JEFFERSON	11.1	18.8	21.2	22.5	25.1	41.2	35.1	44.4	58.8	63.9	65.9	82.0	77.4	78.4	130.4	51.8
KULM	6.9	18.2	15.6	21.5	19.5	35.3	30.3	35.9	42.9	51.1	46.3	66.2	71.0	70.4	104.6	42.4
LAURA	11.4	16.8	14.8	18.1	20.4	34.4	32.0	37.5	50.3	53.8	58.9	62.7	67.0	68.7	105.4	43.5
NW#10	12.9	14.1	14.6	17.6	18.4	33.7	31.4	40.9	53.8	63.7	65.7	68.5	72.1	77.8	118.3	46.9
SCARLET	10.0	20.7	19.9	17.4	24.0	38.6	39.3	47.2	62.9	63.4	75.2	76.7	77.0	79.6	137.8	52.6
SPILLMAN	15.4	20.9	21.3	16.0	26.0	39.1	41.1	45.3	62.5	63.4	77.0	76.1	77.9	82.5	131.7	53.1
STANDER	.	.	.	.	.	.	.	.	.	.	.	.	.	.	116.5	116.5
WA7824	11.1	17.6	17.0	17.9	23.5	42.1	38.0	43.1	47.7	66.9	72.0	77.5	82.9	79.6	129.0	51.1
WA7839	12.9	17.6	18.1	21.4	23.8	40.6	31.8	40.0	50.1	55.8	68.2	77.7	79.2	81.0	124.4	49.5
WA7841	14.2	19.2	17.6	18.3	24.1	40.6	33.2	41.8	53.8	59.0	67.8	71.4	75.5	77.7	129.7	49.6
WA7859	13.1	19.3	19.2	20.4	22.8	36.7	33.4	43.8	57.0	54.6	68.7	71.5	75.1	78.0	122.7	49.1
WA7860	10.8	19.4	18.3	19.6	24.2	33.1	34.5	41.0	51.9	60.3	69.5	77.3	80.2	82.5	115.1	49.2
WA7872	10.1	16.9	19.0	21.8	22.3	39.8	35.4	38.5	47.0	61.6	60.2	72.4	82.4	75.3	123.8	48.4
WPB 926	11.4	18.2	17.4	21.9	22.5	38.7	33.2	43.4	48.8	53.3	63.9	74.7	78.0	81.1	120.1	48.4
ZEKE	12.1	18.5	19.2	23.0	23.8	39.3	35.1	42.6	47.4	56.0	56.1	76.0	84.7	87.4	141.3	50.8
Spring Durum																
KRONOS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	96.7	96.7
NPB871104E	.	.	.	.	.	.	.	.	.	.	.	.	.	.	139.0	139.0
Hard White Common																
ID377S	18.6	19.6	22.6	25.7	26.7	43.5	41.3	54.7	67.2	70.5	81.7	81.4	84.5	87.7	130.4	57.1
ID533	13.7	20.9	22.2	23.0	25.9	42.8	42.1	45.4	64.4	69.5	78.2	80.4	88.5	87.1	124.4	55.2
ML107-184(2)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	126.4	126.4
ML107-2-25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	122.6	122.6
ML107455	13.2	20.1	19.7	21.0	25.7	41.3	37.5	45.5	66.3	69.1	76.2	79.7	79.9	80.2	135.2	54.0
WINSOME	12.7	18.7	19.8	24.7	27.5	44.3	37.4	48.6	69.3	62.2	75.7	83.5	75.6	86.1	133.2	54.6
NURSERY MEAN	11.8	18.7	20.3	21.9	25.3	38.4	39.4	42.7	57.1	64.7	71.0	77.6	79.4	83.2	123.5	52.9
CV %	4.3	2.4	3.3	3.4	2.6	3.3	3.8	5.6	4.3	5.7	6.0	6.2	5.9	5.6	12.0	2.8
LSD @ .10	31.4	11.0	13.8	13.4	8.9	7.3	8.3	11.1	6.4	7.5	7.2	6.9	6.4	5.7	8.3	9.1

1999 WSU SPRING WHEAT VARIETY TRIAL SUMMARY

October 28, 1999

TEST WEIGHT (LBS/BU)

VARIETY NAME	BICKLETON	HORSE HEAVEN	LIND ANNUAL	POMEROY	LIND FALLOW	DAYTON	RITZVILLE	DUSTY	LAMONT	REARDAN	FAIRFIELD	ST. JOHN	FARMINGTON	PULLMAN	ROYAL SLOPE	VARIETY MEAN
Soft White Common																
ALPOWA	57.3	57.8	62.5	56.6	64.0	59.5	60.9	62.5	61.2	62.3	62.9	61.5	59.5	61.8	65.0	61.8
BZ 692-108	56.4	57.4	61.9	55.3	62.2	58.5	59.8	60.4	60.5	61.1	61.8	60.2	58.0	60.9	63.5	60.5
EDWALL	56.4	56.5	60.6	54.5	61.3	57.3	58.7	59.6	59.6	59.4	60.4	58.5	55.2	57.3	61.8	59.0
FIELDER	57.3	57.3	62.0	56.6	62.7	59.9	59.7	60.7	60.5	61.4	62.0	59.8	57.8	59.5	63.7	60.6
ID506	56.3	57.5	62.6	57.8	63.1	59.2	61.3	61.5	60.0	60.5	62.2	58.6	57.9	60.7	62.8	60.6
ID525	57.4	57.8	62.7	55.3	63.3	60.8	60.7	60.9	61.6	61.1	63.0	60.9	58.2	61.0	64.4	61.3
ID526	56.3	59.1	62.1	56.0	62.5	59.6	60.4	60.6	60.4	61.0	61.3	60.2	58.5	61.3	63.8	60.8
ML037,(C6-2)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	63.7	63.7
OR942845	58.6	59.1	62.6	56.2	63.7	60.6	59.2	61.6	60.8	61.9	62.3	61.0	58.6	62.0	63.9	61.4
PENAWAWA	58.2	57.1	61.1	55.1	63.1	59.2	61.0	61.5	61.4	61.8	62.3	60.4	58.6	60.3	64.3	61.0
VANNA	55.3	56.9	61.2	55.5	62.9	59.6	60.5	60.8	60.2	61.1	62.0	59.0	56.8	59.9	63.7	60.4
WA7850	55.6	59.6	62.3	55.0	62.6	59.9	60.7	60.4	60.4	61.1	61.8	60.4	59.0	61.2	63.5	60.9
WA7863	59.0	60.1	61.3	56.4	62.6	58.3	59.8	61.2	60.2	60.5	61.7	60.4	58.4	60.8	62.9	60.6
WA7864	55.7	59.2	60.7	54.4	62.7	57.5	59.4	61.8	60.4	61.4	61.9	59.8	58.4	60.6	63.2	60.5
WA7867	57.0	57.8	61.6	57.0	62.4	57.5	59.6	60.2	59.8	60.8	60.8	59.3	58.1	60.6	61.9	60.1
WA7877	58.8	59.8	61.2	56.1	62.5	59.3	61.8	61.6	60.4	61.0	61.6	59.1	58.0	60.7	63.6	60.7
WAKANZ	56.7	56.0	61.5	54.7	62.7	59.0	58.5	60.8	59.8	60.8	61.6	59.4	58.1	60.8	64.1	60.4
WAWAWAI	58.1	56.5	61.8	58.7	62.8	60.7	61.1	62.2	61.9	62.5	62.7	61.6	60.4	61.7	64.5	61.8
Soft White Club																
CALORWA	57.0	60.2	62.1	53.7	63.2	57.5	62.1	61.5	60.3	61.5	61.3	60.5	57.9	60.3	62.6	60.6
Hard Red Common																
96W51402	.	.	.	.	.	.	.	.	.	.	.	.	.	.	65.0	65.0
96W51505	.	.	.	.	.	.	.	.	.	.	.	.	.	.	65.4	65.4
BONUS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	61.8	61.8
BUTTE 86	58.2	60.1	62.8	56.5	63.1	60.9	62.2	61.6	61.1	61.2	61.4	59.5	59.2	60.3	64.9	61.3
BZ 992-322	54.8	56.1	61.7	55.3	62.5	60.0	60.9	60.9	60.5	61.1	61.2	58.6	56.8	58.9	62.9	60.2
CONAN	58.5	59.6	62.7	55.3	62.4	60.8	59.7	61.2	60.1	60.6	61.7	59.2	57.5	59.3	64.1	60.7
EXPRESS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	64.3	64.3
JEFFERSON	58.8	59.4	62.1	55.9	63.4	60.9	61.1	61.8	61.0	61.7	62.4	59.4	58.2	60.1	64.3	61.2
KULM	57.2	56.7	62.5	58.0	63.0	61.5	60.7	62.6	61.5	62.3	62.1	60.6	61.0	62.2	65.1	61.9
LAURA	58.1	58.4	62.0	58.3	62.2	60.5	60.6	61.7	60.5	60.7	61.5	59.6	59.7	60.7	64.5	61.1
NW#10	54.6	57.3	58.9	53.5	59.4	57.8	58.8	59.1	58.4	58.4	59.6	56.5	52.2	55.6	60.1	57.7
SCARLET	56.4	59.2	61.4	56.5	62.3	60.2	61.3	61.3	60.2	61.1	61.2	58.4	57.2	59.6	64.3	60.5
SPILLMAN	58.6	57.4	60.6	58.1	62.5	59.4	60.7	60.9	59.6	60.0	61.3	58.9	55.5	58.8	63.5	60.0
STANDER	.	.	.	.	.	.	.	.	.	.	.	.	.	.	63.5	63.5
WA7824	56.7	58.3	60.6	55.7	61.9	60.2	61.9	61.7	60.3	62.0	61.7	59.6	58.9	59.6	63.9	60.7
WA7839	56.4	59.1	62.0	57.4	62.6	60.9	62.0	61.9	60.7	61.5	62.6	59.7	57.9	59.6	63.7	61.0
WA7841	57.0	55.5	61.7	55.9	62.6	59.5	60.5	60.6	59.7	59.8	61.3	58.5	56.0	58.5	62.7	59.9
WA7859	55.8	60.1	61.0	55.8	62.6	61.0	61.3	60.6	60.7	61.1	61.9	59.3	58.4	59.3	64.7	60.7
WA7860	55.9	57.2	60.7	56.7	62.1	59.9	62.1	62.5	60.7	61.9	62.2	59.9	59.5	59.7	64.8	61.0
WA7872	55.7	56.9	62.4	57.3	63.0	60.9	61.3	61.6	60.8	61.4	61.6	59.6	58.5	60.0	64.3	61.0
WPB 926	56.3	59.2	62.2	54.4	62.3	60.3	60.6	61.2	60.1	61.1	61.8	59.4	56.9	59.2	62.8	60.4
ZEKE	56.9	59.1	60.6	55.7	61.4	59.0	60.6	61.5	59.8	61.1	61.1	59.3	58.6	59.8	64.1	60.4
Spring Durum																
KRONOS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	63.3	63.3
NPB871104E	.	.	.	.	.	.	.	.	.	.	.	.	.	.	64.1	64.1
Hard White Common																
ID377S	58.0	59.3	62.2	56.2	63.1	61.5	60.6	62.9	61.5	62.1	62.7	60.6	59.8	59.9	64.1	61.6
ID533	56.0	59.2	62.5	56.3	63.8	62.0	60.5	62.7	61.9	62.4	63.3	61.1	60.4	61.6	64.4	62.0
ML107-184(2)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	62.1	62.1
ML107-2-25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	62.9	62.9
ML107455	56.6	58.8	60.9	56.4	62.8	60.3	61.4	61.4	60.1	61.4	61.6	58.3	57.5	59.3	62.9	60.4
WINSOME	57.3	58.8	62.4	55.9	63.6	59.8	60.4	62.2	60.2	61.3	61.8	58.6	56.5	59.2	63.6	60.6
NURSERY MEAN	57.0	58.2	61.7	56.1	62.6	59.8	60.6	61.3	60.5	61.2	61.8	59.6	58.1	60.1	63.7	60.8
CV %	*	*	0.9	*	0.6	0.4	*	0.4	0.5	0.5	0.6	0.9	0.8	0.7	0.7	0.3
LSD @ .10	*	*	1.2	*	0.8	0.6	*	0.6	0.6	0.7	0.8	1.3	1.2	1.1	1.0	0.9

1999 WSU SPRING WHEAT VARIETY TRIAL SUMMARY

October 28, 1999

PROTEIN (%)

VARIETY NAME	BICKLETON	HORSE HEAVEN	LIND ANNUAL	POMEROY	LIND FALLOW	DAYTON	RITZVILLE	DUSTY	LAMONT	REARDAN	FAIRFIELD	ST. JOHN	FARMINGTON	PULLMAN	ROYAL SLOPE	VARIETY MEAN
Soft White Common																
ALPOWA	11.7	12.2	13.1	10.8	13.0	9.5	9.7	8.4	9.4	9.0	9.5	11.3	10.1	11.2	10.8	10.6
BZ 692-108	12.6	12.5	12.0	9.9	12.3	9.3	10.3	8.2	8.4	9.1	9.3	10.9	9.9	10.9	10.3	10.2
EDWALL	11.3	12.8	12.3	10.4	12.3	10.2	9.8	8.4	9.6	9.4	9.8	10.8	10.6	11.3	10.6	10.5
FIELDER	11.6	12.8	13.1	11.0	13.5	10.3	10.9	8.8	9.6	9.5	10.3	11.0	10.3	11.4	11.0	10.9
ID506	11.9	13.6	12.3	11.1	13.9	10.5	10.8	9.5	9.2	9.1	9.9	11.6	10.6	11.2	9.7	10.8
ID525	11.0	12.6	12.9	10.6	13.3	10.9	11.3	9.6	9.6	9.6	10.3	11.1	10.9	12.0	11.1	11.1
ID526	11.2	12.5	12.1	10.1	12.3	9.9	10.4	8.4	8.6	9.0	9.2	10.5	10.2	11.1	10.2	10.2
ML037,(C6-2)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11.0	11.0
OR942845	12.4	14.0	14.6	11.2	14.8	12.3	12.1	8.8	9.1	9.2	10.1	11.0	10.6	11.7	11.6	11.4
PENAWAWA	11.6	12.4	12.3	10.0	13.1	10.0	10.0	8.8	9.3	9.2	9.7	11.1	10.4	11.3	10.9	10.6
VANNA	11.8	13.4	12.5	9.7	13.5	10.4	10.6	8.0	8.5	8.6	9.5	10.9	9.7	11.0	10.6	10.4
WA7850	12.8	12.9	12.5	10.7	13.4	10.9	10.8	8.4	9.0	9.0	9.7	10.7	10.2	11.5	10.3	10.6
WA7863	12.1	14.5	12.9	10.9	13.4	10.2	11.1	9.1	9.6	9.2	9.6	11.1	10.5	11.8	11.0	10.9
WA7864	12.8	13.8	13.0	10.7	13.6	10.5	11.0	8.8	9.7	9.5	10.0	10.6	10.3	11.0	11.0	10.9
WA7867	13.1	13.1	12.3	10.8	12.2	10.4	10.6	8.7	9.5	9.0	9.6	10.2	10.4	10.9	10.7	10.5
WA7877	14.6	14.8	13.0	11.1	13.4	10.7	11.4	8.5	8.7	9.0	9.3	11.7	10.2	11.3	10.7	10.8
WAKANZ	12.6	12.8	11.9	10.6	13.2	10.0	10.1	8.7	9.0	9.4	10.2	11.9	10.2	11.8	10.4	10.7
WAWAWAI	11.9	12.7	13.1	10.5	13.8	10.8	11.5	9.6	10.0	10.0	10.5	11.0	10.7	11.7	11.0	11.2
Soft White Club																
CALORWA	14.0	14.3	12.3	10.6	12.5	9.8	11.4	9.3	12.0	9.6	10.2	11.3	10.3	11.1	10.7	11.0
Hard Red Common																
96W51402	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11.4	11.4
96W51505	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11.6	11.6
BONUS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12.1	12.1
BUTTE 86	11.6	15.2	14.7	13.2	15.3	12.5	11.7	10.2	13.3	12.4	14.3	14.3	14.3	15.3	14.3	13.7
BZ 992-322	14.0	16.9	15.1	12.6	15.1	12.6	11.4	11.0	13.1	11.6	13.1	13.3	13.0	14.2	12.2	13.2
CONAN	14.2	15.1	15.3	13.8	15.6	13.4	12.8	11.7	14.6	13.2	14.3	14.4	13.9	14.9	12.8	14.0
EXPRESS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12.3	12.3
JEFFERSON	14.9	13.5	15.1	13.9	15.2	12.1	11.4	10.4	12.6	11.8	12.9	13.2	13.0	14.3	12.0	13.0
KULM	13.1	15.4	16.1	14.2	16.3	12.7	13.0	11.0	14.7	13.9	15.1	14.4	14.2	15.8	15.6	14.5
LAURA	13.6	14.9	16.1	13.9	16.3	12.5	11.6	10.9	13.5	12.8	14.0	14.5	14.2	15.1	14.8	14.0
NW#10	11.6	13.5	16.4	14.2	16.5	13.7	12.6	9.8	12.7	11.6	13.1	12.9	13.4	14.4	12.4	13.3
SCARLET	13.8	15.1	14.9	13.6	15.6	11.8	10.9	9.9	13.0	10.9	12.6	13.3	13.2	14.0	12.3	12.9
SPILLMAN	13.9	15.6	14.4	12.5	15.1	11.9	10.6	10.3	11.8	11.4	12.5	12.4	12.4	14.2	12.1	12.6
STANDER	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11.2	11.2
WA7824	12.5	14.7	15.6	14.2	14.5	12.2	11.8	10.0	13.9	11.4	12.8	13.6	13.5	14.0	12.5	13.1
WA7839	13.2	13.3	15.2	13.5	15.1	12.3	12.0	10.9	14.0	12.9	12.9	13.2	13.2	14.4	12.0	13.3
WA7841	13.7	13.8	15.6	13.5	15.4	13.3	12.0	10.9	13.6	12.4	13.5	13.3	13.8	14.7	12.2	13.5
WA7859	12.4	13.9	14.7	12.6	15.0	11.4	11.7	9.8	13.9	12.8	13.2	13.4	13.9	15.2	12.8	13.2
WA7860	11.8	13.4	14.9	12.4	15.0	11.3	11.8	10.5	13.4	12.3	12.9	12.7	13.8	13.9	11.6	12.9
WA7872	12.6	14.2	15.6	13.5	15.8	12.7	12.5	9.9	14.6	12.7	13.7	13.3	14.0	15.0	12.9	13.6
WPB 926	13.0	15.2	15.7	14.1	15.4	12.1	11.9	10.9	14.8	13.2	13.4	13.8	13.6	14.0	12.8	13.6
ZEKE	14.7	15.5	15.1	13.2	15.3	12.2	12.4	10.5	14.7	12.4	13.7	13.3	12.6	13.3	12.1	13.3
Spring Durum																
KRONOS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	13.3	13.3
NPB871104E	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11.9	11.9
Hard White Common																
ID377S	13.7	15.4	14.1	13.6	14.7	11.4	11.2	9.3	11.5	10.3	11.0	11.7	11.7	13.3	11.4	12.0
ID533	13.6	14.8	13.9	13.2	14.5	11.5	10.7	9.2	11.2	10.6	11.6	11.5	11.9	12.9	10.6	11.9
ML107-184(2)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10.8	10.8
ML107-2-25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	10.6	10.6
ML107455	15.0	15.5	14.3	13.3	14.2	11.3	10.6	9.4	10.8	10.3	11.8	11.4	11.6	12.7	10.5	11.8
WINSOME	13.2	14.9	13.1	12.2	13.2	10.9	9.8	9.2	10.9	10.3	10.9	11.7	11.3	11.9	10.6	11.4
NURSERY MEAN	12.8	14.0	14.0	12.1	14.3	11.4	11.2	9.6	11.4	10.7	11.6	12.2	11.9	12.9	11.6	12.0
CV %	*	*	0.6	*	0.4	0.7	*	0.5	1.0	0.5	0.5	0.9	0.6	0.5	0.5	0.3
LSD @ .10	*	*	3.6	*	2.3	5.2	*	4.6	7.1	4.2	3.8	6.2	3.9	3.2	3.3	4.4

Molecular Marker-Assisted Selection of a Harrington x Baronesse Spring Barley Cross

PI: Dr. Andris Kleinhofs
Cooperators: Dr. Steve Ullrich and Dr. Diter von Wettstein

Harrington and Baronesse are two barley cultivars that are grown in the Pacific Northwest. Baronesse is a high yielding, two-row spring barley that is primarily used for animal feed. This cultivar was originally developed in Europe, but has adapted very well to the growing conditions in the PNW. Harrington is also a two-row spring barely, but is used mostly as a malting variety. This cultivar was developed in Canada and consistently yields significantly lower than Baronesse in the PNW.

Two yield QTLs (quantitative trait loci) of Baronesse were discovered by Tom Blake at Montana State University. One was genetically mapped to the long arm of barley chromosome 2 (2HL) and the other to the long arm of barley chromosome 3 (3HL). The goal of this project is to utilize the genetic linkage map produced by the North American Barley Genome Mapping Project as well as molecular markers from other sources to transfer these QTLs from Baronesse to a Harrington background. By transferring these QTLs we hope to 1) increase the yield of Harrington while 2) maintaining the good malting quality that Harrington posseses. Farmers could then produce a spring barley that would have a competitive yield with Baronesse and could be sold as a malting variety with a higher premium.

This project has been a molecular marker-assisted backcross breeding scheme. What this means is that after the initial cross hybridization was made, the resulting progeny were backcrossed to Harrington to eliminate any unwanted Baronesse alleles. Two experiments were conducted. The first involved a two backcross scheme, while the second involved a three backcross scheme. After each backcross and selfing operation, progeny were selected using molecular markers based on thier genotype in the chromosome 2HL and 3HL regions. Yield trials were conducted on BC_2F_4 lines at Spillman Farm in Pullman in Spring '99. From this data, two regions on chromosome 2HL and one region on chromosome 3HL have been targeted as potential high yielding regions.

Two field experiments are currently under way for Spring '00. The thirty highest yielding lines based on 1999 field data from the BC_2 scheme were planted in two locations, Spillman Farm in Pullman and at Aberdeen, ID. Ninety lines were selceted from the BC_3 scheme based on genotype and were also grown at these locations. These ninety BC_3F_5 lines are completely homozygous in the target regions. All of the planted lines will be analyzed for yield, plant height, and malting quality.

TRANSGENIC BARLEY IN THE PALOUSE

Positive chicken feed trials with transgenic barley (GMO) containing a novel β-glucanase

Diter von Wettstein

GMO stands for genetically modified organisms and is now widely used to designate exclusively plants, animals, and microorganisms, that have been genetically transformed with one or several isolated and cloned genes. The genes provide the organism with a novel trait. Typically the gene(s) cannot be transferred into the organism in any other way. As has happened initially with many scientific innovations, gene transfer by transformation is viewed by some citizens and by some biologists as more risky or less ethical than other methods of plant and animal breeding or of curing human diseases. But then all our crop plants are genetically modified from wild species. The large yields, the beautiful barley and wheat fields in the rolling hills of the Palouse are first and foremost the results of breeders, who selected some 5,000 to 2,000 years ago from the wild relatives of barley and wheat mutants and hybrids providing the grain with the large starch and protein storage capacity present in to-days cultivars. If the citizens in Babylon had indulged in a comparable attitude and thinking as adversaries of genetic transformation, the development of agriculture with cereals would not have taken off and sustained the formation of the great cultures of Mesopotamia.

The production value of Washington State's barley crop has declined from \$ 87.5 mill. in 1997 to \$43.4 in 1999, primarily because of a drop of the barley bushel prize from \$ 2.4 to \$ 1.5. In spite of constant variable costs of \$116/acre, the net revenue per acre was -\$22 in 1998 and -\$11 in 1999 compared to +\$57 in 1997 and +\$89 in 1995. Low cash returns from the barley crop are likely to remain, if the present uses of barley grain (90% for feed of cattle and pigs, 10 % for malt and <1% for human consumption) cannot be augmented by other uses. At WSU's Department of Crop and Soil Sciences we are therefore in close cooperation with the biotechnology industry trying to develop grain containing recombinant proteins of high value.

Recombinant proteins are synthesized with genes introduced into the organism by genetic transformation. For example the continuously rising demand of insulin for treatment of diabetes is covered by synthesis of the hormone with the insulin encoding human gene transformed into yeast or *E.coli* bacteria. Without the production by this fermentation process the supply could no longer be guaranteed. The recombinant human urokinase-plasminogen activator produced in fermentors with transformed *E. coli* saves now numerous people from paralysis, when they are hit by a stroke. But the production of recombinant proteins by fermentation is expensive and requires energy derived from non-renewable fossil oil. Plants on the other hand use for the synthesis of proteins energy derived from sun-light, which is converted by the green chloroplasts into chemical energy.

During the last year we have discovered that it is possible to produce 1 g of recombinant protein per kg of developing barley grain and that the protein is preserved during maturation of the grain, if it is deposited in the storage protein bodies of the endosperm.

Furthermore the recombinant protein, we have studied extensively, (1,3-1,4)-β-glucanase survives in active form the germination in the malting plant.

The transgenic barley plants that are shown in the nursery at the Spillman farm are of two types. One group synthesizes the novel beta-glucanase during germination/malting and the other with a higher product yield during development of the grain. Barley is today not used as feed for broiler chickens, as it is considered to be of low nutritional value, being a low energy grain. The reason is that chickens and other birds do not synthesize the enzyme (1,3-1,4)-β-glucanase in their stomachs or intestine. The enzyme is however required to de-polymerize the 5-10g water-soluble and 20-40g of insoluble β-D-glucan present in 1kg of barley grain. As first observed by Leo Jensen and James McGinnis in 1957 at Washington State College (former name of WSU), its absence leads to a high viscosity of the feed in the intestine, causing a limited uptake of nutrients, a slow-down of growth of broiler chicks and unhygienic sticky droppings adhering to the chickens and the floors of the production cages. The enzyme can be purchased and added to the feed, but the expenditure of $7 per ton of feed for the additive prevents the application of this solution.

In our project supported by the Washington Technology Center, Galina Mikhaylenko tested the transgenic grain in a broiler chicken feed trial with the professional advice from Professor John Froseth at the Department of Animal Sciences. 240 broiler chicks were distributed to cages with 5 birds in each and 4 different diets provided. One diet consisted of the standard diet with 62% corn, 24% soybean meal and additions of fishmeal, beef tallow, dicalcium phosphate, limestone, iodized sodium chloride, methionine, vitamins and trace mineral mix. In the second diet 62% corn were substituted with barley, in the third diet 6.2% normal malt was included in the barley and the fourth diet contained 6.2% transgenic malt added to the barley. The barley diet revealed its nutritional inferiority. But the barley diet with the transgenic malt containing the genetically engineered heat stable (1,3-1,4)-β-glucanase provided a diet that supported equal chicken growth and feed efficiency as the corn diet in the 3 week trial. Chickens fed the barley diet without the transgenic malt developed the sticky droppings symptom, while the supplement with transgenic malt prevented the sticky droppings. Analyses of the stomach and intestine contents confirm the differences in the viscosity between the corn and barley diets lacking the novel enzyme.

The gene that is being used is remarkable from two points of view: It has been synthesized as a hybrid gene with the polymerase chain reaction (PCR) from two genes encoding a (1,3-1,4)-β-glucanase in *Bacillus subtilis*. This achieved a high temperature tolerance of the enzyme for survival to the heat evolved during kiln drying, feed-pellet pressing and pasteurization of the feed against *Salmonella* infection. The genetic code of the gene has further been optimized for high expression in barley cells.

It should perhaps be stressed, that the transgenic grain is applied as an additive to normal barley as grown in the State of Washington. This addition would allow feeding normal barley with the added transgenic grain to the 40mill.broiler chicks produced annually in Washington (production value $ 74.5 mill). In turn this could make corn grain import into the state superfluous. Feeding the 40mill.broiler chicks with barley would require 280,000 t of normal barley, amounting to about one third of the total barley production in the State.

We endeavor to develop transgenic barleys that synthesize in the developing grain human recombinant proteins in high demand as health care products. These include mother milk proteins like α_1-antitrypsin, lactoferrin and lysozyme. Of special interest is the development of grain producing human fibrinogen, the raw material of fibrin sealants to stop bleeding in surgical operations and traumas. A demand of more than 500kg of fibrinogen is projected by the year 2005 with a revenue value of $ 342 mill. If it can be produced as recombinant protein in barley instead of in milk of transgenic sheep, it would not require more than 1200 acres. Barley is an ideal crop for such ventures as it is not hybridizing with any other plant species and growing cereals for clean seed production is a highly developed tradition for Washington farmers. Plants are not hosts to human and animal viruses, an advantage of producing health care products in grain, rather than in transgenic animals. The growing of barley crops producing novel enzymes, health care products and other recombinant proteins will be on a limited acreage of the individual farm but can provide a high cash return from the product, similar to the controlled production of sugar beets that guards against overproduction.

To realize the potential of transgenically modified cereals for the enhanced cash return to the grain farms, more financial support as presently available is required, especially for the actual breeding activities. The production of a transgenic line takes about 15 months with much hand labor. Only some of the ideas we are pursuing will be successful or economically sustainable, but if we don't try, we cannot know. In our projects undergraduates and graduate students participate and they perceive the possibilities as highly exciting. They value the combination of genetic engineering in the laboratory with tending the plants in the greenhouse and field as well as learning about animal trials and trying to obtain a marketable product. Any financial support small or large for fellowships, student time slips or equipment is highly appreciated. Donations will be designated with the **donors name** such as S. Smith **Fund for Development of Barley towards Improved Cash Return** and attached to the R.A. Nilan professorship for Barley Research and Training. Address for inquiries: Patrick Kramer, director, College of Agriculture and Home Economics, Washington State University, P.O. Box 64 62 28, Pullman WA 99164-646228. Tel.1-509 335-2243, e-mail: kramerp@wsu.edu.

New Bean Varieties for Washington Growers

A. N. Hang, M. J. Silbernagel, P.N. Miklas and V.I. Prest

Washington Agricultural Research Center, WSU-Prosser, USDA-ARS, and UI-Kimberly have recently released one small red and two kidney bean lines.

'LeBaron' is a new short season, small red dry bean cultivar targeted for production in Washington, Idaho, Oregon and Canada. LeBaron is suited for late planting and double cropping after pea or other early maturing crops in the Pacific Northwest.

Maturity:	75 to 85 days, 8 to 10 days earlier than 'NW-63' and 'Rufus'
Growth habit:	Varies from upright, short vine to floppy, medium vine
Diseases:	Resistant to bean common mosaic virus, similar to Rufus; mild tolerance to Fusarium root rot; susceptible to common bacterial blight, rust and white mold
Lodging:	Moderate, less lodging than NW-63 and Rufus
Yield:	Similar to Rufus but less than NW-63
Seed size	Larger than NW-63 (110%) and Rufus (105%)
Seed appearance:	Standard small red similar to Rufus.
Canning quality:	Better canner than NW-63 and Rufus when rated for clumping, splitting, color, uniformity and clear brine color.

Yield, harvest maturity, and lodging data for LeBaron compared with standard small red cultivars.

	Othello, Washington			**Kimberly, Idaho**			**All Locations (20)**	
	Yield lbs/a	Maturity days	Lodging[1] 1 to 9	Yield lbs/a	Maturity days	Lodging[1] 1 to 9	Yield lbs/a	Maturity days
				1999				
LeBaron	2491	83	8					
Rufus	3015	98	9					
NW 63	2786	94	8					
UI 259	3190	95	8					
				1998				
LeBaron	**2728**	**76**	**7**	**2408**	**91**		**2379**	**91**
Rufus	2429	86	9					
UI 259	2767	85	8	1706	92		2480	100
NW-63	3013	86	8	2669	90		2531	101
				1997				
LeBaron	**3494**	**87**	**3**	**2348**	**85**	**5.4**	**2115**	**88**
Rufus	3183	97	7					
UI 259				3079	88	5.9	2431	95
NW-63	3655	96	5	3219	89	6.7	2339	95

'USWA-33' is a new light red kidney cultivar with high yield potential and better canning quality than California Early Light Red Kidney ('CELRK') and 'Kardinal'

Maturity:	Similar to Kardinal (88 to 94 days), one week later than CELRK
Growth habit:	Upright bush
Diseases:	Resistant to bean common mosaic and curly top viruses; tolerant to Fusarium root rot; sensitive to zinc deficiency
Yield:	Greater yield potential than CELRK or Kardinal
Seed size:	Larger than Kardinal and slightly smaller than CELRK
Seed appearance:	Nice color and shape with fewer blunt ends than Kardinal
Canning quality:	Slightly better than CELRK and Kardinal

Yield, harvest maturity, and lodging data for USWA-33 compared with standard light red kidney cultivars.

	Othello, Washington			Kimberly, Idaho			All Locations (20)	
	Yield lbs/a	Maturity days	Lodging[1] 1 to 9	Yield lbs/a	Maturity days	Lodging[1] 1 to 9	Yield lbs/a	Maturity days
				1999				
USWA-33	**2030**	**86**	**1.0**					
CELRK	1773	84	1.0					
Kardinal	2102	87	1.0					
Chinook 2000	1651	92	1.0					
				1998				
USWA-33	**1536**	**86**	**2.0**	**1241**	**89**		1716	**104**
CELRK	1712	77	2.0	1452	88		1535	95
Chinook 2000	1492	84	4.0	1623	93		1601	103
RedKanner	1367	87	3.0	1515	94		1934	105
Kardinal	1422	87	2.0					
				1997				
USWA-33	**2691**	**92**	**2.0**	**1729**	**91**	**2.8**	1731	**100**
CELRK	2016	85	1.0	1638	87	2.2	1692	93
Chinook 2000	2227	91	1.5					
Kardinal	2276	90	2.0					

'**USWA-39**' is a new dark red kidney cultivar with higher yield potential than the standard cultivars 'Montcalm' and 'RedHawk'.

Maturity:	One day later than Montcalm and five days later than Red Hawk
Growth habit:	Upright bush
Diseases:	Resistant to bean common mosaic and curly top viruses
Yield:	Greater yield potential than Montcalm and Red Hawk
Seed size:	Larger than Montcalm (102%) and Red Hawk (107%)
Seed appearance:	Uniform color and shape
Canning quality:	Similar to Montcalm and Red Hawk.

Yield, harvest maturity, and lodging data for USWA-39 compared with standard dark red kidney cultivars.

	Othello, Washington			**Kimberly, Idaho**			**All Locations (20)**	
	Yield lbs/a	Maturity days	Lodging[1] 1 to 9	Yield lbs/a	Maturity days	Lodging[1] 1 to 9	Yield lbs/a	Maturity days
				1999				
USWA-39	1501							
RedHawk	1443							
				1998				
USWA-39	**1373**	**88**	**6**	**1325**	**94**		1857	**104**
AC Calmont	1177	85	4	1624	92		1805	104
Montcalm	1057	88	6	974	95		1521	104
RedHawk	1006	83	3	1175	92		1562	101
Drake	945	75	1					
				1997				
USWA-39	**1842**	**92**	**1.0**	**1227**	**94**	**3.4**	1521	**103**
Isles	1433	92	1.5	1021	93	2.4	1417	101
Montcalm				1169	92	2.8	1448	102
RedHawk	1464	92	2.0					
Drake	1045	81	1.0					

[1] Scale 1 to 9 with 1=upright and 9=prostrate
No lodging data available in 1998

Dry Bean Variety Trial in Othello 1999

An N. Hang, V.I. Prest and P.N. Miklas

WSU-Prosser is one of the 20 locations in the US and Canada participated in Cooperative Dry bean nurseries each year. Thirty six commercial dry bean and advanced breeding lines of all market classes: black, navy, great northern, pink, pinto small red and kidney were seeded at Othello, Washington on May 27, 1999.

Plots were uniformity treated with Sonalan (ethalfluralin) and Eptam (S-ethyl dipropylthiocarbamate) (1 and 2 qt/a, respectively) preplant incorporated. Fertilizer application was adjusted to 100 lb N and 80 lb P per acre before planting. All bean seeds were treated with Captan. Field was furrow irrigated 24 hours per week at 30 days after planting to reproductive stage.

Seed emergence, seedling vigor, bloom and physiological maturity were recorded. All bean lines were harvest at maturity (80 to 110 days depending upon early, medium or late maturity lines).

Yield, seed size, days to flower and days to maturity were presented in the following table.

1999 Cooperative Dry Bean Nursery

	Line	Market Class	Mean Yield lb/A	MIN Yield lb/A	MAX Yield lb/A	100-Seed Wt. grams	50% Bloom days	Seed Fill Duration days	PM days	Yield per day lb/A/day	EM days	VIG	LG 1=no 9=all	Plt Ht cm
1	I9606-6	Blk	2889.5	2352.3	3361.8	22.7	54.5	48.5	103.0	58.8	12.0	3.0	2.1	37.0
2	ICB10-5	Blk	2857.1	2622.7	3239.6	22.6	52.5	46.0	98.5	59.6	12.5	2.0	3.3	36.0
3	MIDNIGHT	Blk	3216.7	3039.0	3392.4	21.6	60.5	47.0	107.5	68.5	12.0	3.0	2.3	50.1
4	SHINY CROW	Blk	3177.0	2499.8	3734.1	23.5	53.5	52.5	101.0	62.1	11.5	1.8	4.3	32.9
5	AC COMPASS	Navy	2841.0	2356.6	3313.4	23.5	54.5	44.0	98.5	70.1	12.3	4.3	3.1	34.8
6	ISB 1256	Navy	2820.3	2563.1	3223.2	20.9	53.0	48.0	101.0	57.2	12.0	3.8	2.3	40.0
7	ISB 1814	Navy	2659.7	2460.8	3111.8	21.2	53.5	51.0	104.5	55.1	11.8	5.1	3.3	40.7
8	Mackinac	Navy	2575.2	2206.5	3076.0	19.8	61.5	44.0	105.5	57.0	11.8	4.3	2.3	42.7
9	ND91-076-01	Navy	2812.3	2525.8	3148.8	18.9	62.0	37.5	99.5	80.2	12.8	3.9	1.0	50.7
10	ND91-117-05-02	Navy	3713.8	2744.5	4421.7	19.9	60.5	47.0	107.5	76.2	13.0	4.3	2.9	39.5
11	VISTA	Navy	2778.3	2296.6	3534.8	20.1	63.0	45.0	108.0	57.3	13.3	3.6	3.8	39.5
12	MATTERHORN	GN	3479.1	2531.3	4045.6	36.1	51.0	42.5	93.5	73.7	4.0	5.3	3.5	50.0
13	UI-465	GN	3419.9	2931.4	3780.1	39.5	45.5	53.0	98.5	63.5	7.3	5.0	7.5	35.0
14	US-1140	GN	3481.0	3084.7	3697.9	32.3	40.0	44.5	84.5	75.2	1.8	2.8	9.0	37.0
15	WEIHING	GN	2722.0	2385.5	2983.7	37.4	48.0	45.5	93.5	54.8	5.8	5.3	5.0	51.0
16	L94C356	Pink	2493.0	2176.1	2991.2	31.4	45.0	35.5	80.5	62.9	1.8	2.3	5.0	35.5
17	VIVA	Pink	3192.2	2538.8	3694.1	27.0	46.0	40.5	86.5	72.7	2.3	4.3	8.5	32.5
18	92235	Pinto	2733.2	2325.7	3226.8	36.5	43.5	42.5	86.0	58.6	2.3	2.0	5.0	34.5
19	AC-Pintoba	Pinto	2975.3	2011.6	3596.9	38.1	49.5	42.5	92.0	65.4	2.5	3.3	4.5	45.5
20	Buster	Pinto	3360.4	3036.1	3682.9	37.2	48.0	43.5	91.5	74.6	2.5	4.3	4.5	47.0
21	Chase	Pinto	2294.8	2135.0	2624.8	31.7	50.5	38.5	89.0	63.0	2.5	4.5	9.0	40.0
22	Elizabeth	Pinto	2799.6	2273.3	3234.2	36.1	47.0	40.0	87.0	68.3	5.8	4.8	6.0	41.0
23	ISB-5893	Pinto	2708.0	2187.3	3208.1	38.5	48.5	44.5	93.0	61.2	2.8	3.8	8.5	35.0
24	Kodiak	Pinto	2931.4	2849.1	3047.3	39.7	50.0	42.0	92.0	69.1	3.3	3.0	5.5	47.5
25	Mesa	Pinto	3009.9	2336.9	3653.0	37.3	52.0	39.0	91.0	85.0	3.8	4.3	8.5	38.0
26	UI-320	Pinto	2675.3	1963.0	3200.6	38.9	45.5	41.5	87.0	61.8	5.5	5.3	3.5	35.0
27	NW-63	Red	2786.5	2127.5	3432.4	32.1	42.5	51.0	93.5	42.2	3.5	5.0	7.5	34.0
28	UI-259	Red	3190.3	2493.9	3768.9	35.0	46.5	48.0	94.5	61.2	3.0	4.8	7.5	39.0
29	AC-Calmont	DRK	1989.6	1768.1	2384.8	47.1	45.5	49.0	94.5	42.7	4.5	3.3		50.0
30	Montcalm	DRK	1720.4	1222.3	1999.8	50.2	45.0	50.5	95.5	37.6	4.5	4.3		49.0
31	RedHawk	DRK	1655.0	1349.4	1925.1	45.4	43.0	48.0	91.0	34.9	4.5	3.8		47.0
32	CELRK	LRK	1772.7	1241.0	2354.9	49.3	39.0	45.0	84.0	48.4	2.8	2.8	1.0	47.0
33	Chinook-2000	LRK	1651.3	1323.3	2063.4	50.1	42.5	49.0	91.5	40.2	6.5	5.0	1.0	50.5
34	Beluga	WK	1892.4	1181.2	2440.9	48.2	43.0	51.0	94.0	44.4	4.8	3.0		49.5
35	Lassen	WK	1607.3	837.3	2041.0	46.6	38.5	46.0	84.5	43.8	4.0	2.5		43.5
36	USWA-70	WK	1589.6	968.1	2089.5	53.4	44.0	48.0	92.0	40.6	4.3	3.0		51.5
	Trail Mean		**2665.5**	**2192.9**	**3131.3**	**34.1**	**49.1**	**45.3**	**94.3**	**59.7**	**6.4**	**3.8**		**41.6**
	LSD (0.05)		**655.03**			**3.46**				**20.00**	**1.09**	**1.11**		**6.24**
	CV (%)		**17.20**			**4.91**				**16.49**	**12.09**	**20.88**		**8.14**

Washington Sugarbeet Variety Trials, 1999

An N. Hang & Virginia I. Prest

Thirty-four sugar beet varieties were seeded in randomized plots with 8 replications at two locations with different soil types and microclimates. These two locations represent a majority of the sugarbeet production acreage in Washington State. The variety trials were managed the same as the remainder of the field, receiving the same fertilizer, irrigation, pest management and cultivation inputs by the grower (Table 1). Washington State University planted, harvested and collected data.

The average frost-free season at Moses Lake is 160 days and 170 days at Ephrata. Average temperature is about 2°F warmer in Ephrata than that of Moses Lake.

Varieties were also entered in the curly top and leaf spot nurseries for evaluation. The curly top nursery was conducted in Idaho and the leaf spot nursery was conducted in Colorado.

Planting

At Ephrata plots, the top of the bed was knocked of to clear away volunteer wheat used as winter cover. The beet seeds were planted into the remaining hill with a John Deere Flex planter fitted with cone seeders in 4 row plots on 22 inch row spacing by 25 foot in length. Following planting, the grower made a Roundup Ultra application to control volunteer wheat.

At the Moses Lake location, beet seeds were direct seeded in to beds with the same planter and using the same plot dimensions.

In-Season

All plots were thinned at the 6 to 8 leaf stage to a plant population of 170 beets per 100 feet. Both variety trials grew well under circle irrigation. Full ground cover was established by the last week of June. Field tours were conducted the last week in June. Bolting notes were collected throughout the growing season and there were less than 1% of beet population set bloom. At both locations, irrigation inputs and soil water levels were monitored using catch cans and neutron probe readings.

Harvest

Moses Lake plots were topped the same day as plots were dug. At Ephrata, plots were topped two days prior to digging. One full row was taken from the middle of each plot. All beets were counted and weighed. Beets were sub-samples and taken to Pacific Northwest Sugar Company's lab for tare, sugar concentration and nitrate-N determinations. Dry matter and other components determinations were performed by Best Test Analytical Lab in Moses Lake.

Results

Mean yield of the 34 varieties at Ephrata was 42.3 and Moses Lake was 39.4 T/A, a difference if 2.9 T/A (Table 3 and 4). Although the Moses Lake plots were planted only one day after the Ephrata plots, the plant development lagged two weeks. This field was located in an area with a cooler microclimate and the soil type was a silt loam, so perhaps it did not warm up at the same rate as Ephrata's sandy soil type. However the mean sugar concentration and dry matter content was slightly higher at the Moses Lake location, possibly from the same microclimate that slowed initial growth. Further analysis of the relationship between sugar production, dry matter content, weather conditions and grower management practices are planned over the next few years.

Variety trials at both location yielded higher than the growers' portion of the field. At the Ephrata location, the grower's portion of the field yielded 37.8 T/A. The variety trial was located in an area that was treated with 5 gal/A Vapam in a band in the fall of 1998. This may account for the variety trials higher yield. At the Moses Lake trial location, the growers field yielded 30.8 T/A. The portion of the field not included in the variety trial had poor stand; we suspect planter problems.

Table 1. Field Specifications and Grower Management Practices

Trial Location	5NW & F NW, Ephrata	8 NE & Q NE, Moses Lake
Soil Type	Quincy Fine Sand	Shano Silt Loam
Planting Dates	Grower Field – March 27 Variety Trial – March 29-30	Grower Field – March 30 Variety Trial – April 1
Grower Variety	CV. Canyon (Hilleshog)	CV. Oasis (Novartis)
Field History	1998 Crop – wheat followed by volunteer wheat for winter cover Fertilizer 1998 Fall – 100P 150K 1999 In-Season 30N w 10%thio-sul	1998 Crop – wheat Fertilizer 1999 Preplant – 130N 30S 0.5B 1999 In-Season – 45N 30P 7S
Pest Control	Combination chemical and mechanical	Combination chemical and mechanical
Harvest Date	October 18 (203 days)	October 11 (193 days)

Table 2. Field performance of commercial sugarbeet varieties in Washington State University variety trials.

	Location 1 - Ephrata					Location 2- Moses Lake				
	Root Yield (T/A)	Sugar Content (%)	Sugar (lb/A)	Dry Matter (%)	Rank	Root Yield (T/A)	Sugar Content (%)	Gross Sugar (lb/A)	Dry Matter (%)	Rank
ACH										
Crystal 211	38.4	19.83	15201	26.1	2	40.8	19.58	15950	26.6	24
Crystal 9901	40.5	19.18	15582	25.4	6	36.2	20.22	14587	29.1	9
Crystal 9908	45.7	19.15	17516	25.1	33	41.2	19.37	15930	26.1	22
Tomcat	42.1	19.43	16303	25.7	16	41.6	19.42	16131	26.0	27
BetaSeed										
Beta 7KJ5109	44.3	18.99	16820	25.1	24	38.2	19.77	15112	26.7	11
Beta 8088	40.8	20.09	16404	26.6	17	39.6	20.13	15910	26.8	21
Beta 8118	43.6	19.32	16719	25.6	22	40.2	19.74	15854	26.7	18
Beta 8220	40.6	19.24	15600	25.3	7	39.9	19.99	15945	27.0	23
Beta 8348	39.9	19.09	15229	25.4	3	38.7	19.74	15288	26.8	12
Beta 8422	38.2	19.53	14825	25.9	1	40.7	19.39	15785	26.2	17
Beta 8468	45.2	18.9	17053	24.9	31	36.7	19.79	14523	26.8	5
Beta 8757	43.1	20.41	17427	26.6	32	41.8	19.48	16255	26.6	28
Beta 8919	40.6	19.62	15881	25.7	10	40	19.88	15861	26.8	19
Hilleshog										
HM 2930	43.9	19.33	16970	25.5	28	40.3	19.91	15640	26.9	15
HM Canyon	40.5	19.43	15694	25.7	8	39.5	20.11	15865	26.6	20
HM Dillon	41.4	19.7	16273	26.0	15	38.2	19.7	14530	26.0	6
HM Oasis	44.4	19.2	17009	25.5	30	39.8	19.71	15687	26.6	16
HM Owyhee	41.6	19.39	16114	25.5	13	42.6	19.31	16475	26.0	32
HM PM21	43.9	18.99	16668	25.9	20	38.8	19.83	15369	27.3	13
HM WSPM9	42.7	19.57	16704	26.0	21	37.4	19.58	14538	26.8	8
Seedex										
SX Blazer	42.9	19.8	16930	26.1	27	42.9	19.48	16700	26.2	33
SX Bronco	41.7	19.67	16413	26.0	18	40.6	20.01	16264	27.0	29
SX Chinook	44.2	19.95	17643	26.2	34	39.2	19.91	15560	26.8	14
SX Ranger	38.7	19.88	15398	26.3	4	40.6	19.74	16027	26.7	25
SX Stampede	43	19.32	16605	25.8	19	37.3	19.74	14696	26.7	10
SX Wrangler	43.9	19.05	16739	25.4	23	36.4	19.62	14259	26.9	2
Spreckels/Holly Hybrids										
97HX706	43.8	19.44	16997	25.8	29	37.4	19.43	14425	26.5	3
98HX802	44.1	19.23	16927	25.8	26	40.8	19.81	16117	26.6	26
99HX901	42.5	19.83	16853	25.9	25	36.8	19.73	14495	26.8	4
99HX960	40.8	19.1	15578	25.2	5	36.6	19.86	14534	27.1	7
99HX961	43.7	18.6	16211	24.8	14	42.9	19.18	16459	26.0	31
HH 111	41.8	19.05	15893	25.1	11	36.6	19.36	14116	26.7	1
HH 119	41.4	18.91	15698	25.0	9	43.2	19.61	16969	26.4	34
HH 120	42.5	18.9	16020	24.8	12	41	19.89	16332	26.6	30
Trial Means	**42.3**	**19.37**	**16347**	**25.6**		**39.4**	**19.69**	**15538**	**26.7**	
LSD (0.05)	**5.25**	**0.91**	**1956.3**	**1.1934**		**4.77**	**0.8053**	**1830**	**1.2683**	
CV (%)	**11.7**	**4.4**	**11.3**	**4.4**		**11.4**	**3.85**	**11.1**	**4.5**	
Pr>F	**0.1512**	**0.0586**	**0.3688**	**0.2122**		**0.0134**	**0.1458**	**0.0552**	**0.0480**	

Grower Field Information

Canyon	37.8	18.6	14062

Grower Field Information

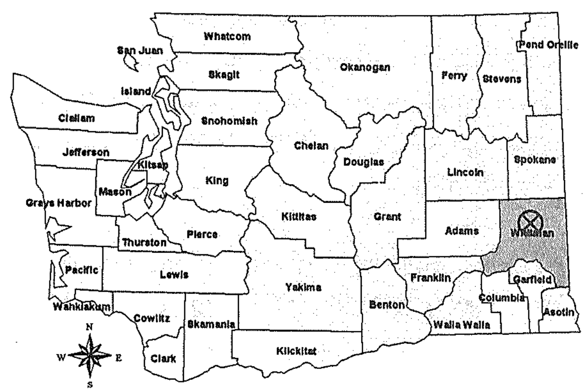
Oasis	30.8	18.6	11458

Direct-Seed Cropping Systems Research: The Cunningham Farm

R. James Cook, Dave Huggins, Eric Gallandt, Joe Yenish, Bruce Fraizer, and Richard Rupp

The Cunningham Farm cropping systems project is a new and one of a network of cropping systems projects underway or planned for eastern Washington and adjacent northern Idaho and northeastern Oregon to provide the knowledge and technology needed by growers to reduce inputs and increase crop diversity while protecting the soil resource. Building research capacity for competitive cropping systems requires the combined experience, expertise, and resources of growers, researchers, industry, and agency people of the region. The project is therefore grounded in the premise that coordination and implementation of team efforts will lead to creative solutions not possible by more singular efforts.

OVERVIEW: WSU's Cunningham Farm



Located in Whitman County, five miles Northeast of Pullman, the 140-acre Cunningham Farm includes soils and topography representative of the annual cropping region. A group of some 14 WSU and 8 USDA-ARS researchers is currently working to develop and implement a coordinated cropping systems project designed to meet the needs of growers specifically in this higher precipitation region of the Inland Northwest. University of Idaho scientists will join the project later this year. Guided by an Advisory Committee comprised of a diverse constituency, the research conducted at the Cunningham Farm will strive to develop new guiding principles and practices fundamental to reducing risks, increasing profits, and improving environmental quality through direct-seeded cropping systems.

SCOPE

The Cunningham Farm project will serve some 2.6 million acres in Washington and 1 million acres in Idaho, representing the higher-precipitation areas where:

- annual cropping has long been practiced;
- spring and winter crops may be grown and opportunities exist to develop greater rotation diversity;
- the majority of growers continue to depend on intensive, tillage; and
- there exists great resource variability and the potential to intensively manage differing landscape features in diverse ways while enhancing the competitive advantage of the region.

CURRENT OBJECTIVES OF THE CUNNINGHAM FARM PROJECT

1) To obtain baseline data and develop detailed histories and maps of yield, weed, pathogen, insect pests, fertility, and other variables/features as a basis for (a) planning and implementing a comprehensive, direct-seed cropping-systems project and (b) providing a resource to attract and compete for diverse sources of outside funding.

2) To acquire and organize personnel, equipment, and funding sources needed to plan, implement, review, and maintain this comprehensive, direct-seed cropping systems project.

3) To establish specific cropping systems experiments within a total agricultural landscape management system.

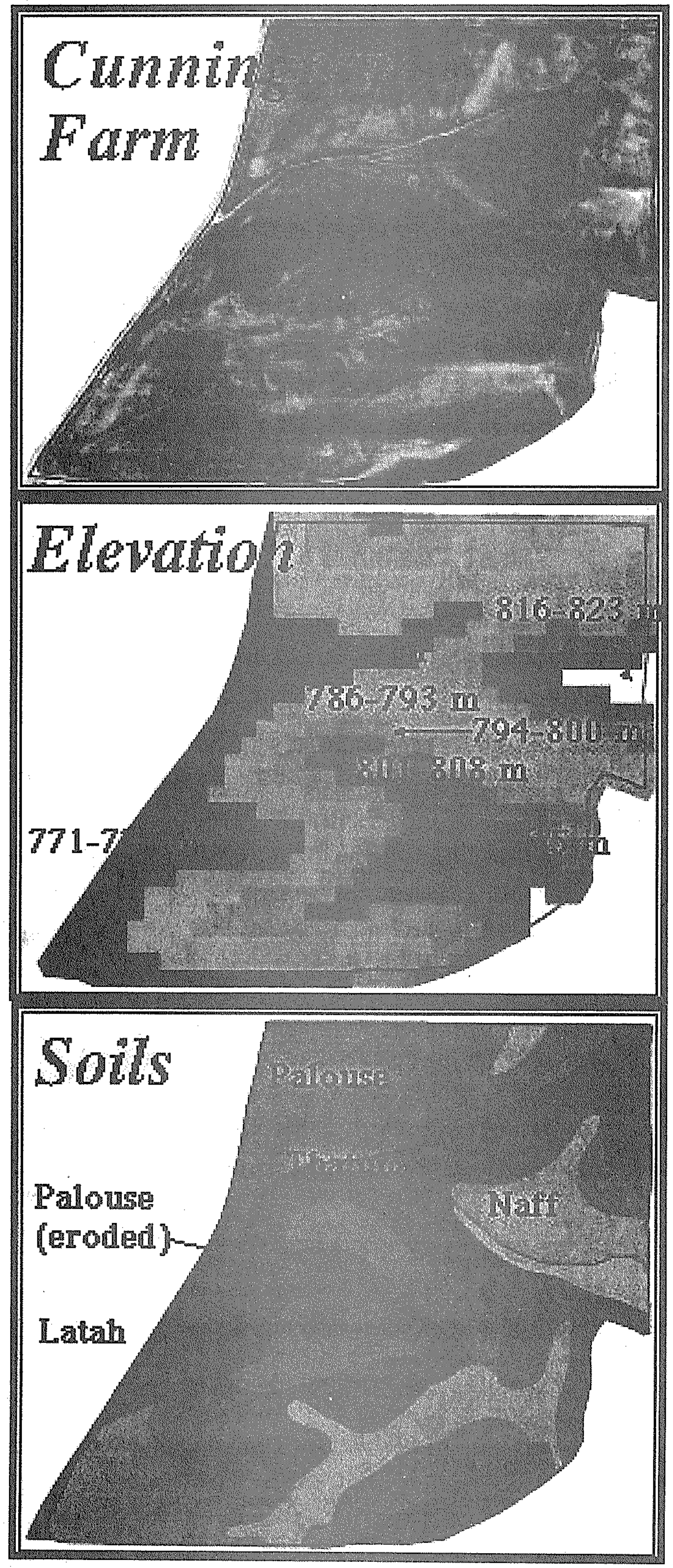
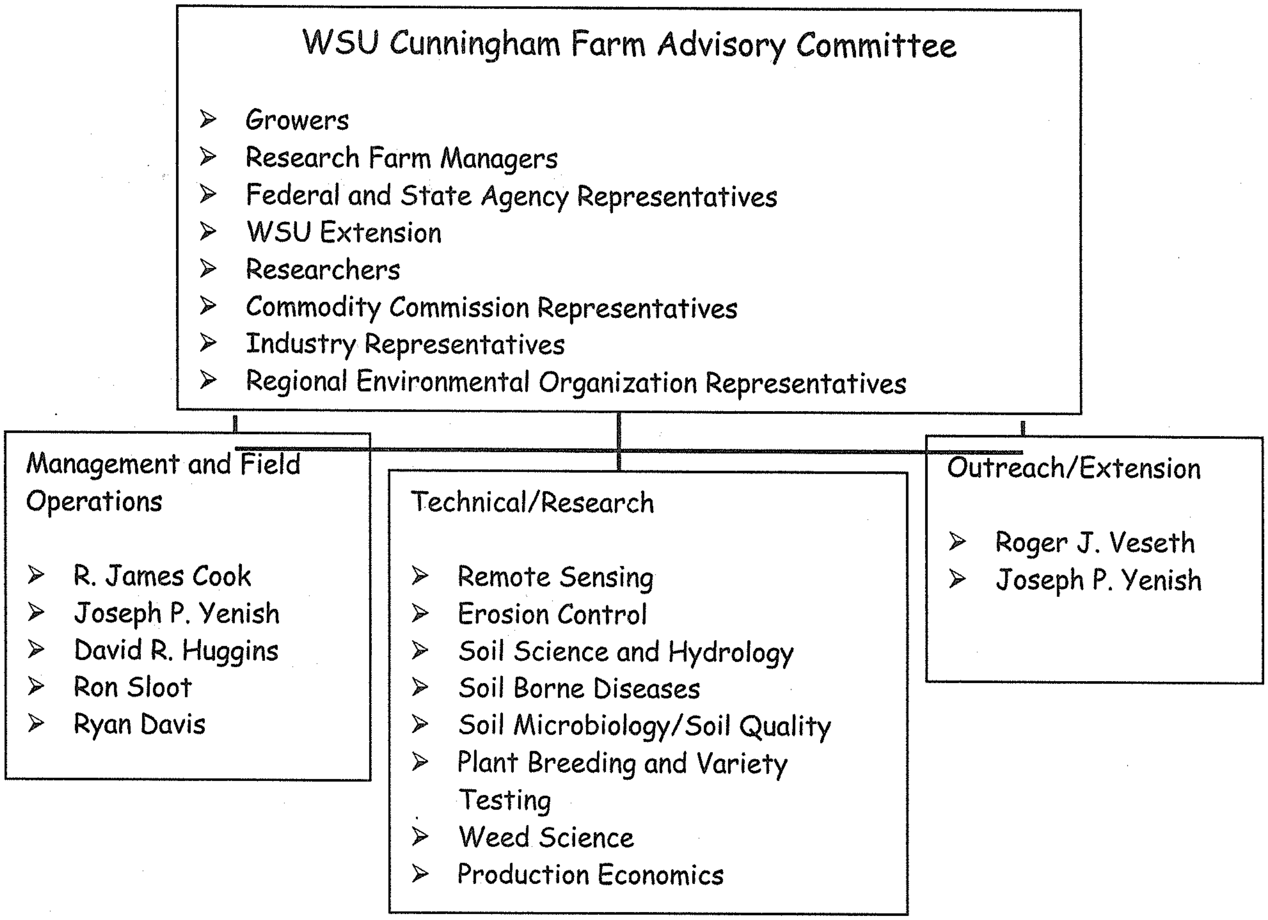


Photo taken in July 1996 (top). The border is our area of interest, 66.5 ha. The elevation map (middle) shows the general topography of the site. Soils at the site (bottom) include Palouse (45%), Thatuna (35%), and Naff Silt Loams (20%).

Organizational chart for the WSU Cunningham Farm.



Accomplishments 1999/2000

Equipment. Since the Cunningham farm is a new "agronomy farm" for Washington State Unversity under management of the Department of Crop and Soil Sciences, much of this past year has been devoted to equipping the farm mainly for large-scale plot research. This includes: a new 15-foot Great Plains direct-seed drill provided by the Great Plains company as a prototype with double-disk openers on 10-inch spacing and fertilizer deep-banding capability within each seed row at planting; a new direct-seed plot drill equipped with five Cross-slot openers for seed and fertilizer placement on 10-inch spacings; a 1985, 2.5-ton International truck with a new grain box equipped with hydraulics; a new grain auger for transfer of seed from the truck to the drill hopper box; a new three-point-hitch sprayer with 40-foot boom and foam-marker capability; a 5 hp transfer pump with hoses for use to pump either water or fertilizer solution; and a weather station equipped for continuous monitoring of air and soil temperatures, wind direction and speed, precipitation, global radiation, relative humidity, and soil moisture at multiple depths. A new 6410 John Deere tractor purchased for the Department of Plant Pathology through the 1998 College of Agriculture and Home Economics equipment fund is available for use with the sprayer and other light-weight tractor work. In addition, a 95H John Deere combine equipped with both a yield monitor and a weigh system within the hopper box, and a 3000-gal tank mounted on a flat-bed trailer for hauling water have been made available to this project. We leased the tractor for use with the 15-foot drill.

Appointment of an Advisory Committee. A 12-member advisory committee was appointed in early 1999. This committee has met twice: June 21 on the Cunningham farm and November 10 at WSU. Based on the advice from this committee, the entire farm will be planted to spring barley (Baronesse) in 2000 as the second crop (following DNS in 1999) before initiation of the cropping systems study in 2001.

Creation of a detailed landscape data base. Before launching the first cropping systems project, which will commence in 2001, a major effort has gone into the creation of a database for soil properties, weed and pathogen infestations, and other parameters essential to understanding yield and quality variability across the farm in the years ahead. The database under development for 90 of the 140 acres of this farm may well be the most detailed for any 90-acre field in the Pacific Northwest.

- Created a Digital Elevation Model (DEM) using a survey-grade Global Positioning System (GPS) with accuracy within 1 inch and a highly detailed latitude, longitude and elevational data for the entire farm. This information is integral to the spatial analyses of data collected across the farm.

- Using the Geographic Information System (GIS), a randomized non-aligned grid averaging 100 feet between points was established across 92 acres of the Cunningham farm. Each point of the grid has a latitude, longitude, and elevation and points that can be relocated with a GPS. The established grid is used for all sampling to enable spatial analysis and correlation of variables such as yield, protein, pests, and soil and landscape attributes. Each variable constitutes a layer of information in the GIS that can be analyzed to further understand crop and landscape relationships.

- To create a soil database, soil profile cores (0-5 ft) were collected with a hydraulic probe equipped with butylate liners on a non-aligned grid pattern across 92 acres of the farm. Detailed morphological descriptions including horizon depth, color, structure, consistence, and rooting depth have been completed on 40% of the intact cores. Following detailed description of intact cores, the soil profile core was divided into 3 surface depth intervals of 0-10, 10-20, and 20-30 cm and from 30 to 150 cm by subsurface horizons. These samples will be analyzed for various soil properties including total C, N, and S.

- Weed seed populations were assessed from 369 sample locations, using a pint of soil collected from the upper 10 cm of the soil profile. The number and species of emergent germlings were determined from these soil samples. A cluster analysis of the data indicates that the weed species can be grouped on the basis of biotic factors, e.g., the effects of interactions with other weeds, and soil and other abiotic factors. Henbit seed are distributed independently of all other species. When windgrass forms associations, the associations are positive. When lambsquarters forms associations, they are negative. Ryegrass and mayweed tend to occupy plots that lambsquarters does not.

Wild oat seed are distributed throughout the study area at the Cunningham farm, with some of the highest densities found in the central parts of the field, and in the lower and middle elevation positions in the landscape, and densities being significantly higher on foot and sideslopes than on the higher shoulders and summits. When considered alone wild oat seeds are about as likely to be found on steep as on gentle slopes. Wild oat seed densities do not exceed 30 seeds per pint of soil.

Mayweed seed is found more toward the lower positions in the landscape than wild oat, with the highest densities located near the field borders (up to135 seed per pint of soil) and on the toeslopes . Even the footslopes have significantly higher seed densities than positions upslope. Within the landscape of the Cunningham farm study area, the distribution of wild oat seed is independent of aspect, whereas mayweed seed are more likely to be found on northerly than on southerly facing slopes.

- Populations of Fusarium culmorum (cause of Fusarium root and crown rot of cereals), F. solani f.sp. pisi (cause of Fusarium root rot of peas) and Pythium irregulare and P. ultimum (cause of seedling blights and root rot of cereals and pulses), were determined in soil from the top 15 cm of 226 locations marked by GPS over the 90-acre study site. Populations of the two Fusarium species were in the range of 100-500 spores per gram of soil, with 1000 to 2000 spores per gram of soil at 5-10% of the sites. Populations of the two Pythium species were in the range of 100 to 200 spores per gram of soil with 400-500 spores at 5-10% of the sites. Apart from a remarkably uniform distribution, no particular pattern was evident based on elevation, aspect, or soil type, although the analysis is continuing.

- Infrared and color aerial photos were taken at several times during the year. These images have been georeferenced and the data are being analyzed. We also made ground based observations in conjunction with the aerial images to attempt to correlate the image data with parameters such as crop yield and weed density.

- Hyperspectral data (about 750 megabytes!) was provided from a flight in August by Earth Search Sciences, Inc. Their Probe1 instrument collects data in 128 narrow spectral bands. We recently acquired the software to allow us to fully analyze the data and this effort is just underway.

- More datasets will be added soon. We have also been able to construct a very detailed (centimeter resolution) digital elevation model from the GPS survey done this past fall. This model will allow us to research the interaction of the landscape with the other experimental data being collected at Cunningham. We also will use the model to examine the role of microclimates in soil properties and agricultural production.

<u>**Site-specific yield and protein measurements for HRSW in 1999**</u>. Except for a small parcel (20 acres) set aside for weed research, the entire farm was direct seeded in the spring of 1999 to WB926R and yields and grain protein were then determined as sites identified by GPS. Prior to planting, soil samples (0-5 ft) were collected on 30% of the field in a detailed grid for analysis of soil water and nitrate. Soil samples were also collected in representative portions of the field to formulate an N, P, S fertilizer recommendation. Fertilizer was band applied at planting based on soil tests and goals of 60 bu/A, and 14% grain protein. Following physiological maturity and prior to harvest, grain and straw samples were collected for analysis of grain yield, protein, sulfur, aboveground residue biomass and N, S content. Following harvest, soil samples (0-5 ft) were collected for water and nitrate analysis. Grain yield averaged 44 bu/A but ranged from 24 to 71 bu/A across the 92-A field. Grain protein averaged 13.7% but ranged from 11 to 18% across the field. Analyses of spatial patterns of yield, protein and N uptake and use efficiency are continuing.

The full cropping systems project will be designed over the course of the current "year 2" and implemented in year 3, which will commence in 2000. No tour is planned for this project in 2000, but anyone wishing to visit this site or learn more about the project should contact any one of the three individuals named below.

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EFFECTS OF TILLAGE AND CULTIVAR ON RESIDUE DECOMPOSITION AND SOIL QUALITY

Tami Stubbs, Ann Kennedy and Kim Kidwell

Collaborators: Frank Young, Steve Ullrich, Curtis Hennings, William Pan, William Schillinger, Gerald Stubbs, Mike Stubbs

INTRODUCTION

Residue cover increases water-holding capacity and improves soil stability; however, excessive levels may impede stand establishment in no-till systems. The unavailability of effective management strategies has hindered adoption of conservation tillage practices. Decomposition of cereal crop residues is often associated with fiber and nutrient content; however, little information concerning the decomposition potential of straw from cereal cultivars currently grown in the Pacific Northwest is available. Even though the biological and ecological processes involved are not well understood, soil microorganisms are a key factor in controlling the rate of residue decomposition. Soil analyses coupled with microbial activity and microbial community structure patterns will enhance our understanding of the biology of the system to more fully exploit the ecology of no-till systems as a way to optimize residue management strategies.

The biological factors controlling the 'transition period' from conventional or minimum tillage to no-till require investigation to develop appropriate management strategies for the establishment years of no-till cropping systems. Knowledge of residue decomposition rates for various cereal cultivars and alternative crops will permit the inclusion of varieties with specific decomposition rates in the crop rotation as a means of maintaining residues at desired levels. Knowledge of residue decomposition of various crop species will aid growers in designing crop rotations to fit their specific needs.

OBJECTIVES

- Monitor changes in biological and chemical soil quality parameters over time with continual minimum tillage and no-till as affected by crop species and variety.
- Characterize residue decomposition potential of cereal varieties, and how decomposition potential varies with management and location.

METHODS

Soil quality. Soil samples were collected each spring and fall from the cropping systems trial at Ralston, and from the annual spring cropping trials at Ralston and Dusty. Sampling began March, 1996 at Ralston and March, 1997 at Dusty. Samples were analyzed for pH, electrical conductivity (EC), readily mineralized carbon (RMC; available C), dehydrogenase enzyme activity (microbial activity), and fatty acid methyl esters (FAME; microbial community structure).

Residue decomposition. Spring wheat and barley straw samples were collected from Ralston and Dusty, and winter wheat samples collected from Lind, Dusty and Farmington, Washington. Internode straw was analyzed for hemicellulose, cellulose, lignin, total C, N and S content, and this information related to decomposition potential.

RESULTS

Soil quality.

Ralston Cropping Systems Trial:

Differences existed in soil quality parameters among crop rotations**; however, there were no clear trends to determine which system was most beneficial. The HRS-HRS and SWW-fallow rotations had the highest, and HRS-SB rotation the lowest EC. The SWS-fallow rotation had highest pH and dehydrogenase enzyme activity, and lowest RMC of all systems. RMC was highest for the SWW-fallow and HRS-HRS rotations. There were differences in EC and pH between east and west sides of the study, with the east side having higher EC and lower pH than the west side. Fatty acid methyl ester data show grouping by season and some grouping of east and west samples. Differences between the two sides of the study may be the result of past cropping history that included canola on the west side.

Ralston Annual Spring Cropping Trial:

Electrical conductivity, pH, RMC and dehydrogenase analyses did not differ with crop species (spring wheat and spring barley) or tillage treatment (no-till and minimum tillage). FAME analysis showed different patterns between no-till and minimum tillage. Mean electrical conductivity has increased from 114 μS/cm in 1996 to 260 μS/cm in 1999. From 1996 to 1999, pH values decreased by 0.2 unit. Readily mineralized C increased from 1996 to 1999. Spring wheat and spring barley cultivars did not affect the results of the soil quality analyses.

Dusty Annual Spring Cropping Trial:

Electrical conductivity values were higher for soil from barley treatments than wheat, and pH was higher for soils from wheat treatments than barley. FAME analysis indicated different patterns for minimum tilled wheat compared to barley, and there were different patterns for soils from no-till and minimum tilled treatments. Other analyses were not affected by crop species or tillage treatment. Mean electrical conductivity increased from 109 μS/cm in 1997 to 337 μS/cm in 1999, and pH decreased from 5.8 in 1997 to 5.5 in 1999. Fatty acid methyl ester data show clustering by season. There were no differences in soil quality analyses associated with spring wheat and spring barley cultivars.

Residue decomposition.

Spring barley, spring wheat and winter wheat plant residues produced with varying tillage treatments at multiple locations in eastern Washington were analyzed for fiber components (hemicellulose and soluble C, cellulose, lignin), and total C, S, and N content. High hemicellulose and total N can be linked to rapid decomposition, and high lignin content and high C:N ratio are associated with slower breakdown. This information may be used as an indicator of residue decomposability, however these results are sometimes difficult to correlate with decomposition in the field. Spring wheat and spring barley were grown with minimum tillage and no-tillage treatments, whereas, winter wheat was produced using conventional, high soil disturbance tillage practices.

Spring barley, spring wheat and winter wheat differed ($P<0.02$) in hemicellulose, cellulose and total C, S, and N contents, however, lignin content did not differ ($P=0.39$) among crops. Fiber and nutrient contents of cereal straw differed among locations, years and cultivars, and C and S content varied with tillage. Rapidly decomposing cultivars included 'Basin' winter wheat, 'ID377S' spring wheat and 'Baronesse' spring barley.

Cultivars that decomposed more slowly were 'Tres' winter wheat, 'Scarlet' spring wheat, and 'Stander' spring barley.

Results from laboratory incubation studies of winter wheat straw decomposition in soil were correlated with hemicellulose and soluble C (R^2>0.66), lignin (R^2>0.41) and total N (R^2>0.67). Levels of winter wheat straw decomposition were highest when percent lignin and C/N were low, and hemicellulose and total N were high, and spring barley decomposition was highest when hemicellulose was high and lignin was low. Results indicate that hemicellulose, lignin and total N content, and C/N ratio may be useful for predicting cereal straw decomposition potential. This information can be used to plan soil-saving crop rotations aimed at managing residue through conservation tillage systems.

TAKE HOME MESSAGES

- Differences in soil quality analyses are beginning to emerge with alternative management; however, no there are no clear trends to detect definite advantages for any of the treatments tested. A greater length of study may be required to determine all of the benefits that will occur if these practices are adopted long-term.
- Cereal cultivars vary in their decomposition rate, and the potential for decomposition varies over tillage treatment, location and year.

**Cropping systems trial rotations: SWW-fallow: soft white winter wheat – fallow; SWS-fallow: soft white spring wheat – fallow; HRS-HRS: continuous hard red spring wheat; HRS-SB: hard red spring wheat – spring barley.

Residue Retention and Water Storage in Low-Rainfall Systems

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This article is a review of research results and grower experiences on factors affecting soil water retention in the low-rainfall cropping areas of the inland Pacific Northwest of the USA. Water storage in the traditional winter wheat-summer fallow system is fairly well understood. A new challenge is to learn how to maximize water storage and water use efficiency for spring-sown crops and long-term no-till systems. If you have comments or questions about this article, please contact me at (509) 659-0355 or e-mail: schillw@wsu.edu.

How Residue Benefits Over-Winter Soil Water Storage

Maximum efficiency in storing winter precipitation is critical to reduce soil erosion and to achieve optimum yield. There are many factors that affect the amount of water stored in soil over the winter. These factors include soil infiltration rate, soil depth, soil texture, and soil structure. Infiltration is greatly influenced by residue and whether the soil has been tilled or not. Our silt loam soils in the inland Pacific Northwest dryland crop production region can hold about three inches of water in each foot of soil, or about 25% by volume. When soil water content is above 25% by volume, such as in surface soils after a heavy rain, the soil is considered saturated. Water loss by evaporation can be substantial when surface soils are saturated, much like from a free water surface.

Residue retards evaporation of water when surface soils are wet by 1) reflecting sunlight which otherwise would be absorbed as heat, 2) acting as a thermal insulator to limit the flow of heat from the atmosphere to the soil, 3) reducing turbulent air exchange by creating a dead air space above the soil surface which reduces the transfer rate of water vapor from the soil to the atmosphere. Surface residue enhances infiltration by allowing water more time to migrate downward in the soil profile where it can be conserved and is less likely to be lost by evaporation. When water runoff from frozen soils is not a factor, the best way to maximize soil water storage during the winter is to leave stubble standing. Soil water storage will increase in a near linear fashion as the rate of surface straw is increased. Standing stubble is more effective in trapping snow and storing water than is flattened stubble.

Conservation of Water in the Winter Wheat-Fallow System

In a review article on summer fallow in the Pacific Northwest, Leggett et al. (1976) reported that over-winter water storage efficiency after wheat harvest from four locations in eastern Washington and one location in northern Idaho ranged from 52% to 73%. Work conducted by Massee and McKay (1979) in the high snowfall regions of eastern Idaho showed that allowing stubble to stand over-winter after harvest trapped snow and increased soil water. Winter wheat yields were increased by 5 bushels per acre for each additional foot of snow trapped.

Ramig and Ekin (1991) measured over-winter soil water storage at Pendleton and Moro, Oregon, from 1978 to 1984. Mean annual precipitation at Pendleton and Moro is 16 and 11.5 inches respectively. Averaged over five years and both sites, 75% of the precipitation occurring between September 1 and March 1 in winter wheat stubble was stored in the soil. In a 6-year study from 1993 to 1999 at Lind, Washington (9.6 inch annual precipitation), an average of 62% of September-March precipitation was stored in winter wheat stubble (W.F. Schillinger, unpublished data).

Experience from the 1980s: No-Till in the Winter Wheat-Fallow Rotation

Our first experience with direct seeding in the low-rainfall areas of the inland PNW occurred in the late 1970s. Several growers attempted no-till, but continued with winter wheat-summer fallow cropping. This system did not work well for most growers due to: 1) the difficulty and expense of controlling Russian thistle and other broadleaf weeds with herbicides during fallow, 2) build up of downy brome populations, and 3) loss of seed zone water during the summer which prevented sowing into residual soil moisture or caused spotty stands which reduced grain yield.

Several studies have documented water storage of no-till vs. conventional summer fallow management practices. In a 4-year study near Pendleton, Oregon, Oveson and Appleby (1971) found that no-till plots consistently stored less water during summer fallow than plots which received stubble mulch tillage during the spring and wheat yield from no-till plots was reduced compared with tilled plots. Lindstrom et al. (1974), in a 2-year study at Lind, Washington, reported that no-till summer fallow had insufficient seed zone water for satisfactory emergence of fall sown wheat. Schillinger and Bolton (1993), reporting on a 10-year tillage method study at Moro, Oregon, found that surface residues with no-till were effective in retarding evaporation during periods of frequent precipitation and low potential evaporation in the spring. However, spring rainfall events in the semiarid Pacific Northwest are seldom of sufficient magnitude to improve water storage by increasing depth of water percolation. In their (1993) study, the no-till system lost soil water at a faster rate than tilled fallow during the dry summer months because of soil capillary continuity, whereas the continuity of the capillary channels from the subsoil to the soil surface were effectively broken in the tilled stubble mulch treatment.

It must be emphasized that some growers in low-rainfall areas of the inland PNW are making the no-till winter wheat-summer fallow rotation work on their farms (Mallory et al., 2000). They do not, however, attempt to sow winter wheat into residual soil water. Instead, they wait until the onset of fall rains and sow at a shallow depth into new moisture. In Oregon, delaying sowing of winter wheat until mid-October and beyond does not reduce winter yield to the extent that it does at Lind, Washington.

Intensive No-Till Spring Cropping

There is presently wide-spread interest in simultaneously increasing cropping intensity and eliminating tillage. The use of spring cropping in combination with no-till sowing would appear to offer the best approach for increasing cropping intensity, improving soil quality, and controlling erosion in conventional fallow areas (Papendick, 1998).

In the first section of this paper, I reported that the quantity of residue and rate of infiltration are two key factors affecting over-winter water storage. In a tillage-based system, the more surface residue present, the more water gets stored in the soil. This holds true for the first several years in the transition to no-till. However, beginning as early as year three, water storage efficiency may improve significantly in no-till systems.

Two current long-term research projects in Washington, at Ralston and the Horse Heaven Hills, compare the conventional winter wheat-summer fallow rotation with continuous no-till spring wheat. At both locations, stubble in both systems is left undisturbed after harvest until spring. During the first few years of the experiments, the best over-winter water storage occurred after winter wheat; presumably due to greater quantities of surface residue compared with no-till spring wheat. However, after two years, over-winter water storage in the no-till treatments increased significantly compared with winter wheat-summer fallow.

Table 1 shows precipitation from harvest in July or August until time spring planting in March at Ralston and the Horse Heaven Hills sites. The percentage of precipitation that was stored in the soil during this time period (i.e., storage efficiency) is also shown. Note that over-winter soil water storage efficiency is consistently higher at both sites in continuous no-till spring wheat compared with conventionally grown winter wheat stubble.

Table 1. Over-winter precipitation and soil water storage efficiency in continuous no-till spring wheat compared with conventionally-grown winter wheat in two long-term studies near Ralston in Adams county, WA, and the Horse Heaven Hills in Benton county, WA. Storage efficiency (SE) is the percentage of precipitation occurring between August and March which was stored in the soil.

Year	**August-to-March Precipitation (in.)†**	**Storage Efficiency (%)**	
		Ralston	
		Winter Wheat Stubble	Continuous Spring Wheat
1997-1998	7.97	60	72
1998-1999	7.80	76	88
1999-2000	7.55	80	85
		Horse Heaven Hills	
		Winter Wheat Stubble	Continuous Spring Wheat
1998-1999	2.99	56	66
1999-2000	3.17	75	83

† Precipitation reported for both the continuous no-till spring wheat and winter wheat - fallow systems is from harvest in July or August until just before planting of spring wheat in March.

Why are these over-winter storage differences occurring? It may be that soil capillary continuity, via root hairs and other channels, is gradually improving under no-till. Breaking soil capillary continuity with tillage has long been known to be effective in retarding evaporative loss of soil water from beneath the tillage depth. The same principle for capillary continuity applies to water infiltration; i.e., the tillage layer is likely hampering infiltration compared with the unbroken capillary channels with no-till. This is certainly a very interesting and important phenomenon which we will continue to investigate.

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Alternative Dryland Crop Rotation Research Using No-Till: The First Three Years in Adams and Douglas Counties

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OBJECTIVES: The objective of the study is to determine the long-term feasibility of diverse, cereal-based, no-till cropping systems for low-rainfall dryland areas of the inland Pacific Northwest. Specific objectives are:

1. Evaluate and compare three long-term no-till annual spring cropping systems: (*i*) a 4-year safflower/yellow mustard/wheat/wheat rotation; (*ii*) a 2-year wheat/barley rotation, and (*iii*); continuous wheat.
2. Measure the effects of the three annual spring-sown rotations on root disease, soil moisture dynamics, and grain yield of wheat.
3. Record weed species shifts and weed ecology as related to no-till sowing and alternative annual spring cropping systems. Screen herbicides for controlling weeds in broadleaf crops.
4. Document the long-term cumulative effects of minimum disturbance no-till sowing practices on physical and biological properties of the surface soil.
5. Evaluate the agronomic and economic of potential of diverse annual spring cropping compared with winter wheat/summer fallow.
6. Through field days, research reports, and winter meetings, demonstrate and promote no-till and alternative farming practices to growers and agricultural support personnel.

ABSTRACT OF RESEARCH PROGRESS: We have completed three years of a planned six-year study to compare three no-till annual spring cropping systems: (*i*) a 4-year safflower/yellow mustard/wheat/wheat rotation; (*ii*) a 2-year wheat/barley rotation, and (*iii*); continuous wheat. Experiment sites are located in Adams and Douglas counties.

Lack of spring rainfall in 1999 reduced yields at both sites compared with previous years. There were no differences in wheat yield due to rotation at either site. Rhizoctonia root rot bare patches in wheat and barley covered 5% of total plot area in Adams county. Previous crop history had no significant effect of level of rhizoctonia infection in wheat. Russian

thistle was again the dominant weed in 1999 at both sites. Marestail and prickly lettuce are troublesome in safflower and yellow mustard but can be brought under control when the rotation reverts to wheat. To date, we have found no differences in the population of any weed species in wheat due to rotation. Safflower and yellow mustard extract more water from the soil profile than does spring wheat, and the soil water shortfall carries over to the next spring.

RESULTS AND DISCUSSION: This study was initiated in 1997 at two locations. The Adams county site is on the Ron Jirava farm near Ritzville. Precipitation at the Jirava site averages 11.5 inches, elevation is 1850 ft asl, and the soil is a deep Ritzville silt loam. The second research site is located northwest of Mansfield in Douglas county on the Brad Wetli farm. Annual precipitation at the Wetli site is 10.5 inches, elevation is 2700 ft asl, and depth of the Touhey loam soil averages only 2.5 feet. The dominant cropping pattern on these shallow soils in Douglas county is winter wheat/summer fallow.

The plot design is the same for both Adams and Douglas county sites. We are testing three spring-sown cropping systems: 1) a 4-year safflower/yellow mustard/wheat/wheat rotation; 2) a 2-year wheat/barley rotation and; 3) continuous wheat. Each system is replicated four times in a randomized block design with each sequence of all rotations sown each year (i.e., 28 plots at each site). The experiment covers 20 acres in Adams county and 8 acres in Douglas county.

At the Adams county site, crops are sown with a 30-foot-wide Flexi-coil 6000 no-till disc drill which bands fertilizer near the seed with double-shoot disc openers in one pass through the field. The Douglas county site is sown with an 8-foot-wide Cross-slot drill which causes minimal soil disturbance and also delivers seed and all fertilizer in one pass. Fertilizer rate (nitrogen, phosphorous, and sulfur) is held constant in all plots at each site and is based on soil test and soil moisture availability.

<u>Sowing in 1999</u>: Fertilizer rate in Adams county was 48-10-0-10 lb./acre, applied as 40 lb. N and 10 lb. S in an aqua NH_3 mix, plus an additional 8 lb. N and 10 lb. P as granular starter. Extensive soil water measurements taken in mid-March in Adams county showed significant differences ($P < 0.001$) in water content as affected by the previous crop. There was 9.5" and 9.6" of water in the 6-foot soil profile when the previous crop was safflower and yellow mustard, respectively, versus an average of 10.9" of water when the previous crop was wheat or barley. Glyphosate was applied at 16 oz./acre to plots in early April and all crops were sown between April 10-19. Sowing rates per acre were: wheat 70 lb., barley 70 lb., safflower 36 lb., and yellow mustard 7.5 lb. Yellow mustard seedlings were killed by frost and the plots were re-sown on April 30.

In Douglas county, plots were sprayed with 16 oz./acre glyphosate in late April and all crops were sown on May 5. Total water content in the 2.5 foot soil profile was 5.5". Fertilizer rate was 30-8-0-8 applied in Solution 32 formulation. Sowing rates for all crops were the same as in Adams county.

Plant Stand Establishment: As in previous years, plant stand establishment of safflower and yellow mustard were hampered in 1999 at the Adams county site where plots are sown with the Flexi-Coil 6000 drill (Table 1). The Flexi-Coil 6000 drill has fertilizer and seed + starter fertilizer disc openers (i.e., double shoot) in the same row. The problems we have experienced are due variable soil cover among rows. Plants stands of all crops sown with the Cross-slot drill in Douglas county have been excellent during all years (Table 1). We may use the Cross-slot to sow broadleaf crops at the Adams county site beginning in the year 2000.

Table 1. Plant stand establishment of four crops sown no-till in Adams and Douglas counties in 1997, 1998, and 1999. Plots in Adams county were sown with a Flexi-coil 6000 disc drill and in Douglas county with a Cross-slot disc drill.

Crop	Location and Year†					
	Plants per ft^2					
	Adams County			Douglas County		
	1997	1998	1999	1997	1998	1999
Safflower after y. mustard	2.5	3.2	0.8	5.0	3.8	5.8
Y. mustard after safflower	1.8	0.7	0.8	7.0	2.4	10.6
Barley after wheat	8.6	15.3	9.0	10.3	20.4	15.2
Wheat after barley	---	20.7	10.6	---	22.2	13.9
Wheat after y. mustard	---	20.0	9.4	---	20.5	16.5
Wheat after wheat	9.6	18.6	9.7	10.9	26.2	13.3

† All crops were sown into spring wheat stubble in 1997, which was the first year of the study.

Rhizoctonia Root Rot: Severe infection of rhizoctonia root rot occurred in wheat and barley at the Adams county site in 1999. The clearly visible rhizoctonia patches were mapped with a global positioning unit and are shown in Fig. 1. The land area with rhizoctonia patches ranged from 3.2% (wheat after barley) to 7.3% (barley after wheat), but differences among treatments were not significantly different (Table 2).

We were surprised to find the high incidence of rhizoctonia severity in the four-year rotation where wheat follows two years of broadleaf crops. We plan to superimpose experiments in the plots in the 2000 crop year to study the possible association of zinc, copper, and other micro-nutrients with rhizoctonia disease (Cook).

Table 2. Percent land area in wheat and barley plots with rhizoctonia bare patches at the Adams county site in 1999 as measured by a global positioning system. There were no significant differences in rhizoctonia patches among rotations.

Crop Rotation	Percent of plot area with Rhizoctonia patches
Four year rotation	
Safflower	---
Yellow mustard	---
1st year wheat	3.4
2nd year wheat	6.6
Two year rotation	
Wheat	3.2
Barley	7.3
Continuous wheat	6.5

Weeds: Populations of all weed species and the dry biomass they have produced by time of crop harvest were again measured in 1999. A 3-sq.-yard sampling frame was used to collect weeds from three locations in each plot at both Adams and Douglas county locations. Russian thistle is the dominant weed at both sites. Marestail, prickly lettuce, tumble mustard, tansy mustard, and lambsquarter were present in safflower and yellow mustard crops (for which there are no labeled in-crop herbicides) (Tables 3 and 4). However, these weeds have been brought under control with 8 oz. of Salvo (2,4-D) plus 3 oz. Harmony extra applied in the tillering stage when the rotation reverts back to wheat. To date in Adams county, there have been no significant differences in any weed species in wheat as affected by crop rotation treatment (Tables 3 and 4).

In addition to Russian thistle, marestail and annual bursage are problem weeds in Douglas county. The proliferation of weeds in safflower and yellow mustard may be largely due to the slow growth rate of these broadleaf crops at this northerly and high elevation site (see crop yields section). In-crop weed control for cereals in Douglas county has been with 2,4-D (1997) and 1.5 pints of Bronate (1999). Russian thistles produced more than 400 lb./acre biomass in 1998 when we missed the opportunity to spray weeds in cereals in Douglas county (Table 5), but populations in cereals were brought under control in 1999 (Table 6). We plan to continue monitoring weed ecology and possible weed species shifts at both sites.

Table 3. Dry biomass produced by four weed species, as well as total weed biomass, in 1998 in Adams county as affected by crop and crop rotation.†

	Russian Thistle	Marestail	Prickly Lettuce	Tansy & Tumble Mustard	Total† Weeds
	lb./acre				
Four-year rotation					
Safflower	283 b‡	179 a	154 a	256 b	882 b
Yellow mustard	542 a	93 b	15 b	512 a	1162 a
1st-year wheat	23 c	1 c	0 b	2 c	27 c
2nd-year wheat	17 c	15 c	10 b	9 c	54 c
Two-year rotation					
Wheat	17 c	6 c	11 b	4 c	37 c
Barley	20 c	6 c	1 b	2 c	31 c
Continuous wheat	29 c	15 c	17 b	10 c	72 c

† Total weed biomass also includes small quantities of lambsquarter, downy brome, volunteer barley, volunteer wheat, pigweed, and prostrate knotweed.
‡ Within-column averages followed by a different letter are significantly different at the 5% probability level.

Table 4. Dry biomass produced by five weed species, as well as total weed biomass, in 1999 in Adams county as affected by crop and crop rotation.

	Russian Thistle	Mares-tail	Prickly Lettuce	Lambs-quarter	Tumble Mustard	Tansy Mustard	Total† Weeds
	lb./acre						
Four-year rotation							
Safflower	622 b‡	20 a	77 a	34 ab	141 a	40 a	934 b
Yellow mustard	1102 a	2 b	65 a	80 a	38 b	40 a	1329 a
1st-year wheat	88 c	1 b	0 b	0 b	0 b	1 b	95 b
2nd-year wheat	169 c	8 ab	0 b	0 b	0 b	2 b	182 b
Two-year rotation							
Wheat	65 c	6 ab	0 b	0 b	0 b	0 b	71 b
Barley	27 c	4 b	0 b	0 b	0 b	0 b	38 b
Continuous wheat	56 c	11 ab	6 b	0 b	0 b	0 b	68 b

† Total weed biomass also includes small quantities of Canadian thistle and prostrate knotweed.
‡ Within-column averages followed by a different letter are significantly different at the 5% probability level.

Table 5. Dry biomass produced by two weed species, as well as total weed biomass, in 1998 in Douglas county as affected by crop and crop rotation.

	Russian Thistle	Marestail	Total Weeds†
	lb./acre		
Four-year rotation			
Safflower	2004 a‡	165 b	2267 a
Yellow mustard	1437 ab	367 a	2045 a
1st-year wheat	860 bc	35 b	1248 b
2nd-year wheat	408 c	34 b	478 c
Two-year rotation			
Wheat	540 c	54 b	638 bc
Barley	404 c	39 b	523 c
Continuous wheat	481 c	31 b	513 c

† Total weed biomass also includes small quantities of annual bursage, lambsquarter, sunflower, pigweed, and mustard.

Table 6. Dry biomass produced by three weed species, as well as total weed biomass, in 1999 in Douglas county as affected by crop and crop rotation.

	Russian Thistle	Marestail	Annual Bursage	Total† Weeds
	lb./acre			
Four-year rotation				
Safflower	1137 a‡	248 a	197 a	1742 a
Yellow mustard	757 b	245 a	172 a	1200 b
1st-year wheat	32 c	1 b	6 b	39 c
2nd-year wheat	115 c	2 b	55 b	172 c
Two-year rotation				
Wheat	32 c	7 b	4 b	37 c
Barley	27 c	8 b	6 b	40 c
Continuous wheat	55 c	4 b	14 b	69 c

† Total weed biomass also includes small quantities of lambsquarter, downy brome, volunteer barely, volunteer wheat, pigweed, and prostrate knotweed.
‡ Within-column averages followed by a different letter are significantly different at the 5% probability level.

Crop Yields: Although over-winter precipitation was greater than average, total precipitation at the Adams county site was only 7.81 inches from September 1, 1998 to August 31, 1999. March through June cumulative rainfall was 1.18 inch. Below freezing temperatures occurring on May 22 and July 3 severely reduced yellow mustard yields. Safflower produced 1050 lb./acre despite harsh growing conditions. Wheat averaged 26.7 bu./acre with no significant difference in yield among rotations. Barley yields were a disappointing 0.76 ton/acre. Yields of all crops in all rotations since 1997 in Adams county are shown in Table 7.

Table 7. Crop yields in three rotations in Adams county: a 4-year safflower/yellow mustard/wheat/wheat rotation; a 2-year wheat/barley rotation and; continuous spring wheat. All crops were direct sown with a Flexi-Coil 6000 drill as part of a long-term cropping systems study.

	Units	1997†	1998	1999
Four year rotation	lb/acre			
Safflower	lb/acre	1420	720	1040
Yellow mustard	bu/acre	1430	340	110
1st year wheat	bu/acre	---	41.1‡	26.7
2nd year wheat	bu/acre	---	---	25.3
Two year rotation				
Wheat	bu/acre	---	40.3	27.8
Barley	ton/acre	2.30	1.13	0.76
Continuous wheat	bu/acre	64.3	40.5	26.9

† All crops were sown into spring wheat stubble in 1997, which was the first year of the study.
‡ Wheat yields among treatments were not significantly different at the 5% probability level in 1998 nor in 1999.

In Douglas county, precipitation from September 1, 1998 to August 31, 1999 was 10.3 inches. Yellow mustard and safflower do not appear well adapted to the very shallow soils and cool temperatures at this site as growth and yield from these crops in 1999 were low for the third straight year (Table 8). Wheat yield was 18.3 bu./acre averaged across treatments and there were no significant differences in yield due to crop rotation. Barley was difficult to harvest because of short plant height with grain yield only 0.35 tons/acre. Yields of all crops in all rotation combinations in Douglas county since 1997 are shown in Table 8.

Table 8. Crop yields in three rotations in Douglas county: a 4-year safflower/yellow mustard/wheat/wheat rotation; a 2-year wheat/barley rotation and; continuous spring wheat. All crops were direct sown with a Cross-slot drill as part of a long-term cropping systems study.

	Units	1997†	1998	1999
Four year rotation	lb/acre			
Safflower	lb/acre	630	340	420
Yellow mustard	bu/acre	410	140	330
1st year wheat	bu/acre	---	27.6‡	18.2
2nd year wheat	bu/acre	---	---	15.9
Two year rotation				
Wheat	bu/acre	---	25.5	20.9
Barley	ton/acre	1.20	1.00	0.35
Continuous wheat	bu/acre	19.2	26.2	18.2

† All crops were sown into spring wheat stubble in 1997, which was the first year of the study.
‡ Wheat yields among treatments were not significantly different at the 5% probability level in 1998 or 1999.

Straw Production and Grain Yield Relationships in Winter Wheat

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Interpretive Summary

Winter wheat - fallow is the predominant cropping system in low-precipitation regions of the inland Pacific Northwest of the USA. Wind erosion is a recurrent problem when crop residue, the main source of soil protection, is lacking. Management options that optimize both grain yield and straw production are needed. A 3-year field study was conducted at Lind, Washington, to determine sowing rate and sowing date effects on straw and grain yield, and grain yield components, of winter wheat varieties with semidwarf, standard height, or tall growth habit. Four winter wheat varieties were evaluated at three sowing rates (20, 40, and 60 lb/a) and three sowing dates in August, September, and October. Sowing dates were the main plots and all sowing rate x variety combinations were subplots. The greatest effect of sowing date was on straw production. Straw biomass from mid-August sowing averaged 5,980 lb/a compared with 4,150 and 2,480 lb/a from mid-September and mid-October sowing, respectively. Grain yield was highest for mid-August sowing during two years and lowest for mid-October sowing all years. Averaged across years, the semidwarf variety produced the highest grain yield on all sowing dates and was equal to the standard height and tall varieties for straw production. Variation in grain yield was due primarily to differences in spikes per unit area (SPU) and kernels per spike (KPS). Late sowing resulted in a large reduction in SPU and, therefore, grain yield. For cropland susceptible to wind erosion in the inland PNW, early sowing results in increased wheat straw production and generally higher grain yield compared with mid to late sowing dates.

Abbreviations: HRWW, hard red winter wheat; KPS, kernels per spike; SPU, spikes per unit area; SWWW, soft white winter wheat; TKW, thousand kernel weight.

Study Methods

A 3-year winter wheat variety x sowing rate x sowing date experiment was conducted between August 1994 and July 1997 at the Washington State University Dryland Research Station at Lind, Washington. Annual precipitation at the site averages 9.61 inches. Treatments consisted of four winter wheat varieties (Buchanan, Hatton, Moro and Eltan) evaluated at three sowing rates and three sowing dates. Buchanan and Hatton are tall and standard height hard red winter wheat (HRWW) varieties, respectively. Moro is a standard height, club-spike, soft white winter wheat (SWWW), and Eltan is semidwarf, common-spike, SWWW. Hatton has stiff straw, mid-sized spikes, and moderate tillering. Buchanan and Eltan have a finer, more limber straw, smaller spikes, and profuse tillering. Moro has large spikes, large diameter straw, and low-to-moderate tillering. These varieties are representative of the different market classes and phenotypes grown in the low-precipitation dryland cropping region of the inland Pacific Northwest.

The experimental design was a split plot, with main plots arranged as randomized complete blocks. Main plots were sowing dates, and subplots were all variety x sowing rate combinations. Sowing rates were 20, 40, and 60 lb/a, and sowing dates were approximately 20 August, 16 September, and 21 October. Sowing dates for each month varied by a few days among years.

Precipitation during the study was greater than the long-term average, except for the 1993-1994 fallow cycle, which was drier than average. Soil water content in the seed zone as well as in the total 6 ft profile was measured in mid-August. Available water for winter wheat in the 6-ft soil profile at the end of fallow in mid-August was 2.2, 4.5, and 3.7 inches in 1994, 1995, and 1996, respectively. Soil water content at depth of seed placement for August and September was 11.5, 12.7, and 13.4 percent by volume in 1994, 1995, and 1996, respectively. Seed-zone water content was barely sufficient for stand establishment in August and September of 1994, but was quite adequate in 1995 and 1996. Depth of soil covering the seed was 6.3 inches 1994, 3.9 inches 1995, and 3.9 inches in 1996. Sowing during October in all years occurred after the surface soil had been wetted by rain and only 1 inch of soil covered the seed.

Treated certified seed of all four varieties was sown in 20 ft-long x 8 ft-wide plots with a deep-furrow split-packer drill with 16 inch spacing between rows. Wheat survived the relatively mild winters with little or no cold damage. Broadleaf weeds were controlled during the growing season with herbicide applied in mid-April. In late July, mature plants from 3-ft row sections from each plot were clipped and spike number per unit area (SPU) determined. Spikes were threshed and a subsample was used to determine 1000 kernel weight. Kernels per spike was calculated from the 1000 kernel weight. Grain yield and straw production was determined by taking a 4 ft swath (outside of the hand-sample area) through each plot with a plot combine. The combine cutting bar was operated at ground level and residue was collected on a tarp attached to the back of the combine, then weighed.

Results and Discussion

Altering sowing rate caused significant changes in all variables measured. Grain yield was not decreased by low sowing rate in August, but was reduced compared with medium and high sowing rates in September and October (data not shown). The low sowing rate reduced straw production at all sowing dates, but straw production was similar at medium and high sowing rates. Similarly, there were no differences in SPU among sowing rates for August sowing, but SPU rose incrementally with increased sowing rate for the September and October sowings (data not shown). In all years, the low sowing rate resulted in the lowest straw production. There were no differences in straw production between the intermediate and high sowing rates.

Marked increases in straw production always resulted from early sowing, more than doubling straw produced from the October sowing in all years (Fig. 1a). The quantity of straw decreased about 30% per month, being 71% and 42% of the August amount for September and October, respectively. Grain yield was highest with early sowing in 1995 and 1997 and better than October sowing in all years (Fig. 1b). Spike number was consistently higher for August vs. October sowing and was reduced compared with September sowing only in 1996 (Fig. 1c). There were no consistent sowing date relationships in TKW or KPS (Fig. 1d and 1e).

All varieties consistently produced less straw as sowing date was delayed (data not shown). Moro generally produced the least straw, but not significantly less than Hatton in two years. Grain yield was always highest for Eltan, whereas there were no differences among the other varieties on any sowing date. Moro invariably had the lowest SPU and TKW, but compensated with high KPS (data not shown). Conversely, Buchanan constantly produced an abundant number of spikes with high TKW, but with very low KPS.

Averaged across sowing dates and rates, straw production remained relatively constant (within 1000 lb/a) among varieties each year during the 3-year period. Eltan had a higher grain yield than the other varieties in two out of three years, but there was no consistent trend (data not shown).

Summary

This study was conducted to determine the best combination of sowing rate and sowing date in semidwarf, standard height, and tall winter wheat varieties on straw production, grain yield, and yield components. Grain yield was governed primarily by SPU and KPS, with less influence from TKW. Higher SPU caused a large decrease in KPS, and a small reduction in TKW. Higher KPS resulted in relatively large decreases in TKW. Data underscore the importance of spikes per unit area in the determination of grain yield under low-precipitation conditions.

Results from this study show that early sowing of winter wheat will maximize straw production. In addition, early sowing will likely enhance grain yield compared with medium and late sowing dates. Provided that adequate plant stands are achieved, semidwarf varieties will produce as much straw as standard height and tall varieties.

A comprehensive report on this study with full data sets will be published later this year in the *Pacific Northwest Conservation Tillage Handbook* and in *Wheat Life*. If you have comments or questions about this article, please contact Bill Schillinger at (509) 659-0355 or e-mail: schillw@wsu.edu.

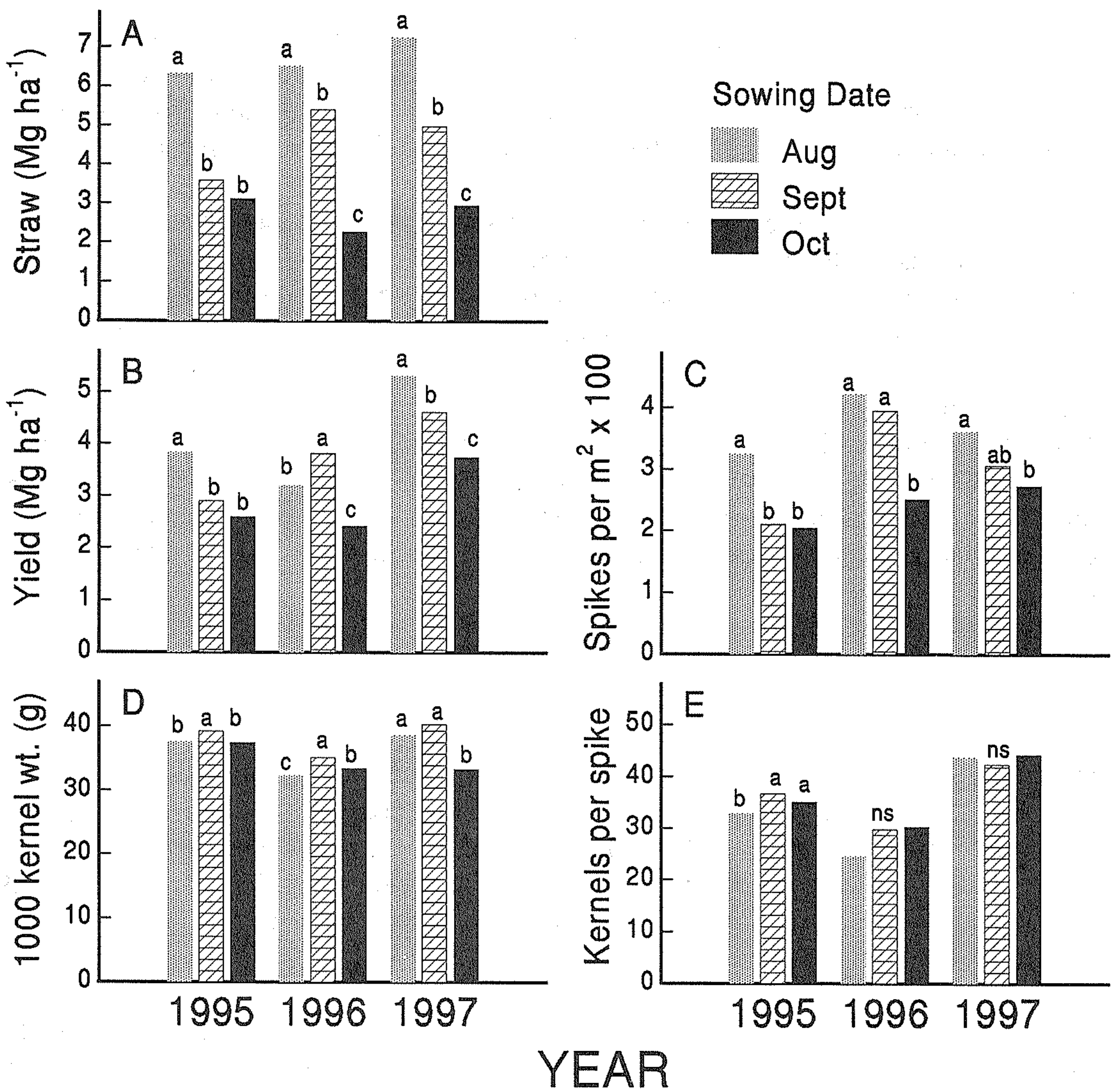

Figure 1. Straw production, grain yield, and yield components as influenced by sowing date in 1995, 1996, and 1997, averaged across four winter wheat varieties and three sowing rates at Lind, Washington. Within-year averages followed a different letter indicate significant differences at the 5% probability level.

Grower-Initiated On-Farm Research on Direct-Seed Cropping Systems in Cooperation with Research Partnerships

Dennis Roe, R. James Cook, Roger Veseth, Trevor Cook, Jon Jones, Tony Ingersoll, Dave Huggins, Ann Kennedy, Dave Bezdicek, Mary Fauci, Joe Yenish, John Burns Ron Sloot, Susan Kerr, Dave Clayton, Kevin Zander, Joe Dahmen, Steve Reinertsen, and a growing list of other collaborators from WSU, U of I, ARS, NRCS, conservation districts, and Ag support companies.

Research and grower experience has shown that the success of direct seed systems is greatly enhanced with the use of longer, more diverse crop rotations for several crop benefits. Some of these benefits are effective pest and disease control, including control of the "green bridge", increased diversity of herbicide classes, effective water use, and spread of field workload.

Highlighted in this article are two examples of direct seed cropping systems initiated by growers in 1998 in cooperation with their local conservation districts, industry persons, and university and extension staff. One study, the Northwest Crops Project, was conceived by Tracy Eriksen, St. John grower, and the Palouse-Rock Lake Conservation District. The other study was initiated by Bickleton grower Steve Matsen, in cooperation with the Eastern Klickitat Conservation District.

Northwest Crops Project

This project focuses on comparison of a four-year rotation of cool season and warm season crops with a traditional three-year cool season crop rotation in this region of winter wheat-spring-barley-broadleaf crops and fallow. The four-year rotation of spring wheat-winter wheat-field corn-spring broadleaf has been successful on the Dakota lakes Research Farm in South Dakota. The study will be for evaluation of the effects of this rotation on future wheat yields and soil quality with field corn in the rotation.

There are eight replications of the rotations on seven farms. All crops will be planted with field scale equipment at each site each year. The plan is to continue the trial through two cycles of the four-year rotation. All sites are in the 15-18 inch rainfall zone on Athena silt loam soils. Such soil characteristics as soil pH, bulk density, and organic matter levels have been measured at three depths: 0-2 inches, 2-4 inches, and 4-12 inches to compare with later measurements for changes in soil quality in 8 years. Surface soil condition has improved in the two years. All seeding is done without tillage and no crop residue is removed.

The participating growers are Tracy Eriksen- St. John, Steve Swannack- Lamont, Dan and Steve Moore- Dusty, Randy Repp- Dusty, John and Cory Aeschliman- Colfax, LeRoy Druffel-Uniontown, David and Paul Ruark- Pomeroy. Scientists from about seven disciplines will be involved in analyzing and interpreting the data from the trials.

Bickleton Study

The primary focus of this study is to identify one or more broadleaf crops for an area that has produced cereal crops, with fallow, or with recrop. The study will compare these continuous cereal systems with 3-year rotations including one year of a variety of broadleaf crops.

The 3-year rotation in this study will be winter wheat-spring barley-broadleaf. Each block for the broadleaf crops is divided into four equal side-by-side plots of dry pea, linola, yellow mustard, and safflower. Each block of broadleaf crops was then seeded uniformly with winter wheat the second year, and will then uniformly with spring barley the third year. This design provides for economy of land-use while comparing the performance, agronomic needs, and rotational benefits of each of four different broadleaf crops. The continuous cereals include both alternating winter and spring wheat, and alternating winter wheat and spring barley.

The Bickleton study will have all replicates and each crop of each replicate included as a complete study on each farm. The study began in 1998 on the Gordon King farm and on the Steve Matsen farm in 1999.

Collaborative Efforts Offer the Greatest Potential

Long-term, collaborative efforts among growers, researchers, conservation districts, Ag industry and Ag support groups provide the greatest potential for rapid development and adaptation of new crops, rotations and management technologies for successful direct seed systems in the Northwest.

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Dark Northern Spring Wheat
Risk and Return

by Aaron Esser

Introduction:

With the price of soft white wheat at such low prices, farmers are looking to produce any crop that will potentially help increase farm income. One crop growers are looking at is Dark Northern Spring (DNS) wheat. DNS wheat, which is defined as being at least 75% dark, hard, vitreous kernels, is one of three subclasses of hard red spring wheat (HRSW).

One thing a grower must understand and manage with DNS wheat production is the risk associated with this crop, especially compared to soft white spring wheat (SWSW). Overall, DNS wheat has greater risk than SWSW in four elements: weather, yield, price and production inputs.

Untimely summer rains may reduce protein content in DNS wheat, but growers have very little control over weather conditions. Timely harvest is one management practice to help reduce risk associated with weather in DNS wheat production.

Yield potentials will vary within regions, varieties and on individual farms, but overall, yield of DNS is about 6 bu/acre less than SWSW in trials throughout eastern Washington (Figure 1). Understanding the yield potential of DNS wheat varieties in specific areas will help growers make better management decisions.

DNS wheat has increased risk in price as the final protein content determines the market price. Premiums and discounts for protein content are historically pretty variable. During the 1990's, DNS wheat with 13% protein was sold for an average $0.31/bu less than DNS wheat with 14% protein, and DNS wheat with 15% protein was sold for an additional $0.19/bu over 14% protein. Overall, discounts for 13% protein DNS wheat during the 90's ranged from -$0.28 to $1.38/bu, and price premiums for 15% ranged from -$0.38 to $1.76/bu.

Understanding the historical price difference between DNS wheat and soft white wheat (SWW) will also help growers make better management decisions concerning DNS wheat production. Figure 2 shows the historical price advantage of DNS wheat over SWW. During the 1990's DNS wheat with 14% protein sold for an additional $0.81/bu more than SWW, and it ranged from as low as -$0.18 to as high as $2.73/bu.

Production inputs are very important for DNS wheat to maximize yield, protein and overall profitability, yet they are poorly understood among growers and researchers. A study at Pullman, WA (20-inch precipitation zone) in 1988 examined the impact of protein and yield with nitrogen applied at 40, 80, 120 and 160 lb N/acre with the nitrogen being applied in the fall, spring and split between fall and spring application.

Additional nitrogen increased yield, but timing of nitrogen application did not impact grain yield. Protein also increased with additional fertilizer (Table 1), and was significantly greater for the fall and split N as compared to the spring applications (Figure 3). This study determined that by final harvest, plant N for the spring application was significantly less than the fall and split application, and soil nitrate levels were significantly greater at the 3 ft depth for the fall applied N. A similar trend was observed for the split application, although not significant.

On-farm Testing of DNS Management Practices

Six on-farm tests were established throughout Adams and Lincoln Counties to look at the agronomic and economic impacts of production inputs and different management practices with DNS wheat production. All nitrogen fertilizer treatments were calculated using residual soil test nitrogen:

Crop Nitrogen Required (lb N/bu x potential yield)
\+ Nitrogen needed for incorporated cereal straw breakdown
\- Estimated N released from organic matter
\- Soil test results:
 NH_4 (1')
 NO_3 (3')
= total N to be applied

Gross economic returns were calculated using the market price at Ritzville Warehouse's FOB price on September 14, 1999. At this time the market price for DNS wheat was \$3.67/bu at 14% protein and an additional \$0.07/bu was added for every ¼% above 14% protein. Twelve cents per bushel was deducted from the market price for every ¼% below 14% protein. Net economic returns were calculated taking the gross return minus variable costs. Variable costs were estimated at \$0.20/lb for nitrogen fertilizer, \$16/cwt for DNS wheat seed, \$12/cwt for SWSW seed and an interest cost of 12%.

An on-farm test located about 2 miles north of Benge, WA was designed to examine the effects of fall vs. spring vs. split nitrogen fertilization on protein for DNS wheat productions and to compare it to SWSW production. Fall fertilizer treatments were done in mid December. Overall, SWSW (63 lb N/acre applied) had the greatest yield with 22.6 bu/acre, and the highest net return above fertilizer, seed, and interest costs with \$44/acre. Within the DNS wheat treatments (96 lb N/acre applied), the spring application of fertilizer had the greatest percent protein with 13.6% and the greatest gross return of \$70/acre. There was no significant difference in protein, gross return, and net return above fertilizer, seed and interest cost between the fall and split application of fertilizer. The split application of fertilizer had the lowest yield with 19 bu/acre.

An on-farm test located approximately 6 miles east of Lind was designed to examine the impact of increasing rates of spring applied nitrogen when fertilizer was applied in the fall. Forty-two pounds of nitrogen fertilizer per acre was applied at the trial location in the fall (late November), and an additional 10, 40 and 70 lb N/acre was spring applied with the "Scarlet" DNS wheat and an additional 10-lb N/acre was applied to Wawawai spring wheat. There was no significant difference in yield among the 4 treatments, and SWSW produced the highest gross return and net return above variable fertilizer with $92 and $72/acre. Within the DNS wheat treatments, applying 112 lb N/acre produced 12% protein, significantly greater than 10.6 and 11.1% protein obtained from applying 52 and 82 lb N/acre, respectively. The application of 112 lb N/acre produced a net return above variable nitrogen of $49/acre, significantly greater than the $39/acre obtained with applying only 52 lb N/acre.

A similar trial was established approximately 10 miles west of Ritzville, WA less the SWSW treatment. Sixty-three pounds of nitrogen fertilizer per acre was applied at the trial location in the fall (early October), and an additional 16, 38 and 60 lb N/acre was spring applied to "Spillman" DNS wheat. There were no significant differences in protein (14.7%), or return above variable nitrogen cost ($70/acre). The application of 123 lb of applied N had significantly greater seed yield with 25.0 bu/acre, and gross return with $97/acre. Applying 79 and 101 lb of applied N/acre produced yields of 22.1 and 21.7 bu/acre and gross returns of only $86 and $84/acre.

An on-farm test located approximately 5 miles west of Wilbur examines increased rates of nitrogen fertilizer with all the fertilizer applied in the spring at seeding. "Westbred 333" DNS wheat fertilized at 3.0, 3.6 and 4.2 lb N/bu with a 50 bu/acre potential bushels with 60, 90 and 120 lb applied N/acre. The application of only 60 lb N/acre produced the lowest yield with 39.6 bu/acre, the lowest protein content of 12.8%, the lowest gross return at $120/acre, and the lowest net returns above fertilizer cost of only $108/acre. The application of 90 lb N/acre had a yield of 41.2 bu/acre, a protein content of 13.6%, gross income of $141/acre and return above nitrogen cost of $123/acre. The application of 120 lb N/acre produced the greatest yield with 42.1 bu/acre, the greatest protein with 14.3%, the greatest gross return of $157/acre, and the greatest return above nitrogen cost of $133/acre.

It should be noted that the surrounding field of DNS wheat was fertilized at a rate of 90 lb N/acre and had a percent protein of 14.2%. The trial was harvested about 14 days later than the surrounding field, and during this period about 1 inch of precipitation fell and may of reduced percent protein on all three treatments.

Much like nitrogen, sulfur application is not well understood in DNS wheat production. An on-farm test approximately 6 miles south of Ralston, WA was designed to get a better understanding of sulfur needs for high protein DNS wheat production. 'Laura' DNS wheat was seeded with 55 lb N/acre applied to all treatments, and sulfur was applied at 10, 15, and 20 lb/acre, or a nitrogen:sulfur ratio of approximately 5:1, 4:1 and 3:1. Spring soil tests showed 8 ppm of sulfur, which is often deficient for this area. There were no significant differences in yield, protein, gross returns, or net returns above sulfur cost with applied sulfur. However, although there was no significant differences, there was a trend for greater yield, protein, gross return and net returns above sulfur cost with increased sulfur application. Further investigation is needed to evaluate DNS response to sulfur in this area.

An on-farm test was also established in the Sandhills area, approximately 15 miles south of Lind, WA, to compare four DNS wheat varieties for yield and protein potential. The varieties were "Kulm", Scarlet, Spillman and "Westbred 926". Significant differences were observed in establishment, yield, protein and gross economic returns. Spillman had the greatest yield at 21.8 bu/acre but had the lowest protein content at 15.2 %. Scarlet yielded 19.2 bu/acre with 15.9% protein, Kulm yielded 14.9 bu/acre with 16.1% protein, and Westbred 926 yielded only 14.3 bu/acre but had the highest protein content at 16.4%. Overall, Spillman and Scarlet had significantly greater gross returns than Kulm and Westbred 926 with $86 and $80/acre. Kulm and Westbred 926 had gross returns of only $63 and $62/acre.

The grower observed that Westbred 926 was slower to establish than the other 3 varieties probably because it was more sensitive to cold wet spring conditions. Consequently, Westbred 926 had at least 32% lower stand population than the other varieties.

<u>Conclusions</u>

Fall applied fertilizer did not greatly increase the amount of available fertilizer in the 2nd and 3rd foot in the soil in these on-farm tests, and consequently, did not appear to positively impact yield, protein and economic returns in DNS wheat production in 1999. On the whole, very little of the fall applied fertilizer was accounted for in spring soil samples when nitrogen was applied in November and December and the bulk of the nitrogen accounted for remained in the 1st foot in the soil profile. At the location near Benge, over 67% of the fall-applied fertilizer was unaccounted for. Most of the nitrogen that was accounted for was in the form of NH_4 (ammonium nitrate) in the 1st foot. Only an additional 3-lb NO_3-N/acre (nitrate) was available in the 2nd and 3rd foot when fertilizer was applied in the fall. At the location near Lind, applying 42 lb N/acre in the fall increased the total available nitrogen in the spring of the year by only 17 lb N/acre. The fall-applied fertilizer that was accounted for was mostly in the form of NH_4 nitrogen in the first foot (13 lb additional N/acre). An additional 6 lb N/acre was available in the form of NO_3 in the third foot, and there was no additional available nitrogen in the first and second foot in the form of NO_3. One potential reason for the large amount of nitrogen unaccounted for at these locations may be in the soil sampling procedure used in the spring of the year given the conditions. Late fall fertilization combined with cold soil conditions in the spring of the year restricted fertilizer movement both vertically and horizontally in the soil profile. A systematic soil sampling method (Figure 4), as defined in the University of Idaho Extension Publication 704, was used which takes soil samples (20 soil cores to form a composite sample) perpendicular to the band row beginning in the edge of the adjacent band. A more appropriate spring soil sampling method may have been to pull soil cores only from the shank marks or use a random sampling method taking 40 to 60 random soil cores to form a composite sample.

At the location near Ritzville when nitrogen fertilization was earlier in the fall, all but 9 lb N/acre was unaccounted for between the spring and fall soil sampling using the systematic soil sampling method. Most of the fall-applied fertilizer was still accounted for in the form of NH_4 in the first foot (47 lb N/acre). An additional 6 lb N/acre was available in the form of NO_3 in the top foot, and only an additional 3 lb N/acre was present in the second and third foot.

<u>How much nitrogen is needed for profitable DNS wheat production?</u>

Under similar market price structures, do not reduce the amount of nitrogen and sulfur fertilizer with DNS wheat production. On-farm tests yield potentials were not achieved in most cases, therefore, greater than recommended fertilizer was available, and protein levels were still below the goal of 14% with all treatments in three of the on-farm tests. However, in all the on-farm tests, the higher rates of inputs were more economical or were not less economical than lower inputs. For example, the trial near Wilbur was fertilized at 3.0, 3.6 and 4.2 lb of nitrogen for a potential yield of 50 bu./acre. However, yield ranged from only 39.6 to 42.1 bu/acre. The actual rate of available nitrogen for a bushel of grain was 3.8, 4.4 and 5.0 lb of nitrogen (Table 2). Applying 5.0 lb of nitrogen/bu. was the only treatment to reach the desired 14% protein content, much higher than previous research has shown.

<u>Field Selection:</u>

Field selection and proper soil sampling is very important in DNS wheat production. Proper soil sampling may be more economically feasible than applying fall nitrogen fertilizer and relying on fall and early spring moisture to move nitrogen into the soil profile. For example, select fields with large amounts of available nitrogen in the 2nd and 3rd foot. If two fields both have 75 lb N/acre available but field A has only 13 lb N/acre available in the 2nd and 3rd foot and field B has 32 lb N/acre available, field B may be more desirable for profitable DNS wheat production without fall fertilization.

Soil sampling is also important following DNS wheat production. With increased nitrogen application, there is a greater chance to have a larger amount of available nitrogen after DNS wheat, and rates for following crops should be adjusted accordingly. It should also be important to monitor where the nitrogen is at in the soil profile and choose crops according to their ability to utilize nitrogen deeper in the soil profile.

<u>Profitable DNS wheat Production:</u>

Profitability between DNS wheat and SWSW will depend greatly on the market price differential between the 2 classes of wheat and the DNS wheat protein premium/discount. Variety selection is also very important in profitable DNS wheat production. At the current protein premiums/discounts selecting a variety with greater yield potential with good protein content can be more profitable than a variety with lower yield potentials but high protein content. For example at the trial near Sandhills, 14 bu/acre Kulm would require a 19.9% protein content to have the same gross return ($80/acre) as the variety Scarlet that yielded 19 bu/acre and 15.9% protein.

<u>Summary for Profitable DNS wheat production:</u>

1. Timely harvest to reduce weather risk.
2. Understand the market price differential between DNS wheat and SWW.
3. Understand protein premiums/discounts and make management decisions accordingly.
   - There is <u>less</u> risk associated with top-dressing for higher protein content with high premiums/discounts.
4. Choose a variety that has performed well in your area, and remember protein content is important but it is often difficult to beat yield.
5. Proper soil sampling prior to and after DNS wheat.
6. Do not use reduced rates of N and S fertilizer. Additional fertilizer will not guarantee protein contents of 14%, but, on-farm tests in 1999 showed that the additional investment was recovered with greater yields and increased protein contents

Table 1. Total nitrogen required for a bushel of grain to reach a desired protein level in hard red spring wheat at Pullman, Washington, and total nitrogen required for soft white spring wheat in different precipitation zones.

% protein	Total N Required (lb N/bu)
12	3.0
14	3.6
16	4.2
SWSW (<21" precipitation)	2.3
SWSW (>21" precipitation)	2.4

Source: Washington State University and the University of Idaho.

Table 2. Potential and actual nitrogen required per bushel of DNS wheat at a 50 bu/acre yield potential in an on-farm test near Wilbur, WA in 1999.

Treatment	Potential N required (lb/acre)	Yield (bu./acre)	Lb Available Nitrogen/bu.†	Percent Protein
60 lb Applied N/acre	3.0	39.6	3.8	12.8
90 lb Applied N/acre	3.6	41.2	4.4	13.6
120 lb Applied N/acre	4.2	42.1	5.0	14.3

† Calculation does not consider nitrogen remaining after harvest.

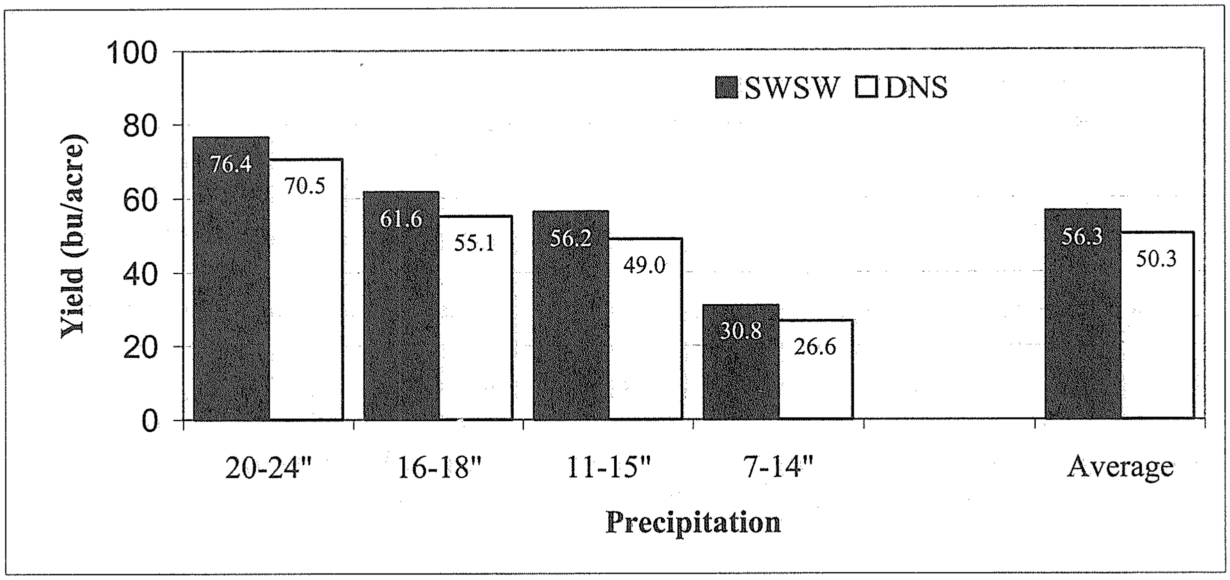

Figure 1. Average yield based on 97, 98 and 99 WSU variety trial results of 4 commercially available SWSW and DNS wheat varieties in different precipitation zones located throughout eastern Washington. Source: http://variety.wsu.edu/.

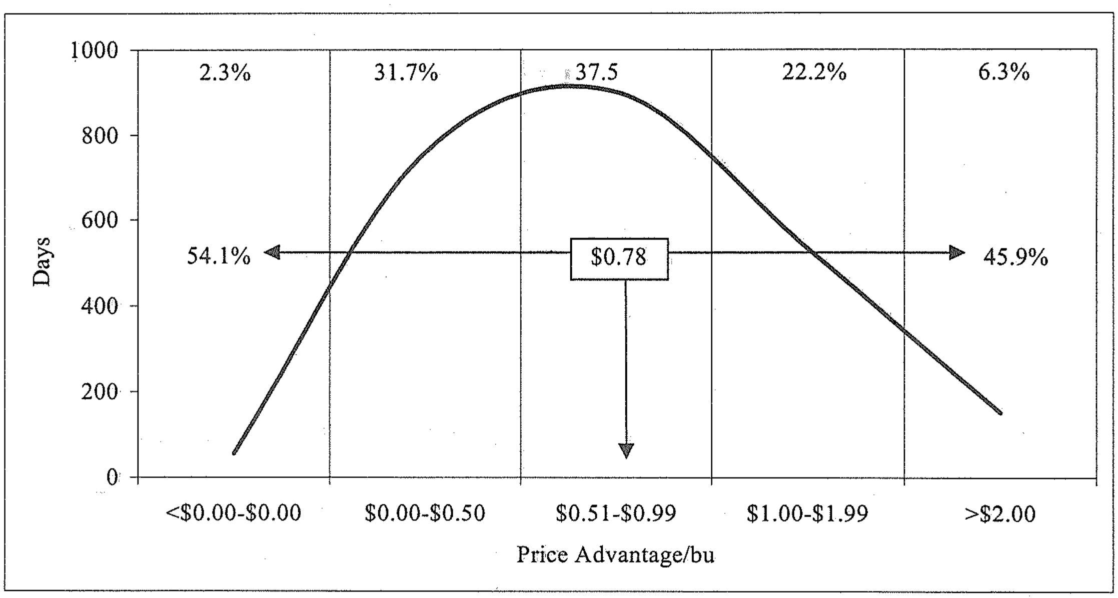

Figure 2. The historical price advantage of DNS (14%) over soft white wheat during the 1990's and how the current price advantage ($0.78/bu) relates to the historical price advantage. For example, 37.9% of the 90's DNS at 14% protein has had a price advantage between $0.51 to $0.99/bu.

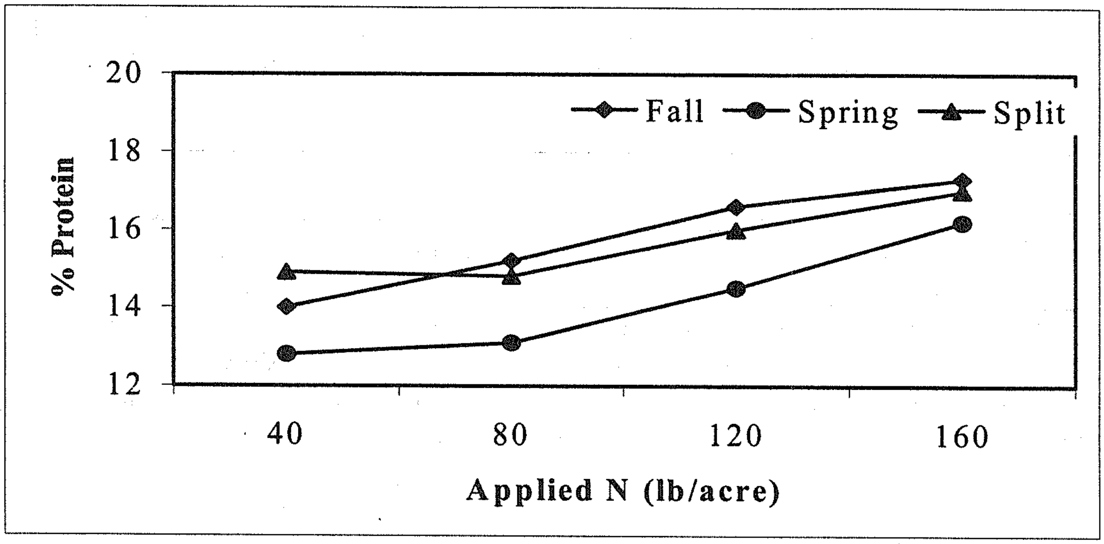

Figure 3. Percent protein with increasing rates of nitrogen applied in the fall, spring and split between the fall and spring at Pullman, WA (20-inch annual precipitation) in 1988.

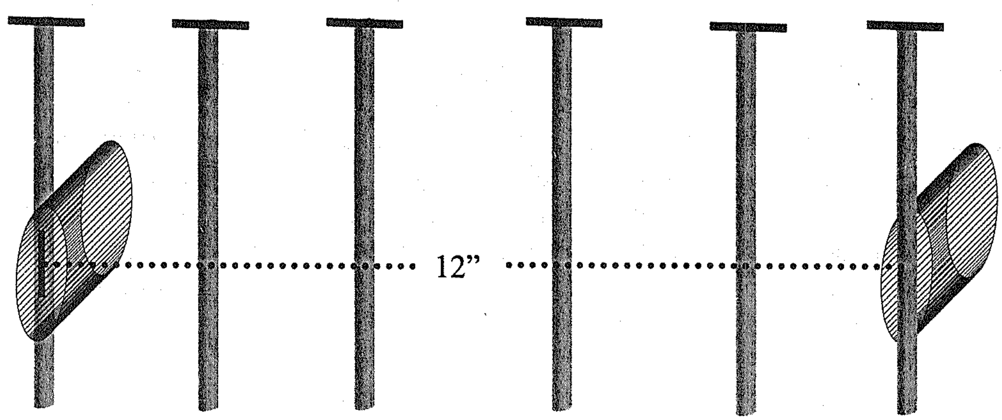

Figure 4. Systematic soil sampling method in a field where fertilizer had been banded with 12-inch shank spaces. Source: Soil Sampling, University of Idaho, Bulletin 704.

PERFORMANCE OF ADVANCED LINES AND VARIETIES OF SPRING BARLEY SEEDED DIRECTLY INTO WHEAT OR BARLEY STUBBLE

R. James Cook, Steve Ullrich, and William Schillinger

In addition to erosion control in all agronomic zones, direct-seeding offers the means to increase the diversity and intensity of cropping in the low- and intermediate-precipitation areas traditionally dependent on a winter wheat/summer fallow rotation, thereby broadening the economic base of the farm and spreading risks over more crops. Areas that currently produce five crops in each field every 10 years have the potential with direct seeding to produce seven or eight crops while cutting the years of summer fallow in half or even less. Areas that currently use a winter wheat/spring cereal/summer fallow rotation have, with direct seeding, the potential to eliminate summer fallow all together. In the higher precipitation areas, such as the Palouse, where annual cropping is already a common practice, direct seeding offers one of the best means by which to reduce inputs.

Spring barley has proven particularly well-suited to direct seeding into cereal stubble. Rhizoctonia root rot has been the most apparent hazard encountered with direct-seeded barley, but tools such as greenbridge management and fertilizer placement are helping greatly to reduce the risk of this disease. Research and grower experience has shown that virtually any drill equipped to 1) place seed through surface residues into good soil contact, 2) place fertilizer directly below or below and slightly to one side of the seed, 3) loosen soil beneath the seed for seminal root penetration, and 4) clear trash from within the seed row will be acceptable.

Further significant advancements towards achieving the high yields possible with direct-seeded spring barley will come with development of varieties with resistance or tolerance to the hazards encountered with this method of farming. Towards this end, research is underway on two fronts: Evaluation of existing varieties to determine their suitability to direct seeding, and identification or development of barley germplasm with resistance to Rhizoctonia root rot for use in the breeding program. In addition to greenhouses tests, a field test to screen both spring barley and spring wheat for resistance to Rhizoctonia root rot is under development on Spillman Farm. The development of Rhizoctonia resistant varieties is a long-term effort.

The variety evaluation studies were begun about six years ago and now include sites near Dusty, Ritzville, Bickleton and Pullman. All tests are done with excellent greenbridge management and a one-pass system that seeds and places fertilizer and loosens the soil directly beneath the seed. All tests have been with spring barley seeded directly into stubble of either spring barley (Pullman, 1999 and Ritzville, 1999a) or winter wheat (all other sites). Yields of a select subset of varieties tested to date are presented in Table 1.

In general, the yields have been good to excellent. The low yields at the Dusty site in 1999 were due to severe Rhizoctonia root rot, which otherwise has been managed reasonable well in these trials. As with experience with conventional seeding, Baronesse has been at or near the highest yielding spring barley in these tests.

Table 1. Yields of spring barley seeded directly into stubble of winter wheat or spring barley stubble.

	Pullman	------------ Ritzville			------------	--------- Dusty	---------		Bickleton	
	1999	1997	1998	1999a	1999b	1997	1998	1999	1998	1999
Variety	(lbs/A)	(lbs/A)	(lbs/A)	(lbs/A)	(lbs/A)	(lbs/A)	(lbs/A)	(lbs/A)	(lbs/A)	(lbs/A)
Crest	3500	2524	2644			3788	3079	1160	1961	
Harrington	3640		2549		1960	3799	2549	1660	1806	2580
Colter		2718				4260				
Baronesse	4400	2955	2899	2140	2100	4373	3120	1600	2022	2920
Meltan	4620	2855	2571			3639	2993	1500	1550	
Camelot	3680		2635		2140	4430	3147	1400	1583	
Gallatin	3360		2679	2120	2000	3816	2679	1740	1748	2520
Maranna						4023				
WA 9792-90	5000					4218				
Chinook			2635		2140		2622		1559	2480
WA 7114-93			2475	2240	2280		2788		1603	2440
WA 8772-93			2514				3093		1650	
WA 8394-93			2509	2020	2100		2534		1596	2220
Pongo				1920	2100					2160
Tofta	4400			2000	2100					2520
Average	4075	2760	2610	2075	2100	4040	2850	1510	1970	2480

Ritzville 1999a – Direct-seeded into winter wheat stubble
1999b – Direct-seeded into spring barley stubble

PERFORMANCE OF ADVANCED LINES AND VARIETIES OF SPRING AND WINTER WHEATS SEEDED DIRECTLY INTO CEREAL STUBBLE

R. James Cook, Steve Jones, and Kim Kidwell

Efforts have been underway for the past several years to evaluate the performance of a limited number of advanced lines and standard varieties of spring and winter wheat as well as seed treatments under direct-seed conditions in the field. The tests are conducted at Bickleton in cooperation with Steve Matsen, Colfax in cooperation with John and Cory Aeschliman, and Pullman on the Palouse Conservation Field Station. The spring and winter wheat tests at the Bickleton site are side by side in the same field. The Colfax site is actually two dedicated sites in separate fields alternated between spring and winter wheat, but still providing data on both kinds of wheat each year. The Pullman site is a single block seeded directly (no tillage) each year for the past 19 years and is alternated between winter and spring wheat. The winter wheat planted in this site in the fall of 1999 was sprayed out in February 2000 because of excessive volunteer spring wheat.

All tests have been done without burning the stubble. Furthermore, all fertilizer has been placed within the seed rows and directly below the seed, with N rates based on soil tests. Soil fumigation has been included at some sites to evaluate the level of root disease pressure.

In general, the yields of both the spring and winter wheat lines and varieties are well within the range expected with conventional tillage and planting (Tables 1 and 2). Furthermore, the highest-yielding varieties under direct seeding tend also to be the highest-yielding varieties under conventional seeding. The high yields on the Palouse Conservation Field Station site are exceptional, considering that 1997,1998, and 1999, represent the 16^{th}, 17^{th}, and 18^{th} consecutive years of continuous no-till and the 12^{th}, 13^{th}, and 14^{th} wheat crops in these time periods. The yields of winter wheat in 1998 and 1999 at Bickleton, both on recrop, are similar to yields in this area on fallow. Hessian fly damage occurred on the spring wheat at the Bickleton site in 1998, which accounts for the low yields for fly-susceptible and high yields for fly-resistant varieties of spring wheat at this site. The low yields of winter wheat at the Colfax site in 1999 were due primarily to poor stands because of an inability of the drill to plant through the heavy residue. This should not be a problem for most commercial no-till drills.

Root diseases, including Rhizoctonia root rot, Pythium root rot, and take-all, are among the major constraints to yields of both winter and spring wheats planted directly into cereal stubble without benefit of fallow or a broadleaf crop in the rotation. Table 3 gives a summary of yields in response to soil fumigation and seed treatments for the combined years at the Colfax and Pullman sites. Seed treatments provide only modest but worthwhile protection of the germinating seed and emerging seedling against early infections by root pathogens. These treatments cannot begin to provide the level of root disease provided by soil fumigation, but the cost of these treatments is still more than offset by even these most yield increases. The yields in fumigated plots shows the potential for winter and spring wheats planted directly into cereal stubble.

Table 1. Average yields of spring wheat lines and varieties seeded directly (no-till) into standing stubble of winter or spring wheat.

	Palouse Conservation Field Station		Spillman	Bickleton		Colfax	
	1997	1999	1999	1998	1999	1998	1999
Variety	(bu/A)		(bu/A)	(bu/A)		(bu/A)	
Penawawa	71.5			18.3		45.8	
Edwall	72.3			20.7		46.3	
Pomerelle	56.8			14.8		37.4	
Centennial	63.7					48.1	
Vanna	66.7			18.4		37.9	
Alpowa	66.3	63.9	71.5	20.7	43.2	47.2	59.9
Wawawai	68.8		72.7	32.1		46.9	
Whitebird	66.7			15.5		47.1	
ID3775	71.3			16.9		50.1	
WPB926	54.4	67.5	50.4	29.4	35.3	55.4	47.4
Express	71.0			18.7		47.2	
Zak		67.2	72.4	32.9		52.4	58.0
Westbred 936				17.0		46.1	
Butte 86				21.6		45.9	
WA7802	64.2			20.8		52.2	
WA7824		66.7	66.6	29.8	39.2	55.4	56.0
WA 007873		60.8	61.6		34.5		45.9
WA 007874		50.9	57.1		40.1		43.9
WA 007875		59.2	64.2		33.8		51.3
WA 007876		51.4	50.7		32.2		42.3
WA 007878		69.9	64.5		40.4		49.5
WA 007879		61.4	78.5		34.4		61.7
WA 007880		67.6	74.0		34.6		53.3
WA 007881			69.1		38.6		56.7
WA 007882			66.6		37.3		50.9
WA 007864		69.4	72.4		35.9		55.1
PI 601814		64.1	60.9		33.4		49.6
WA 007841		52.6	55.1		30.9		46.3
Average	66.1	62.3	65.2	21.8	36.2	46.7	51.7

Each value is an average of six replicates of 8-row plots 24-feet long.

Table 2. Average yields of winter wheat lines and varieties seeded directly into standing stubble of spring wheat.

	Colfax			Bickleton		Palouse Conservation Field Station
Variety	1997 (bu/A)	1998 (bu/A)	1999 (bu/A)	1998 (bu/A)	1999 (bu/A)	1998 (bu/A)
Madsen	72.5	78.6	50.0	38.3	42.5	82.2
Stephens		77.4	45.0	38.2	48.0	85.7
Eltan	92.7	71.4	60.3	39.2	47.1	67.0
Moro				31.6		
Hiller	85.3		43.4	38.6	42.8	75.7
Coda			52.6		47.9	
Buchanan			51.8		32.4	
WA7835	86.3	78.1		41.2		86.2
Bruehl	80.3	77.9	52.0	40.1	40.3	76.8
Rely		71.9	43.0	38.0	42.0	70.2
Rod		75.4	49.9	38.3	43.3	76.7
WA7834	73.6	59.0		33.1		62.7
WA7752		76.5		41.0		76.3
WA7786			45.7			
Rohde		74.3		37.2		69.5
OR92054		73.6		37.7		76.6
Lewjain			52.6	36.0	43.5	66.1
Average	81.7	74.0	49.7	37.8	43.0	74.8

Each value is an average of six replicates of 8-row plots 24-feet long.

Table 3. Yields of winter and spring wheats at the indicated locations and years in response to soil fumigation with methyl bromide or seed treatment with either Raxil-Thiram or Dividend-Apron. The values are based on a statistical test that compares the yield of every treated plot with the corresponding check (untreated) plot for every replication, location and year.

Winter Wheat
1996, 1997
Colfax, Pullman

	Difference from Check
Madsen (check)	80.8 (bu/A)
Fumigated Soil	+10.4**
Dividend/Apron	+4.2**
Raxil-Thiram	-1.5

Spring Wheat
1997, 1998
Colfax, Pullman

	Difference from Check
Alpowa (check)	56.7 (bu/A)
Fumigated Soil	+16.8***
Dividend/Apron	+2.4
Raxil-Thiram	+3.7

YIELD TRENDS IN A LONG-TERM CONTINUOUS DIRECT-SEED WINTER WHEAT/SPRING CEREAL CROPPING SYSTEM

R. James Cook, Ron Sloot, and Ryan Davis

A study was undertaken the fall of 1987 on the Palouse Conservation Field Station near Pullman to evaluate yield trends and root diseases with continuous direct-seeded cereals. The site had already been direct-seeded to winter wheat for five consecutive years (1981-1986) and was then chemical fallowed in 1986-87 prior to launching this study. The current (2000) planting represents the 19th consecutive year where the only tillage performed on this site has been with the drill equipped to plant and fertilize as one-pass. During the 12 years (including the current 2000) that crops have been grown with direct seeding since the chem fallow, the site has been planted to winter wheat four times, spring wheat seven times, spring barley once (1993) and spring peas once (1994), with wheat planted in each of the past six years. Rotations to spring cereals have been essential to manage cheat grass and jointed goat grass. Fumigation plots were included as checks during 1987-92 but were then discontinued. Many replicated seed-treatment, variety, row-spacing, and fertilizer-placement studies have been conducted at the site. The study site has never been burned during the 19 years, but has been planted each year across the direction of the rows of the previous year so as to place maximum amount of seed between rather than within the old stubble rows. Starting in the 1995-96 crop year, the site has been used to evaluate the performance of varieties and selections of winter wheat (cooperative with Steve Jones) and spring wheat (cooperative with Kim Kidwell).

The data in Table 1 present yields in the untreated (natural soil) and fumigated checks together with six years for data on performance of Apron with either Terrachlor or Dividend for management of Pythium and Rhizoctonia, respectively. For each of these yields, rows have been spaced 12 inches apart and fertilizer has been applied directly beneath the seed as a combination of N (solution 32), P, and S based on a soil test and yield goal (usually 100-110 bu/A for winter wheat and 70-80 bu/A for spring wheat). In 1999, the site was planted in the fall with the new no-till plot drill equipped with Cross-slot openers for seed and fertilizer placement on 10-inch spacings. However, due to heavy volunteer spring wheat that survived the winter, the winter wheat was taken out with Round-Up in February and the site reseeded with spring wheat in April, 2000.

The highest yield of winter wheat (Daws, at 128 bu/A in 1988) and spring wheat (Penawawa, at 99 bu/A in 1995) were following the years of chemical fallow and peas, respectively. This confirms the value of a break to either fallow or a broadleaf crop before planting wheat, whether winter wheat or spring wheat. There was no response of the Daws to soil fumigation after the 1-year break to chemical fallow nor of the Penawawa to Apron-Terrachlor after the 1-year break to peas, confirming the importance of crop rotation for control of root diseases.

The lowest yields of winter and spring wheat were in the second (Hill-81 at 57 bu/A in 1989) and third (Penawawa at 49 bu/A in 1990) years respectively. In both of these years, there was a large yield response to Apron-Terrachlor, soil fumigation, or both, further confirming the role of root diseases in these yield depressions. The low yield of Penawawa in 1992 was possibly the result of high temperature during grain fill. The first evidence of take-all decline (the spontaneous disappearance of take-all due to microbiological changes in the wheat rhizosphere) appeared in 1996 and was confirmed by Jos Raaijmakers and Dave Weller in 1997 using their lab test.

Table 1. Long term yield trends in a continuous direct-seed winter wheat-spring cereal cropping system at Pullman, WA (Palouse Conservation Field Station)

	Year	Variety	Check bu/A	w/Apron +PCNB or Apron +Dividend bu/A	Fumigated bu/A
1-5	1981-86	Continuous direct-seeded winter wheat; yield data not available			
6	1986-87	Chemical Fallow			
7	1987-88	Daws	128		124
8	1988-89	Hill-81	57	57	72
9	1989-90	Penawawa	49	57	76
10	1990-91	Penawawa	65		86
11	1991-92	Penawawa	55		7
12	1992-93	Steptoe Barley	(~3.0t/a)		
13	1993-94	Peas			
14	1994-95	Penawawa	99	101	Discontinued
15	1995-96	Madsen	87	101	
16	1996-97	Alpowa	69	75	
17	1997-98	Madsen	82	82	
18	1998-99	Alpowa	64	67	
19	2000	Alpowa			

These results suggest that yields of continuous direct seeded wheat can be maintained or expected to increase over the long term, provided that spring cereals are used to manage cheat grass and jointed goat grass. Rotation to broadleaf crops not only break up pest cycles, but unfortunately, this also disrupts the microbiological process responsible for take-all decline, although the evidence suggests that reestablishment of a take-all suppressive soil is relatively fast during a second and subsequent years of wheat monoculture. Growers might consider dedicating one portion of their land to a continuous direct-seeded winter wheat/spring cereal cropping system and the other portion, e.g. the most productive land, to a 3- or 4-year direct-seeded, crop rotation.

The Wilke Project: Annual Cropping, Direct Seeding Systems for the Intermediate Rainfall Area of Eastern Washington

Ag Horizons Team of WSU Cooperative Extension

Wilke Project Goals:
The Wilke Project is a public-private, cooperative effort currently focused on adapting and demonstrating direct seed cropping systems, with annual cropping and diverse rotations, for the intermediate rainfall area (12 to 17 inches annually) of eastern Washington.

Our goals in using these systems are to enhance soil quality, reduce soil erosion by wind and water, and improve the efficiency and net return of farming operations. We are taking a holistic approach to studying the cropping systems. We want to understand the complex yet fascinating interactions among various components of the biological system and then use these factors to optimize production efficiency. Factors we are considering include crop type (grass or broadleaf, warm or cool season), species, cultivar, weeds, insects, diseases, residue amount and color, seeding and harvest dates, soil microbial relations, and market criteria.

Other goals for the Wilke Project include:
- Extend the findings of the project to area producers
- Develop long term rotations with perennial forages
- Include livestock that are finished for market on stubble and standing grain
- Establish wildlife habitat on the Wilke Farm
- Enhance community sustainability through commodity marketing and processing

Objectives:
Currently we are evaluating two crop rotations:
- A four-year rotation that includes two cool season cereals (spring and winter), one warm season grass, and one broadleaf crop.
- A three-year rotation including crops all adapted to the region; two cool season cereals (spring and winter) and one cool season broadleaf.

Collaborators:
Cooperators and collaborators in the project include:
- the Ag Horizons team of WSU Cooperative Extension,
- the ACIRDS (Annual Cropping, Intense Rotation, Direct Seed) group of Lincoln and Spokane County producers
- the Lincoln Conservation District
- Environmental Protection Agency Region10; Columbia Plateau Agricultural Initiative (CPAI)
- the McGregor Company
- Western Farm Services

- the McKay Seed Company (Almira)
- Monsanto
- the Washington State Department of Fish and Wildlife
- NRCS

Location:
The project is based at the 320-acre WSU Wilke Farm at Davenport, Lincoln County. Both rotations are being grown at the farm in three replications of 8-10 acre strips. An important premise of the project is to use farm -size equipment for all management operations.

In addition, five area grower cooperators are replicating a rotation on their farms. They provide valuable information on the system performance in a variety of microclimates. These on-farm plots are at least 25 acres per crop.

Parameters:
We collect agronomic and financial data from the Wilke Farm and from all the cooperators. Parameters include yield, stand establishment, weeds, insects, diseases, residue, soil organic matter, water infiltration, and earthworm populations. Economics are of primary importance and ultimately will determine the success of the rotations. Due to the whole systems perspective of the Project, we do not draw conclusions from individual crop yields in a single year. Also, some crops have rotational benefits, such as weed control, that are not directly reflected in their individual financial return. We also obtain economic information from conventional cropping systems from three farms adjoining the Wilke Farm.

Results:
The Wilke Project is in its third season in 2000. We will publish a full progress report of the Project that will be available at the Wilke Farm Field Day in July. Following are some of the empirical observations we have made so far (a.k.a. *Mistakes we have made that you can learn from…*)

- The folks who say you should begin any direct seeding system with adequate chaff spreaders on your combine the season <u>before</u> you start direct seeding are absolutely right. Do this – it's cheaper than a new combine is. Chaff spreading reduces problems with seed germination and nutrient tie-up that may be associated with chaff rows.
- Getting good seed to soil contact is crucial to obtaining a good stand. Do the work in setting up your drill to achieve this. Seeding depth control and fertilizer placement are important criteria in drill choice.
- Watch nature (soil temperature and moisture) more than traditional dates to determine optimum seeding time. In 1999, the Wilke Farm was sprayed with *Roundup* prior to seeding in mid-April. However, this cold, dry spring very few weeds had emerged. A second, post-seeding pre-emergence *Roundup* application was necessary, as there was a sudden flush of weeds.
- If you are choosing a crop variety to obtain a premium in a niche market, especially an alternative crop with limited yield data from our area, be sure you know its yield

potential. In 1998, red proso millet had a higher price than white proso millet on the bird seed market. It may have been possible to harvest it direct, without swathing. However, the yield potential was lower than for the white millet so the price premium was not advantageous.

- Make sure that a new crop has pesticides registered for weeds and other potential problems. Safflower in 1998 had one of the better returns of alternative crops on the Wilke Farm. However, lack of registered herbicides for grassy weed control makes it a risky rotational crop.
- Weather affects crops. This statement is too obvious. However, it underscores the value we have obtained from a hundred years of breeding cereals (wheat and barley) that are well adapted and stable in our Pacific Northwest environment. Alternative crops that have not benefited from this research investment are far more susceptible to weather fluctuations. Unseasonably hot weather in July of 1998 reduced yields of most of the alternative crops. Mustard at the Wilke Farm was affected more than an early maturing canola variety grown three miles away, even though mustard is supposedly less heat sensitive than canola. In 1999, frost after emergence damaged mustard and canola stands. Seedlings emerging through heavy residue were actually more susceptible to frost than in areas where the ground was clear of residue and heated up more quickly.
- If a crop has a rotational benefit in the system, don't cancel this out with other management decisions (e.g. losing patience). One of the Wilke crop rotations includes a warm season grass to allow a wider window in the spring for managing weeds prior to seeding. In 1998 we seeded millet on June 6, which allowed for three *Roundup* applications beforehand and greatly reduced wild oat populations. In 1999, we followed a recommendation from the Midwest and seeded the millet earlier (May 24). The spring was unusually cool, and although there were two *Roundup* applications, a lot of wild oats germinated after seeding. Consequently we missed a major rotational benefit of this crop. We will seed millet later in the future.

Extension:
The annual Wilke Farm Field day will be July 12, 2000. There will be a noon barbecue at the Wilke Farm (½ mile east of Davenport on Highway 2), followed by a tour of the Farm. The Reardan variety plot tour will be held on the morning of July 12. There will also be twilight tours of several of the cooperator sites.

For further information on the field tours, or to obtain a copy of the progress report, contact Diana Roberts at WSU Cooperative Extension, Spokane County (509) 477-2167 or e-mail robertsd@wsu.edu.

Crop Management Practices for Direct-sown Cereals

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Cooperating Growers: Donald and Doug Wellsandt, Ritzville, WA.

Introduction

Retention of surface residue is the most effective way to reduce soil erosion due to wind and water. Maintenance of high amounts of residue can only be achieved by crop production practices that minimize disturbance and bury as little residue as possible. Additionally, most research supports the contention that the higher residue levels and reduced soil disturbance associated with direct seeding results greater soil water retention, which in turn leads to greater productivity in low-rainfall environments.

Grower adoption of direct seeding has increased markedly in recent years, but still lags behind other areas of the USA and the world. This may be due to lack of equipment, problems (perceived or real) associated with stand establishment, diseases, or general reluctance to abandon tried-and-true production practices. The potential of direct seeding to reduce both wind erosion and water erosion relative to conventional practices is well-documented and not under question. What is not so clear is whether or not growers, under specific environmental conditions, can practice direct seeding with no loss in profitability. This is especially important with the current situation of low grain prices and slim profit margins.

Study Methods

The objective of this study is to compare direct seeding vs. minimum tillage for spring-sown wheat, barley, and oats at low, medium, and high seeding rates. This experiment was initiated in 1999 in Adams county, Washington in a 12 inch annual rainfall zone. Experimental treatments consisted of one variety each of wheat (Alpowa), barley (Baronesse), and oat (Monida). Each variety was sown at rates of 120, 200, and 280 plants m^2 under both direct seeding and minimum tillage. The minimum tillage operation consisted of one pass of a chisel-point cultivator running three inches deep with an attached long-tine harrow. The experimental design was a split-plot with whole plots arranged in a randomized complete block design and sub-plots consisting of all variety x seeding rate combinations. Each treatment was replicated four times. All fertilizer was delivered in all plots at the time of seeding with a Cross-slot drill. Plant stand establishment was measured 25 days after seeding. Above-ground dry biomass was collected five times during the growing season. Soil water was measured using gravemetric techniques on nine dates during the early growing season at 0-2", 2-4", and 4-6" depths. Yield components (spike density, kernels/spike, and kernel weight) were measured, along with grain yield.

Results

The 1999 growing season at Ritzville was characterized by excellent moisture at planting, with below-average precipitation during the remainder of the growing cycle. Air temperatures were colder than average during April and May. Averaged across varieties and seeding rates, there was no difference in stand establishment between the tillage treatments, demonstrating the ability of the Cross-slot drill to successfully place seed directly into standing residue. As expected, plants per unit area increased with higher seeding rates for all three crops.

Above-ground dry biomass throughout the growing season for both tillage treatments is given in Figure 1. The minimum tillage treatment resulted in slightly higher biomass than direct seeding. Seeding rate, however, had no effect on above-ground biomass for any of the three crops (data not shown). This was apparently due to compensation effects associated with high levels of inter-plant competition with higher seeding rates.

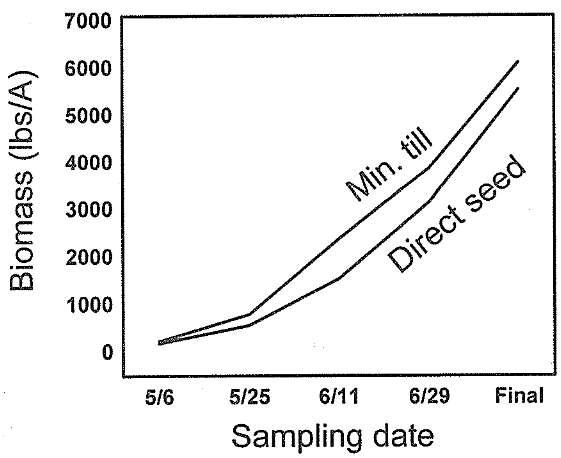

Figure 1. Above-ground biomass of spring cereals for direct seeding compared with minimum tillage on five sampling dates in 1999 at Ritzville, WA. Values are the averages for wheat, barley, and oats across low, medium, and high seeding rates.

Averaged across varieties and seeding rates, grain yield was greatest for the minimum tillage treatment, although the difference was not statistically significant (Table 1). Final above-ground dry biomass was highest with the lowest seeding rate, and the highest grain yield was obtained from the intermediate seeding rate (Table 2); however these differences were small and not statistically significant. The low biomass associated with the highest seeding rate suggests that tillering and overall plant growth were suppressed. Thus, in conditions similar to these, high biomass and subsequently high levels of protective residue cannot be obtained through higher plant densities.

Table 1. Final biomass and grain yield of spring wheat, barley, and oats as influenced by direct seeding or minimum tillage in 1999.

Tillage treatment	Final biomass	Grain yield
	lbs/A	Lbs/A
Minimum tillage	6013	2746
Direct seeding	5442	2547

Table 2. Final biomass and grain yield of spring wheat, barley, and oats in 1999 as influenced by seeding rate.

Seeding rate	Final biomass	Grain yield
Kernels/m^2	lbs/A	Bu/A
120	5968	2598
200	5730	2706
280	5485	2634

Of particular interest in this experiment was the soil water status associated with direct seeding relative to that of minimum tillage (Figure 2). The "zero" reference line refers to values associated with minimum tillage; therefore, bars below this line indicate soil moisture drier than minimum tillage. This figure shows that direct seeding was slightly less efficient at retaining soil water than with minimum tillage. This observation appears contradictory to the notion that direct seeding generally results in more soil moisture than with tillage. On the other hand, tillage may have a positive role in breaking upward capillary flow of soil water. These data agree with other studies conducted in the low-rainfall regions on the inland Northwest which show shallow soil water content during the early growing season to be higher in tilled soil compared with direct seeding. At any rate, these results demonstrate the importance of measuring soil moisture in studies such as this, in which low precipitation limits productivity.

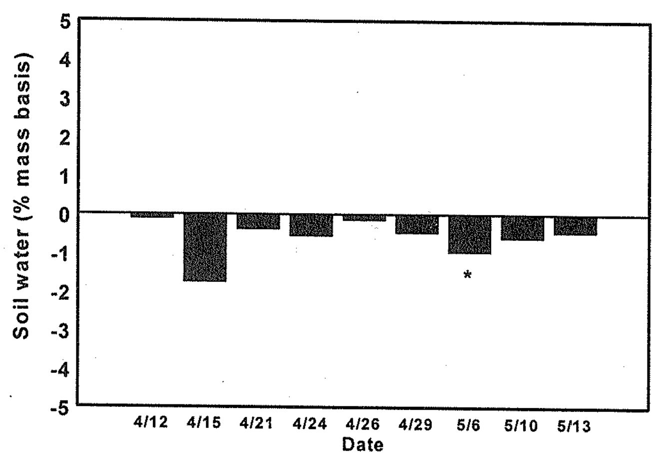

Figure 2. Soil water in the top six inches of soil on nine dates in the early growing season in 1999 near Ritzville, WA. These data show that surface soil moisture with minimum tillage was slightly greater than with direct-seeding.

In order to obtain results across an adequately wide array of environmental conditions, this research will be conducted for at least two more years. The 2000 trial was planted on April 3.

PNW Direct Seed Grower Case Study Publications

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist; Ellen Mallory (former WSU Case Study Project Coordinator); Tim Fiez (former WSU Extension Soils Specialist); Dennis Roe, NRCS Resource Conservationist; and Don Wysocki, OSU Extension Soil Scientist

The first 9 of 16 Pacific Northwest Extension bulletins in a new case study series on "Direct Seeding in the Inland Northwest" have been printed and are available on the Internet. The last 7 of these full color glossy publications will be published in groups of 3-4 over the spring and summer as they move though the PNW review and production process. Information on accessing print and on-line copies is provided below.

Why a NW Direct Seed Case Study Series?
Many established direct seed growers say one of the keys to their success was having other direct seed growers share their experiences and knowledge with them as they developed their own system. This series of 16 case studies will allow grower and Ag support personnel -- and anyone interested in direct seeding -- to learn from growers experienced with direct seeding throughout the Inland Northwest.

Each case study features a single farm operation and typically contains the following components: 1) How the growers started direct seeding, and lessons learned; 2) Description of their current direct seed system including: crops and rotation, residue management, weed, disease and insect control, fertility management and fertilizer application, seeding strategies; 3) Description and evaluation of the drills they are using; 4) - Primary benefits and challenges of direct seeding seen by the growers; 5) Advice for growers new to direct seeding; 6) Economic summary (when available).

The farms featured in this case study series are located across the range of rainfall zones in the Inland NW region of Washington, Idaho and Oregon. They utilize a variety of equipment options and cropping systems. The following is a listing of the first six publication that are available, including annual precipitation and general farm location.

Print Copies -- These case studies are being developed through grants from the Western SARE and PNW STEEP programs and are available free. They can be ordered through your local Cooperative Extension office or directly from the extension publication offices in Idaho (208) 885-7982, Oregon (541) 737-2513 and Washington (800) 723-1763.

Internet Access -- As soon as the publications go to press, they are also put on our PNW Conservation Tillage Systems Web site (http://pnwsteep.wsu.edu) -- click on Direct Seed Case Studies for viewing, printing or downloading in PDF (Acrobat) format, just as they appear in the printed form. The first item on this Web page is an "Overview of the Series," which briefly describes the format of the publications, and identifies the growers, farm locations, and common crop rotations.

New PNW Extension Series - Direct Seeding in the Inland Northwest (first 9 of 16)
PNW514- John Rea Farm Case Study: 7-9 inches annual precipitation, Walla Walla, WA
PNW515 - Aeschliman Farm Case Study: John and Cory, 15-20 inches annual precipitation, Colfax, WA
PNW516 - Frank Lange Farm Case Study: 17-20 inches annual precipitation, near Palouse WA
PNW522 - Steve and Nathan Riggers Farm Case Study: 22-25 inches annual precipitation, Nezperce, ID
PNW 521 - Paul Williams Case Study: 15-18 inches annual precipitation, Davenport, WA
PNW 523 - Thomas Farm Case Study: Mike Sr. and Mike Jr. Thomas, 15 inches annual precip., Prescott, WA
PNW 524 - Jack, Mike and Jeremy Ensley Farm Case Study:18-20 inches annual precip., Colfax, WA
PNW 526 - Melville Farm Case Study: Tim, Kevin and Kurt, 10-26 inches annual precip., Enterprise, OR
PNW 527 - Pat Barker and Steve Shoun Farm Case Study: 18 inches annual precipitation, Dayton, WA

PNW Direct Seed E-Mail List Server

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist; Don Wysocki, OSU Extension Soil Scientist; Russ Karow, OSU Extension Agronomist; Stephen Guy, UI Extension Crop Management Specialist; Bill Schillinger, WSU Dryland Agronomist; Stephen Dofing, WSU Extension Agronomist; and Joe Yenish, WSU Extension Weed Scientist

The Growing PNW Internet / E-Mail Connection

The Internet and e-mail are rapidly becoming major technology access and communications tools for PNW Ag support personnel and growers. Most county offices of cooperative extension, conservation districts, NRCS, Ag service industries, and an increasing number of growers in the Pacific Northwest have Internet / e-mail access. A recent USDA Agricultural Statistics Service study showed that 40% of PNW growers have Internet / e-mail access in 1999, up dramatically from 18% in 1997. Washington growers lead the NW and are second in the nation at 50%. At the same time, growers are increasingly moving towards direct seeding and more intensive cropping systems to improve productions efficiency and profitability, cropland productivity, and environmental protection. The PNW STEEP Internet Web site and new PNW Direct Seed List Server are helping meet this expanding PNW demand for computer technology access and an improved communications network on direct seed cropping systems.

The Internet Web site (http://pnwsteep.wsu.edu) "PNW STEEP Conservation Tillage Systems Technology Source" was initiated in 1997 as part of an educational effort by the PNW STEEP Cropping Systems Specialists Team under the STEEP (Solutions To Environmental and Economic Problems) research and educational program on conservation tillage systems in Idaho, Oregon and Washington. It is also part of the educational efforts under the Columbia Plateau Wind Erosion / Air Quality Project and SARE Direct Seed Case Study Project.

The Web site currently averages over 400 hits per day and now contains a wealth of resources including: the entire *PNW Conservation Tillage Handbook Series* (147 publications), *PNW STEEP III Extension Conservation Tillage Update* newsletters since 1996; proceedings of the 1998 and 1999 Northwest Direct Seed Cropping Systems Conferences, Annual STEEP Research Report; PNW STEEP On-farm Test Results publications, new PNW Direct Seed Case Study Series publications, and will continue to expand access to other related information resources. Printed copies of these publications are limited and it would not be feasible to provide copies to all applicable PNW growers and Ag support personnel who could benefit from the information. However, electronic access through the Internet is a very low cost, effective means of providing unlimited access to up-to-date STEEP and related technologies. A search engine has also been installed which provides extensive key-word searches within the entire Web site.

PNW Direct Seed Systems List Server

The new Pacific Northwest e-mail / Internet list server on direct seed cropping systems offers an exciting communications link on new information resources, events, research results, technology innovations and experiences from the dryland production regions of the Inland Northwest. It will also help provide access to direct seed systems technology from other regions and countries that may be adapted to Northwest production conditions. Messages are received by e-mail and stored on the server Internet site for later access by new subscribers.

This communications network was established to help accelerate the development and grower adaptation of direct seed cropping systems in the dryland production regions of the Inland Northwest -- to improve production efficiency, profitability and competitiveness in global markets, to enhance the productivity of our cropland resources, and to increase protection the environment.

The list server is part of a PNW technology access project by the PNW Extension Cropping Systems Specialists Team under the STEEP (Solutions To Environmental and Economic Problems) research and educational program on conservation tillage systems in Idaho, Oregon and Washington. The Team includes: Roger Veseth - WSU/UI; Don Wysocki and Russ Karow - OSU; Bill Schillinger, Steve Dofing and Joe Yenish - WSU; and Stephen Guy, Larry Robertson, and Brad Brown - UI. It is also facilitated in conjunctions with other related PNW programs, including a new STEEP project on building a Northwest Coalition on Direct Seed Cropping Systems Research.

The initial address list included over 230 county/area Ag extension educators, conservation districts, university and USDA-ARS researchers, extension specialists, USDA-NRCS staff, PNW grower organizations, growers and Ag industries representatives from across the dryland cropping areas of the Inland Northwest. From this initial base network, the List server will expand to interested growers and other Ag support personnel across the region.

The e-mail list server Internet site can be accessed through the PNW Web site above (http://pnwsteep.wsu.edu) for subscription and viewing of earlier messages. You can also subscribe to the list server by sending an e-mail message to Roger Veseth (rveseth@uidaho.edu) including the state, organization / occupation, name and e-mail address of the person(s) to be subscribed. Two examples are: ID grower - John Doe <e-mail address>; OR AgChem Co - Mary Smith <e-mail address>. Note that for your e-mail privacy, the list server member list will not be accessible to anyone except the list server administrator.

All interested growers and Ag support personnel are encouraged to participate in this new list server. A stronger communication network and partnership among growers, researchers, Ag-support groups and agencies, and Ag industry will greatly accelerate the successful development and grower adaptation of direct seed systems in the region.

Questions / Suggestions — If you have questions or suggestions on the new PNW Direct Seed E-mail List Server or other related Internet efforts, contact Roger Veseth, WSU / UI Extension Conservation Tillage Specialist, 208-885-6386 or e-mail (rveseth@uidaho.edu).

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PNW Grower Direct Seed Web Forum

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist

At the request of Pacific Northwest growers, a PNW Grower Direct Seed Forum has been established on the Internet to facilitate in-depth grower-to-grower questions and discussions on direct seed cropping systems and technologies. It will provide a communications tool to help growers search for answers to their questions, as well as to share experiences and innovations. The Forum can be accessed through the PNW Conservation Tillage Systems Web site (http://pnwsteep.wsu.edu) -- click on Grower Direct Seed Forum.

The Forum will expand the communications network initiated with the PNW Direct Seed E-mail List Server in late 1999 for all Ag-related personnel interested in direct seed system --- also linked to the PNW Web site. The main purpose of the Grower Direct Seed Forum is to facilitate more growers-to-grower communications, although others with experience and expertise in various aspects of direct seed cropping systems, such as Ag industry representatives, researchers, extension educators, and other Ag support personnel, are encouraged to actively participate.

The Forum "conference" topics presently include: equipment design and modification; crop rotation; alternative crops; residue management; and management strategies for weed, disease and insect control. Additional conference area can be added on a variety of direct seed system topics.

The number of PNW growers with Internet access is growing rapidly. A 1999 USDA Agricultural Statistics Service study showed that an average of 40% of PNW growers had Internet access in 1999, up dramatically from 18% in 1997. Washington growers lead the NW and were second in the nation at 50%. Along with this rapid Internet access, NW growers are also moving towards direct seeding and more intensive cropping systems to improve productions efficiency and profitability, cropland productivity, and environmental protection. This Grower Direct Seed Forum, as well as the List Server and expanding library of resources on the main PNW Web site, are helping meet this increasing PNW demand for computer access to direct seed cropping systems technologies.

The Forum has a threaded discussion design, which refers to the arrangement of stored messages on the page, allowing participants to follow and respond to discussions starting at the original messages and continuing with successive replies to those messages. Participants can select options to receive e-mail notification when there are new messages on the Forum, or to be sent the messages by e-mail. There are separate mailing lists for each of the "conferences" and you need to select those you are interested in receiving. The Forum is simple to use, plus there is an introductory section that describes how to use the Forum. An excellent help program can also guide you through the process.

For more information, contact Roger Veseth, Forum Manager and WSU/UI Extension Conservation Tillage Specialist, at 208-885-6386 or e-mail (rveseth@uidaho.edu).

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PNW Economics Research Shows No-Till Profitability

Doug Young, WSU Agricultural Economist; Herb Hinman, WSU Extension Agricultural Economist; and Roger Veseth, WSU / UI Extension Conservation Tillage Specialist

Recent research results in the Inland Northwest have confirmed that no-till production costs can be lower and profitability higher than conventional tillage systems. The economic performance of ten experienced no-till growers in the Inland Northwest was the focus of a two-year research effort by WSU agricultural economists Doug Young and Herb Hinman, and graduate student Oumou Camara. The researchers conducted intensive economic case studies of six experienced no-till growers in the 19- to 22-inch precipitation zone of eastern Washington and northern Idaho and four in the 8- to 13-inch zone of central Washington. Copies of the research publications are available through the WSU Cooperative Extension offices and on the Internet.

Low Production Costs

Winter wheat production costs for all six higher precipitation growers' were impressively low and remarkably uniform. Total costs/bu ranged from $2.52 to $2.92 compared to $2.95/bu for a typical conventional tillage budget. The average no-till total production cost of $2.65/bu beat the 1993-97 average market price for soft white winter wheat of $3.72 by more than a dollar. The six no-till growers also had relatively low production costs for spring crops, but the margin was lower than for winter wheat.

Key Management Strategies

The economic success seemed to be attributable to frugal machinery management and learning the proper weed and disease control, fertility management, and other practices to make no-till systems work on their particular farms. Appropriate management for no-till enabled the case study growers to achieve higher than average yields in most cases. These same factors explained the relative success of no-till growers in the lower precipitation zone.

Changing No-Till Trends

The success of this handful of experienced no-till growers stands out from the pattern of slow adoption of no-till in the PNW. Annual surveys of tillage practices by the national Conservation Technology Information Center show that U.S. growers used no-till systems on about 16 percent of cropland in 1998 compared to 3 percent in 1989. In the Pacific Northwest, percent of cropland was in no-till has only grown from 3 percent in 1989 to 5 percent in 1998, although some Inland Northwest dryland counties had 15 to 20 percent in no-till. Fear of economic losses has long been an underlying factor behind the reluctance of many PNW growers to adopt no-till. By providing a better understanding of the nature of and reasons for the economic success of this pioneering sample of no-till growers, this study should accelerate adoption of no-till where it is suitable and reduce economic and environmental losses from soil erosion in the PNW. The results of this study are timely as interest in no-till farming is growing rapidly in the PNW.

Accessing the New Publications

The no-till case studies are summarized in two new WSU Cooperative Extension publications in the Farm Business Management Reports series, available on the Web and in print.

EB 1885 -- Economic Case Studies of Eastern Washington No-Till Farmers Growing Wheat and Barley in the 8-13 Inch Precipitation Zone

EB 1886 -- Economic Case Studies of Eastern Washington and Northern Idaho No-Till Farmers Growing Wheat, Barley, Lentils and Peas in the 19-22 Inch Precipitation Zone

The publications are accessible on the Web site (http://farm.mngt.wsu.edu/onlinepub.html). Print copies of the publications are available for $1.50 through the county WSU Cooperative Extension offices or can be ordered directly through the Bulletin Office, Cooperative Extension, Cooper Publications Bldg., Washington State University, Pullman, WA 99164-5912, (509) 335-2857 (some shipping and handling fees, and sales tax may apply).

These bulletins provide detailed budgets and listings of management practices for each case study no-till grower, who is identified only by letters to preserve anonymity. They are currently the most comprehensive economic case studies of no-till production by Northwest growers. The case study results show that no-till can be very competitive economically when properly implemented.

An overview of these two publications is summarized in PNW Conservation Tillage Handbook Series No. 14 in Chapter 10, and can be accessed on the PNW Conservation Tillage Systems Web site (http://pnwsteep.wsu.edu), or contact Roger Veseth at 208-885-6386 (rveseth@uidaho.edu).

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Wind Erosion Predictions for the Lind and Ralston Projects

Douglas Young and Darin Reppe
Department of Agricultural Economics
Washington State University

In the 10-15 inch precipitation region of eastern Washington, the dominant winter wheat/fallow(WW-SF) system with conventional tillage leaves the the soil vulnerable to wind erosion. Research lead by Frank Young at Ralston WA (11.5 in/yr precipitation) and William Schillinger at Lind, WA (9.5 in/yr precipitation) has been testing two promising conservation systems--continuous no-till spring cropping and minimum tillage WW-SF. This paper presents some background information on wind erosion estimates for the Pacific Northwest and some new predictions using the Wind Erosion Equation and a new air borne dust prediction model for the Ralston and Lind experimental farming systems.

NRI Estimates of PNW wind erosion

Table 1 reports average wind erosion estimates on private land in Idaho, Oregon, and Washington based on the 1987-1997 National Resource Inventories (NRI's) conducted by the USDA Natural Resources Conservation Service (NRCS). Wind erosion from cultivated land has been highest in Washington state where it has increased to over 5 t/ac/yr in the 1990's . As expected, wind erosion rates are much lower on noncultivated crop land (forages, perennials, idle cropland, etc.), CRP land, and pastureland. Again, however, NRCS estimated wind erosion rates on these noncultivated areas tend to be higher in Washington than in Idaho and Oregon.

WEQ Predictions for Ralston and Lind Experimental Cropping Systems

Table 2 presents average annual wind erosion equation (WEQ) predictions by cropping system and by yield level for the Ralston and Lind experiments. The estimates are based on Version 6a of the WEQ Microsoft Excel spreadsheet computer version released in 1999. The software is supported by a training and user's manual (NRCS, Washington State, Wind Erosion Equation with Circular2, March 1999).

The WEQ predictions in Table 1 are exceptionally low in comparison to the state NRI estimates in Table 1 and our prior expectations. The equation predicted zero wind erosion for all Ralston treatments including the "check" of minimum tillage winter wheat-summer fallow. Continuous hard red spring wheat (HRSW) over 1996-97 averaged 42 bu/ac at Ralston, between the 30 to 50 bu/ac yields used in the WEQ predictions in Table 2. WEQ predicted zero wind erosion for both the high and low HRSW yields. The no-till continuous spring cropping treatments at Ralston employed no pre-seeding tillage. The min-till WW-SF system used fewer rodweedings for fallow maintenance than typical in the region.

The minimum and delayed minimum tillage systems at Lind use fewer rodweedings and use herbicides, when needed, for post-harvest control of Russian thistle rather than sweep tillage as in the conventional system. The delayed minimum tillage delays primary tillage from March until mid-May or June and averages one less rodweeding per fallow cycle than the other two systems. Both minimum tillage systems easily maintained the minimum 350 lbs/acre of surface residue at the end of a fallow cycle to preserve eligibility for government transition payments. Winter wheat at Lind over all tillage treatments yielded between 52 and 76 bu/ac during 1996-1998 which received above average precipitation, but fell to 35 to 40 bu/ac in 1999 with typical precipitation..

WEQ predicted zero or near zero erosion at Lind for the minimum and delayed minimum tillage treatments for both the 35 and 60 bu/ac yield levels. WEQ predicted 1.7 t/ac/yr wind erosion for the presumably most erosive conventional tillage WW-SF system at the lower 35 bu/ac yield. However, 1.7 t/ac/yr is less than half of the estimated 1997 Washington state average of 5.1 t/ac/yr (Table 1).

NRCS review of the wind erosion predictions in Table 2 indicated that we had used WEQ correctly (Mike Sporcic, personal communication, February 16, 2000). The NRCS review indicated that the WEQ was likely to underestimate wind erosion for eastern Washington due to several unresolved problems. First, the NRCS review indicated that the Soil "I" factor should be increased for this region. This could increase erosion predictions by 55% or more. Second, the climate "C" factor should be adjusted for eastern Washington conditions. This factor is based on daily average wind speed, but many erosive storms pass through the Pacific Northwest very quickly. The erosive effect of these brief storms is diluted by considered only daily average wind speed.

Dust Emission Predictions by Lee's Model

Lee recently developed a model for predicting dust emissions with different soil, cover, and climate conditions (Lee, By-Hyun. 1998. Regional Air Quality Modeling of PM-10 Due to Windblown Dust on the Columbia Plateau. M.S. Thesis. Department of Civil and Environmental Engineering, Washington State University). Using conventional summer fallow as a base case for dust emissions, Lee estimated that improved (conservation tillage) fallow would reduce emissions by 54% and continuous annual grain cropping would reduce emissions by 95%. (Acknowledgments to Dave Chandler, personal communication, February 11, 2000 for assistance in interpreting these results.) These reductions in dust emissions are more consistent with expectations than the soil losses predicted by WEQ. Lee's predictions are also more consistent with measured differences in residue cover at the Ralston project in 1997. Cover fell to 21% after (minimum tillage) fallow, but no-till continuous HRSW maintained 60 to 70% of surface cover throughout the production period (Young, F. et al., 1999. Maintenance of Surface Residues and N Fertility in Soft White Wheat-Fallow vs. Continuous Hard Red Spring Wheat Cropping. 1999 Field Day Proceedings: Highlights of Research Progress, Dept. Crop and Soil Sciences, Tech. Report 99-1, Washington State Univ.).

Conclusions

The WEQ predicted low and undifferentiated wind erosion for the Ralston and Lind experimental cropping systems. This indicates more wind erosion prediction research by engineers and soil scientists is warranted for this region. More differentiated predictions from a recent dust emissions model show promise for this approach. Reliable erosion predictions are important for societal choices on erosion control. Policymakers and taxpayers require cost effectiveness ratios (tons of soil saved or dust avoided per dollar of cost incurred) to make choices that maximize benefits per scarce taxpayer and grower dollars.

Table 1. Estimated average wind erosion (t/ac/yr) on nonfederal rural land, by state and year.

State	Year	Cropland			CRP land	Pastureland
		Cultivated	Noncultivated	Total		
Idaho	1987	4.7	0.1	4	4.1	0.3
	1992	4.8	0.2	4	1.4	0.2
	1997	3.9	0.2	3.3	1.1	0.2
Oregon	1987	2.4	0.3	1.8	1.3	0.1
	1992	1.9	0.1	1.5	0.1	0.1
	1997	2	0.1	1.5	0	0.1
Washington	1987	3.9	0.9	3.5	1.8	0.3
	1992	5.8	0.4	5	0.2	0.1
	1997	5.1	0.9	4.4	0	0

Source: USDA-NRCS Summary Report, 1997 National Resources Inventory
http://www.nhq.nrcs.usda.gov/NRI/1997/summary_report/table11.html

Table 2. Average annual wind erosion equation (WEQ) predictions by cropping system and crop yield for Ralston and Lind experiments.

Cropping System	Yield	Erosion (t/ac/yr)
	Ralston	
Min-Till WW-SF	60 bu	0
No-Till HRSW-SB	50 bu HRSW, 4000 lb. SB	0
	35 bu HRSW, 2000 lb. SB	0
No-Till SWSW Chem F.	40 bu	0
No-Till Cont. HRSW	30 bu	0
	50 bu	0
	Lind	
Conven. WW-SF	60 bu	1.3
	35 bu	1.7
Min-Till WW-SF	60 bu	0
	35 bu	0.1
Delay Min-Till WW-SF	60 bu	0
	35 bu	0.05

PM-10 Educational Program Promotes Adoption of Wind Erosion Control Practices

H. Holly Wang, Douglas L. Young and Oumou Camara
Department of Agricultural Economics
Washington State University

In the 10-15 inch precipitation region of eastern Washington, the dominant winter wheat/fallow system with conventional tillage leaves the the soil vulnerable to wind erosion. A 1997 survey showed that two effective conservation farming systems--no-till/minimum tillage and continuous spring cropping--had been used to some degree by 20% and 26% of farmers in the region, respectively. Our objective is to examine statistically how an educational program initiated three years before the 1997 survey and selected other variables may have influenced adoption of continuous spring cropping and minimum or no-tillage. The educational campaign was conducted by Natural Resources Conservation Service and Cooperative Extension personnel. The program was named, "PM-10," which refers to dust particles less than 10 microns in diameter which can be hazardous to human health. The educational campaign raised awareness of soil productivity and human health dangers of dust pollution and presented information on specific potentially profitable farming practices to reduce wind erosion.

Data and Estimation

Data were collected in a telephone survey of a random sample of farmers residing in Adams, Benton, Douglas, Franklin, and Grant counties (R. Scott, P. Wandschneider, D. Fultz, and M. Klungland. *Focusing on Wind Erosion and PM-10 Knowledge and Practices: A Dryland Farmer Survey.* Dept. Ag. Econ., Washington State Univ., September, 1997). Complete questionnaires used for this analysis included 266 farmers. This represented 59% of the original sample--a relatively high response and completion rate for a telephone survey. Table 1 reports the means and standard deviations for the variables utilized in this study.

Model Framework

A Logit regression appropriate for binary (adopt, not adopt) dependent variables was used to explain the adoption of no/min till and continuous spring cropping in response to variables representing the knowledge of PM-10 information, perceived on-farm erosion, farm size, portion of land leased, off-farm income, farmer's education, and farmer's age. Another regression model, Ordered Probit, was used to investigate the farmers' changes in practices due to wind erosion in response to the same set of explanatory variables.

Higher levels of knowledge of PM-10 issues are expected to contribute positively to adoption of wind erosion control practices. It is likely that area farmers would have been familiar with the technical term, PM-10, only through the recent PM-10 wind erosion educational campaign. Another variable elicits the growers' frequency of problems with wind erosion in the past ten years. This variable measures the farmer's perception of the wind erosion threat on the farm as opposed to his/her knowledge of the broader set of wind erosion dangers and solutions conveyed in the PM-10 educational campaign.

Results

Table 2 reports the sign and the statistical significance of estimated coefficients of all explanatory variables for the three adoption equations. Knowledge of PM-10 was positively related to the adoption of no/min-till, the adoption of continuous spring cropping, and the number of changes made in farming practices due to wind erosion, with higher than 90% significance levels. In contrast, perception of the number of erosion problems experienced in the last 10 years was significantly related only to the level of changes made. The unspecified nature of the practices adopted in the "changes made" variable gives these results a less clear interpretation than those for adoption of specific conservation practices. It is possible that different farmers have different perceptions of what constitutes "changes made" in response to wind erosion.

Compared to water erosion, where more visually apparent gullies and sediment plains might motivate adoption, the more subtle effects of wind erosion on soil productivity and the landscape might not be sufficient to motivate conservation practices. Our results suggest the subtle nature of wind erosion might make adoption less likely unless the problem is accompanied by an educational program which: (1) highlights the threats of wind erosion to human health and soil productivity and (2) outlines specific potentially profitable practices for solving the problem.

Farm size was the only significant socioeconomic variable in the two logit models. These results indicate larger farms are more likely to adopt these effective, but potentially risky, wind erosion control practices in this region. The financial risk of buying expensive no-till drills might be more easily managed by larger farms. Larger farms might be better equipped for switching to spring cropping which concentrates farming operations into a narrow spring window which necessitates more machinery and possibly hired labor. If no/min. tillage and continuous spring cropping are profitable, larger farmers will multiply these gains over more acres.

Education was positive and significant at barely the 15% level in only the no/min-till equation in this study. Farmer's age, percentage of land leased, and off-farm income failed to show any statistically significant relationships for adoption of the erosion control practices.

The reasons for the lack of a significant relationship between theoretically appealing socioeconomic variables, including age, off-farm income and land leased, and adoption of wind erosion control practices is not entirely known. One reason may be the theoretical arguments are generally premised on the assumption of profitable new technologies. Wind erosion control is a new concept in the study area and the evidence on the profitability of no/min-till and annual spring cropping in the region is very limited. Perceived risk is an important omitted variable in the adoption model. Many farmers probably view any change from the traditional wheat-fallow cropping system as risky in this 9- to 15-inch annual rainfall region. While risk factors are likely to be important, risk perceptions and risk preferences are difficult to elicit under any circumstance and were not collected in this telephone survey.

The two logit equations predict 74% to 80% of adoption choices correctly. The ordered probit equation predicts 47% correctly, but this is not particularly low considering the four different levels of the dependent variable.

Conclusions

Simple perception of a wind erosion problem, or membership in a particular socioeconomic category, was not sufficient to explain adoption of wind erosion control practices of a sample of 266 eastern Washington farmers. This study provided strong statistical support for a targeted educational program which: (1) highlighted the threats of wind erosion to human health and soil productivity and (2) described specific potentially profitable farming practices for solving the wind erosion problem.

An advantage of the two-pronged educational campaign conducted in this arid farming region is that it appealed both to farmers' sense of social responsibility and to their profit motive. Policy makers may often be in the position of promoting new environmentally sound technologies. These results suggest that a broad-based educational campaign may be a useful first step in promoting such technologies.

Table 1. Descriptive Statistics for Dependent and Independent Variables, 266 Farms, 1997.

Variable	Mean	St. Deviation	Description
No/min till	.203	.40	1=adopted, 0= no
Cont. cropping	.259	.44	1=adopted, 0= no
Level of changes made	1.579	.91	0=no change, ..., 3=a lot of changes
Knowledge PM-10	1.305	.97	0=not heard of, ..., 3=very knowledgeable
Perceived problems	1.139	.89	0=no, 1=1 to 2, 2=3 to 4, 3= more than 5
Farm size	3,263	2,593	acres
% of land leased	23.8%	30.5%	
Off-farm income	1.327	.707	1=most from farm, ..., 3=most from off-farm
Education level	1.045	.761	0=no post secondary, ..., 2=college graduate
Age	53	13	years

Table 2. Regression Coefficient Signs, Significance and Equation Performance Measures

Factors	No/min till(Logit)	Cont. sp. Crop(Logit)	Changes(Order. Probit)
Knowledge of PM-10	+**	+**	+***
Perception of Problems	-	-	+***
Farm Size	+***	+*	+
Lease %	-	-	+
Off-farm Income	+	+	-
Education	+*	+	+
Age	+	-	-
Constant	-***	-*	+**
c_1			+***
c_2			+***
% Correct Predictions	80%	74%	47%

NOTE: ***, **, and * denote significance at the .05, .10, and .15 level, respectively.
The significantly positive parameters, c_1 and c_2, indicate higher probability of making more changes.