COOPERATIVE EXTENSION
WASHINGTON STATE UNIVERSITY

Department of Crop and Soil Sciences

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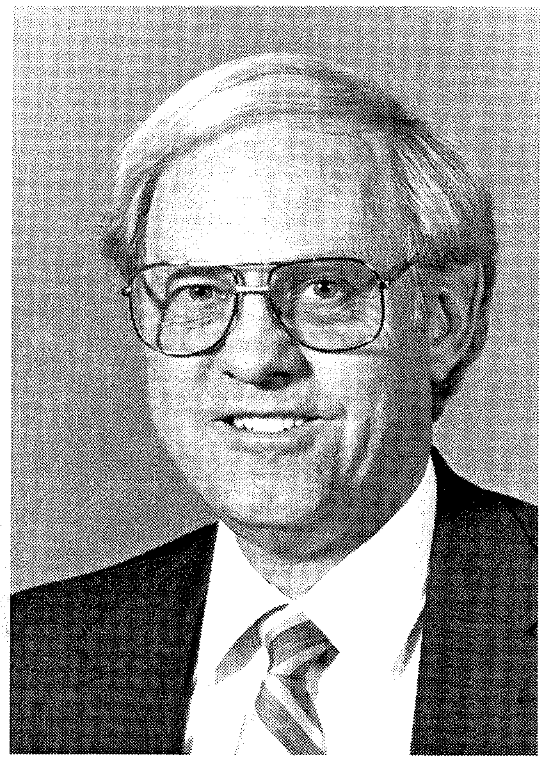

Dedicated to Dr. Dwane Miller

2001 Field Day Proceedings: Highlights of Research Progress

WSU Dryland Research Station, Lind • June 14, 2001
WSU / USDA-ARS Cunningham Agronomy Farm, Pullman • June 28, 2001
WSU Spillman Agronomy Farm, Pullman • July 12, 2001

John Burns and Roger Veseth, Editors

Contributing agencies: Washington State University, U.S. Department of Agriculture and Department of Crop and Soil Sciences

DEDICATION TO DWANE G. MILLER

Dr. Dwane G. Miller retired from Crop and Soil Sciences Department at Washington State University in April 1999. He served as Department Chair from 1987 to 1996.

Dr. Miller was born in Cheyenne, Wyoming and raised on a cattle ranch near Carpenter. He received his B.S degree in agronomy and agricultural education in 1960 from the University of Wyoming. He taught vocational agriculture for two years at Albin, Wyoming before entering graduate school at the University of Wyoming where he obtained his M.S. degree in agronomy in 1964 and Ph.D. degree in crop science in 1966.

In 1966, he accepted a position at Southern Oregon College in the biology department teaching plant sciences courses. In 1967, he was appointed Assistant Professor at Washington State University in the Department of Agronomy and Soils (now Crop and Soil Sciences), a position he held until 1977. From 1977 through 1981 he was Chair of the Plant and Soil Sciences Department at Texas Tech University. From there he moved to Montana State University as Chair of the Plant and Soil Sciences Department until 1987, when he returned to WSU as Chair of the Crop and Soil Sciences Department.

Dr. Miller was involved in research on chemical induction of male sterility in wheat using gametocides as chemical hybridizing agents. His early research in the 1970's was a pioneering effort on this alternative system to producing hybrid wheat. His research showed how gametocides work and disclosed the mode of action in creating male sterility. He also conducted research on hail damage in wheat and peas, and his database serves the industry today in field adjusting of hail damage in crops across the Inland Northwest.

He taught a variety of crops courses at WSU and he established an outstanding record as an innovative and dedicated instructor. Dr. Miller coached the WSU crops team for 7 years and his teams were competitive nationally. He received the R. M. Wade Award for Excellence in Teaching in 1971. He served on numerous professional committees for the American Society of Agronomy and Crop Science Society of America, and was elected as a Fellow in ASA in 1990, one of the highest awards in that professional society.

During his time as Chair of the WSU Crop and Soil Sciences Department, Dr. Miller was responsible for initiating talks with the Washington Wheat Commission and Washington Barley Commission that led to a $1,000,000 endowment for the O.A. Vogel chair in wheat breeding and genetics and the $500,000 R.A. Nilan professorship in barley breeding and genetic with the help of legislative action for matching funds. He also provided leadership in regional research programs as co-chair of the Columbia Plateau Wind Erosion / Air Quality Project from 1992 to 1998.

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Fertilizer, Seed and Amendments

Blue Mountain Seed
Cenex
Connell Grain Growers
Curtis Hennings
Latah Co. Growers
McGregor Company
Pacific Calcium
Ritzville Chemicals
Ritzville Warehouse Co.
UAP Northwest
Walter Implement Co.
Whitman Co. Growers
Wilbur-Ellis
WSCIA Foundation Seed Service

Herbicides

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Aventis Crop Science
BASF Corporation
Bayer Corporation
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E.I. DuPont de Nemours & Co.Gustafson, Inc.
FMC Corporation
McGregor Company
Monsanto Co.
Sedagri
Syngenta
UAP Northwest Agri Products
Valent USA Corporation
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Equipment/Cash Contributors

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Columbia Tractor
Conserva Pak Seeding Systems
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Grant Co. Grain Growers
Great Plains
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Johnson Union Warehouse
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Krause Corporation
Lincoln/Adams Crop Improvement Assn.
McGregor Company
McKiernan Bros.
Palouse Welding
Potash and Phosphate Institute
WA Wheat Commission
Whitman Co. Growers
Wilbur-Ellis
Syngenta

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Dale/Dan Bauermeister..................Connell

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Bret/Dan Blankenship ... Washtucna
Doug/Dan Bruce ... Farmington
Rick Brunner ... Almira
Steve Camp ... Dusty
Cenex Full Circle/Grant Torrey ... Moses Lake
Larry Cochran ... Colfax
Tom Cocking ... Colfax
Rob Dewald ... Davenport
Dick/Shep Douglas ... Wilbur
Mike Druffel ... Colton
Leroy Druffel ... Uniontown
Roy Druffel ... Pullman
Richard Druffel & Sons ... Pullman
Roger/Mary Dye ... Pomeroy
Jim Els ... Harrington
Tracy Eriksen ... St. John
Eslick Farms ... Dayton
Jim Evans ... Genesee ID
Farr Farms ... Albion
Karl Felgenhauer ... Fairfield
Greg/Gary Ferrel ... Walla Walla
Fletcher Bros. ... Dayton
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Curt Greenwalt ... Spangle
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Hal Johnson ... Davenport
Rick Jones ... Wilbur
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Ron Juris ... Bickleton
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Duane Kjack ... St. John
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Roger/Randy Koller ... Mayview
Bob/Mark Kramer ... Harrington
Jerry Krause ... Creston
Randy Kulm ... Lind
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Steve Matsen ... Bickleton
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Jim/Mike Moore ... Kahlotus
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Kevin Wigen ... Rockford
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CUNNINGHAM AGRONOMY FARM

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

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

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

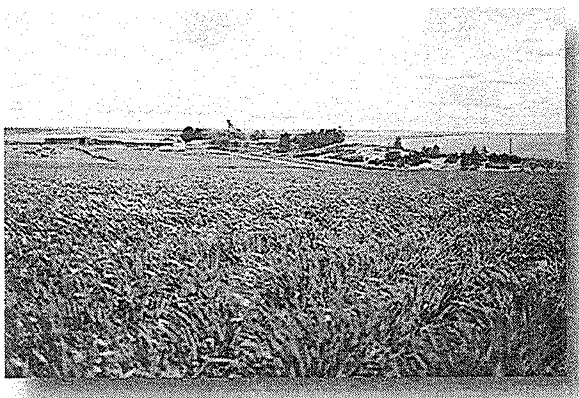
These two goals are intended to facilitate the greatest technological changes for Northwest agriculture since the introduction of mechanization early in the 20^{th} century. Growers and agribusinesses are recognizing both the need for and opportunities presented by these changes.

The past 3 years have been used to obtain site-specific data and develop physical maps of the 140-acre farm, with the greatest detail developed for a 90-acre watershed using 369 GPS-referenced sites on a nonaligned grid. Maps are available or being developed from archived samples for soil types and starting weed seed banks, populations of soilborne pathogens, and soil water and nitrogen supplies in the profile. This has been achieved while producing a crop of hard red spring wheat in 1999, spring barley in 2000, and initiating six direct-seed cropping systems (rotations) starting in the fall of 2001. Yield and protein maps were produced for the crops produced in 1999 and 2000.

The 90-acre portion of this farm is unquestionably the most intensively sampled and mapped field in the Inland Northwest. Some 20-25 scientists and engineers are now involved in various aspects of the work started or planned for this site. A 12-member advisory committee consisting of growers and representatives of agribusiness and government regulatory agencies provide advice on the long-term projects and the day-to-day farming operations, both of which must be cutting edge to compete scientifically and be accepted practically. This farm can become a showcase of new developments and new technologies while leading the way towards more profitable and environmentally friendly cropping systems based on direct seeding and precision farming.

HISTORY OF THE DRYLAND RESEARCH STATION

The Washington State University Dryland Research Station was created in 1915 to "promote the betterment of dryland farming" in the 8-to 12-inch rainfall area of eastern Washington. Adams County deeded 320 acres to WSU for this purpose. The Lind station has the lowest rainfall of any state or federal facility devoted to dryland research in the United States.



Buildings and grounds of the WSU Dryland Research Station at Lind.

Research efforts at Lind throughout the years have largely centered on wheat. Wheat breeding, variety adaptation, weed and disease control, soil fertility, erosion control, and residue management are the main research priorities. Wanser and McCall were the first of several varieties of wheat developed at the Lind Dryland Research Station by plant breeding. Twenty acres of land can be irrigated for research trials. The primary purpose of irrigation on the Dryland Research Station is not to aid in the development of wheats for higher rainfall and irrigated agriculture, but to speed up and aid in the development of better varieties for the low-rainfall dryland region.

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

The facilities at Lind include a small elevator which was constructed in 1937 for grain storage. An office and attached greenhouse were built in 1949 after the old office quarters burned down. In 1960, a 40' x 80' metal shop was constructed with WSU general building funds. An addition to the greenhouse was built with Washington Wheat Commission funding in 1964. In 1966, a deep well was drilled, testing over 430 gallons per minute. A pump and irrigation system were installed in 1967. A new seed processing and storage building was completed in 1983 at a cost of $146,000. The Washington Wheat Commission contributed $80,000 toward the building, with the remaining $66,000 coming from the Washington State Department of Agriculture Hay and Grain Fund. A machine storage building was completed in 1985, at a cost of $65,000, funded by the Washington Wheat Commission.

Growers raised funds in 1996 to establish an endowment to support the WSU Dryland Research Station. The endowment is managed by a committee of growers and WSU faculty. Grower representatives from Adams, Franklin, Benton, Douglas, Lincoln, and Grant counties are appointed by their respective county wheat growers associations. Endowment funds support facility improvement, research projects, equipment purchase, and other identified needs. Also in 1996, the State of Washington transferred ownership of 1000 acres of adjoining land to the WSU Dryland Research Station.

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

PALOUSE CONSERVATION FIELD STATION

The Palouse Conservation Field Station was established as one of 10 original erosion experiment stations throughout the United States during the period 1929 to 1933. The station consists of a number of buildings including offices, laboratories, machine shop, a greenhouse, and equipment buildings, as well as a 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.


Aerial view of the Palouse Conservation Farm

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, and roadside seedings has been in use since the farm was purchased.

Dick Hoffman was appointed farm manager in 1994.

WINTER WHEAT BREEDING AND GENETICS
2000 PROGRESS REPORT

Steven R. Lyon, Research Technician Supervisor
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Soft White Winter Wheat:

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. 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. Data from the WSU Variety Testing Program and various private companies corroborated results from 5 years in our breeding trials: on a statewide average, Bruehl out-yields Madsen, Eltan and Rely.

Bruehl was sold as foundation seed in the fall of 2000. The Washington State Crop Improvement Association reported that Bruehl had the largest distribution of foundation seed of any new variety released by WSU. They sold 334,920 pounds of Bruehl in the fall of 2000 and were sold out by October 1st. They anticipate significant acreage of registered Bruehl to be planted statewide in the fall of 2001.

Several of the Cephalosporium (Cg) resistant breeding lines performed extremely well under both inoculated and natural field conditions and had very good quality. It is unknown exactly how much yield reduction is occurring each year due to Cg stripe, but results from our preliminary yield trials show a yield increase of 6 to 18% over released varieties even under low disease pressure. This year the entire Cg nursery is being evaluated in replicated yield trials at 4 locations across the state. The top lines from these trials will be entered into our most advanced nursery. We are continuing to cross the most popular soft white varieties to wild species and have many lines in early generation head rows in a Cg inoculated nursery.

Breeding lines with foot rot resistance in an Eltan background have been narrowed down to the top 30 based on field and laboratory evaluations. This nursery is now in replicated yield trials at several locations across the state. The top lines from these trials will be entered into our most advanced nursery.

Soft white breeding lines with superior emergence were identified this fall from field evaluations. Several of these new lines had already been promoted into our most advanced white breeding nursery due to their yield potential and other agronomic and quality characteristics. Those with continued exceptional performance will be entered into the Variety Testing Program's Preliminary/shadow nursery in the fall of 2001.

Hard Red/White Winter Wheat:

Development of a hard white and hard red Eltan is proceeding as planned. Ninety hard white selections were first field tested in 98/99 and first year quality tests indicated that 70% had better noodle color score than Eltan and 25 % had better loaf volume, confirming the dual purpose nature of these wheats. We are awaiting quality results from the 99/00 crop year. The hard red Eltan selections are also being screened for quality and other agronomic characteristics.

For the second year we planted the annual Western Wheat East-European Regional Yield Trial nursery in Pullman, Lind and Douglas County to screen their hard red and hard white lines for quality and adaptability. Those with acceptable agronomic and quality characteristics are being crossed with our best hard wheats.

We obtained 103 lines from the Texas Agricultural Experiment Station based in Dallas, Texas. These lines will also be evaluated for quality and adaptability and possibly entered into our crossing-block.

Twenty hard white lines from Australia were harvested at Pullman this year. We are awaiting results from the Wheat Quality Lab for their quality evaluations and then the top lines will be crossed with our best hard wheats.

We have established collaborative efforts with breeding programs in China, Austria, Japan, India, and Switzerland in order to continue to expand our genetic base and develop improved varieties.

We make every effort to procure any hard seed that is released from breeding programs nationally and internationally as soon as it is announced and evaluate it for adaptability and quality. If it is acceptable we use it as a parent in our breeding program.

We established a nursery at the Lind Field Station exclusively for screening for fusarium dryland foot rot in 1999. All of our advanced and preliminary yield lines were again evaluated for susceptibility/ tolerance to this disease.

Sixty-four bulk selections from Dr. Ed Donaldson's former hard wheat breeding program were evaluated. These lines were selected based on pedigree analysis, as they appeared to be the most promising hard red and hard white lines from over 400 bulk populations that he had shelved due to budget constraints. Twenty-two of these lines have been advanced for further agronomic and quality evaluations.

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.

Advanced hard red and hard white lines were evaluated for emergence capabilities under natural field crusting on two seeding dates in Franklin County. We were able to identify those lines with superior and inferior emergence capabilities. We will now also be able to evaluate tillering and yield response with partial stands.

The first hard wheats to come totally through our program have now been advanced to replicated yield trials. These lines have been intensely selected for disease and strict quality characteristics in the greenhouse, laboratory and field. Selection for release will be based on emergence capabilities, yield and test weight, and consistent hard wheat quality under various environments. Twenty hard red breeding lines and 43 hard white breeding lines are in advanced replicated yield trials. These are in addition to the 90 hard white lines and 17 hard red lines in an Eltan background that are also in field trials. Targeted release for a new hard wheat is 2003.

Breeding Plot Trials:

Results (bu/a) of promising lines from selected locations:

2000 Hard Red 2 Varietal Performance

	Lind	Pullman	Dusty	St Andrews	State ave
Eltan	80.2	85.7	79.1	66.3	87.9
Finley	70.0	67.6	64.9	62.5	75.5
J950272-001	60.2	112.3	82.3	55.6	86.2
5J950358-01	63.0	74.3	68.1	59.9	75.9
5J950368-02	75.4	105.8	72.9	68.9	89.4
5J950373-04	74.9	101.7	72.8	55.4	81.9
5J950391-02	54.2	110.5	64.5	53.3	85.0
5J950395-06	62.7	103.4	75.6	52.4	84.1
5J950414-02	81.6	76.5	67.8	72.4	76.2
5J950374-07	65.8	96.2	84.7	60.9	83.2
5J950391-01	55.7	91.7	70.8	56.0	78.2

2000 Soft White Common Varietal Performance

	Anatone	Bickleton	Colton	Connell	Dusty	Harrington	Lamont
Madsen	117.1	51.7	103.0	43.6	89.1	89.7	131.6
Eltan	106.0	39.6	92.0	53.2	85.9	94.7	120.4
Rod	104.5	61.4	109.7	51.0	102.0	99.0	145.1
Stephens	95.1	57.9	97.8	35.3	90.3	99.4	108.2
VO95280	111.4	61.2	100.2	55.1	94.2	106.3	111.0
VO96406	85.1	51.5	93.8	61.3	116.0	102.5	112.4
V096408	92.7	56.4	104.6	60.7	106.8	106.9	132.4
VO96409	113.0	62.7	100.6	60.6	113.9	101.6	127.2
VO96410	89.1	59.9	96.2	58.6	103.9	102.6	124.0
VO96411	100.0	60.0	102.7	60.6	97.6	97.7	131.4
VO96511	98.0	64.9	95.8	61.4	89.8	105.6	136.9

	Pomeroy	Pullman	Reardan	Ritzville	St. Andrews	Waterville	State ave
Madsen	106.7	120.7	123.5	96.8	48.1	96.1	93.7
Eltan	85.2	95.6	124.5	102.5	57.9	110.7	89.9
Rod	114.4	124.7	125.7	102.7	52.9	102.5	99.6
Stephens	81.3	116.2	98.4	98.1	47.0	83.1	85.2
VO95280	119.8	109.3	132.0	112.6	56.6	109.5	98.4
VO96406	107.8	113.2	133.8	107.9	74.0	100.8	96.9
V096408	118.0	116.4	131.1	97.4	64.9	103.0	99.3
VO96409	124.4	107.4	120.2	93.1	72.7	102.2	100.0
VO96410	105.1	107.5	137.4	104.9	71.3	100.9	97.0
VO96411	117.9	108.0	123.6	98.7	63.6	106.9	97.6
VO96511	110.3	107.8	130.8	103.0	67.9	109.6	98.6

2000 Cephalosporium Yield Trial – Pullman

Variety	No inoc	inoc
J99C0009	117.3	130.2
J98C0002	114.0	129.9
Madsen	**121.4**	**122.4**
J99C0002	133.1	106.3
J99C0008	118.4	118.5
J98C0001	129.7	103.7
Stephens	**125.5**	**107.0**
J99C0003	131.0	94.5
J99C0005	117.3	102.5

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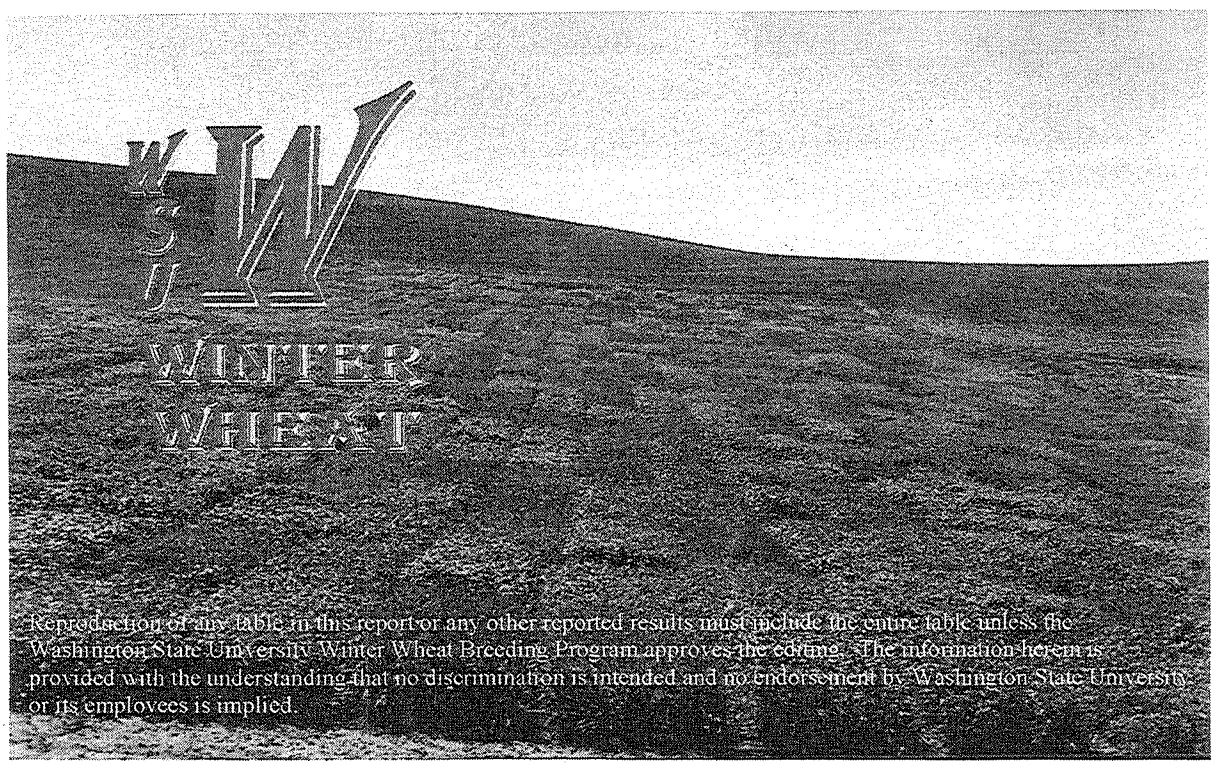

WINTER WHEAT STAND ESTABLISHMENT AND EMERGENCE COMPARISONS

S. Lyon[1], S. Jones[2], K. Campbell[3], J. Burns [4], B. Schillinger[5]
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Stand establishment is the most important single factor affecting winter wheat production potentials in low-precipitation dryland regions of the inland PNW. Sixty percent of Washington's winter wheat production area (central and south central Washington) falls within low-precipitation regions that are characterized by receiving only 6-12 inches of precipitation per year. In dry years, winter wheat must be planted as deep as 8-inches to reach adequate moisture for germination. Until recently, growers in these regions have been unable to take full advantage of 40 years of extensive soft white winter (SWW) improvement with semidwarf varieties because of the limited capacity of semidwarf wheats to germinate and emerge from deep planting depths. Growers desiring to raise soft white winter wheat have almost exclusively planted Moro, (Oregon State University-1965) due to Moro's ability to emerge from deep planting depths. The release of EDWIN soft white club (WSU-1999) represents the emphasis the WSU Winter Wheat Breeding Program in cooperation with the WSU Dryland Research Station (Lind, WA) placed on evaluating emergence characteristics to find a replacement for a 35-year old variety – MORO. Worth noting, EDWIN was developed from crosses with semidwarf wheat lines.

SEMIDWARF CONSTRAINTS: All commercially available SWW varieties, except 'Moro', carry Rh (*reduced height*) dwarfing genes (Rht_1 or Rht_2). Semidwarf SWW varieties typically have coleoptile (seeding leaf sheath) lengths 30 to 40% shorter than non-semidwarf SWW varieties. Seeded too deep, semidwarf varieties often have the first or second true leaves 'split' from the coleoptile before emergence which results in 'kinked' and 'yellow-colored' leaves that are incapable of penetrating the soil surface. In cases where 'kinked' leaves do emerge, plants are generally too weak to survive.

SOIL CRUSTING: Superimposed on the 'genetic' inability of semidwarf SWW to emerge from deep seeding depths is soil 'crusting'. "Crusting" is caused by rain showers and rapid soil drying after seeding that causes compacted layers that impedes coleoptile emergence. Again, the coleoptile is the key component in varietal adaptation since rapid seedling growth habit often provides enough time for emergence before crusting occurs. In addition to Moro SWW, Hard Red Winter varieties such as Buchanan, Finley, Wanser and Weston have long coleoptiles (3-4 inches) and rapid rates of elongation. These varieties can attain over 60% emergence within two weeks of planting, even when planted 6-8 inches deep (Chart 1).

BREEDING ADVANCES: – EDWIN: EDWIN (WSU-1999) is soft white winter club wheat with emergence abilities equal to MORO and are superior in yield, test weight, straw strength, rust resistance, winter hardiness and end-use quality. From a historical perspective, a 1995 WSU SWW breeding trial in Connell, WA (Bauermeister farm) ushered in the release of EDWIN. During September 1995, 1.4 inches of precipitation 7-

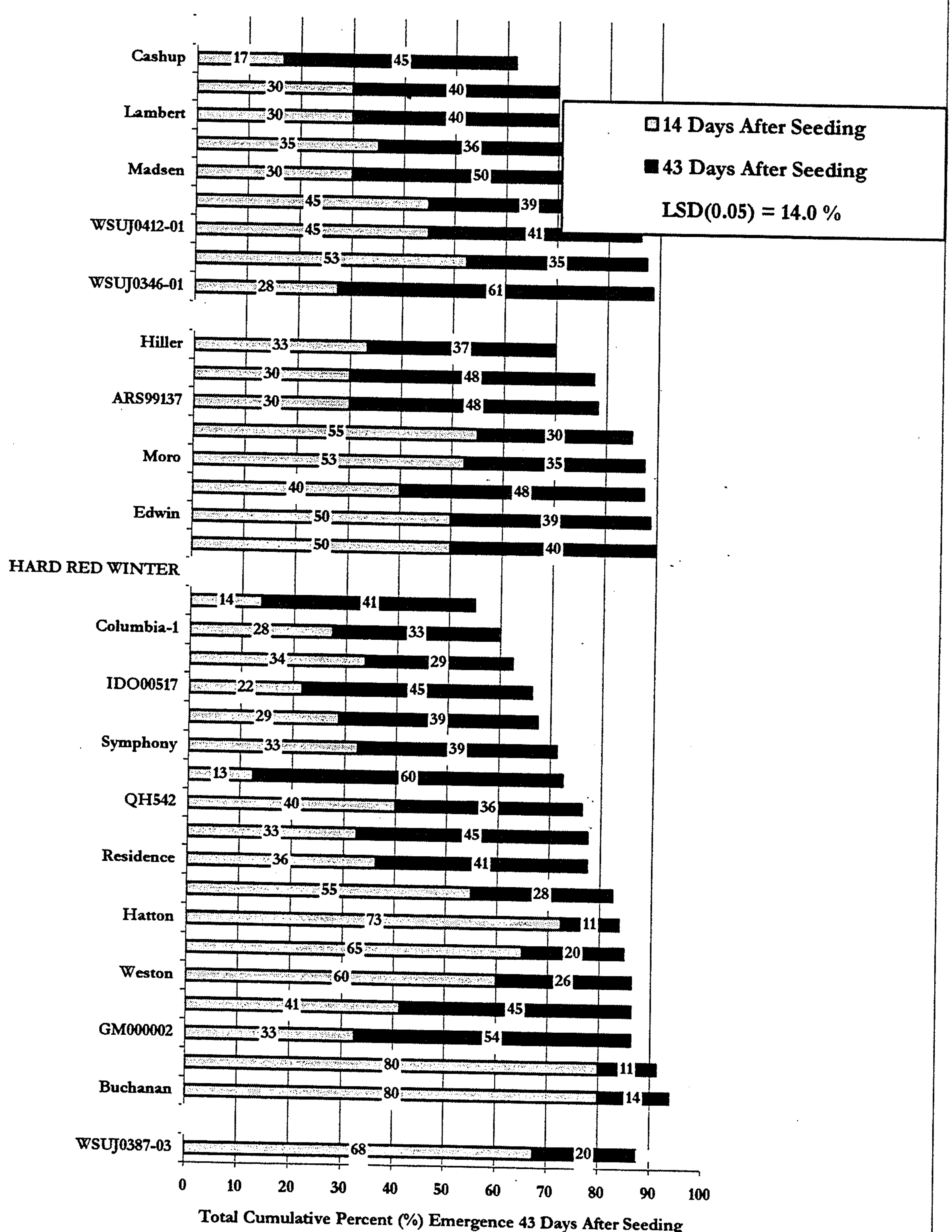
days after seeding caused severe crusting. Emergence notes taken 20 days after seeding had only two of more than 300 selections with seedling emergence greater than 40%, MORO and WA7834. WA7834 became EDWIN. Release of EDWIN has been somewhat overshadowed with recent releases of other soft white common and club wheat varieties. EDWIN was available as Registered seed in fall 2000 and represented the first variety in 35 years to replace MORO.

EMERGENCE EVALUATONS 2000-2001: Emergence notes taken during September and October 2000 at a Connell, WA in the WSU Variety Testing SWW Shadow (preliminary) nursery and Advanced Hard Red, Advanced Hard White and Advanced Club nurseries of the WSU Winter Wheat Breeding Program again showed the variability that exists between varieties (Chart 1). These nurseries were seeded on September 5, 2000 at a six-inch depth. Four days after seeding (DAS), 0.12 inches of rain fell that resulted in soil crusting. Emergence was evaluated 14 (19 Sep) and 43 (18 Oct) DAS. It is apparent a major strength of the variety such as Buchanan (WSU, 1989) is its ability to attain over 80% emergence within the first two weeks of planting. In contrast, varieties not considered adapted for the Connell, WA area such as Madsen, Cashup, Rely, and Estica attained 30% emergence or less in the same two week period. Only 50% of the varieties being tested in the 2000 Connell nurseries attained adequate stand populations (>80% emergence) 43 days after seeding. In general, all varieties that reached 80% emergence had at least 50% emergence within 2-weeks after seeding. As reflected in Chart 1, there is a number of promising new winter wheat lines (both soft white and hard red) that have excellent emergence potentials.

Acknowledgements

The WSU Dept of Crop and Soil Sciences, Winter Wheat Breeding Program, Dryland Research Station-Lind and the Variety Testing Program in cooperation with the USDA-ARS Club Wheat Program would like to acknowledge Dan and Dale Bauermeister, Connell, WA, for their many years of cooperation. In addition, research-funding support from the Washington Wheat Commission for the Connell trials and many other similar trials is enabling continuation of 106 years of varietal improvement of winter wheat at WSU.

CHART 1. Winter Wheat Varieties That Had 45%-50% Emergence Within 2-Weeks After Seeding Showed Significantly Greater Stand Establishment After 6-Weeks (WSU Winter Wheat Breeding Program, Connell, Sept-Oct 2000)



CLUB WHEAT CULTIVAR DEVELOPMENT AND SOFT WHEAT GERMPLASM ENHANCEMENT: USDA-ARS WHEAT BREEDING AND GENETICS

Kim Garland Campbell, Todd Linscott, Lynn Little, Scott McDonald, Ben Sakkarapope

Growing conditions were favorable for winter wheat in Eastern Washington, Northern Idaho, and Northeastern Oregon in the year 2000. A mild winter was followed by a cool spring and moderate summer. Disease pressure was light. State average yields of winter wheat were 73 bu/a in WA, 62 bu/a in OR and 90 bu/a in ID. In Washington, soft white wheat was the predominant class grown with 1,455,400 acres planted, club wheat acreage increased to 12% of the total crop or 235,000 acres.

As part of the USDA-ARS Wheat Genetics, Quality, Physiology, and Disease Resistance unit, the objectives of the ARS breeding and genetics program are:

- To develop improved club wheat cultivars for the Pacific Northwest
- To develop wheat germplasm with
    - better emergence
    - improved winter hardiness
    - improved end-use quality
    - resistance to rusts and soil borne disease
    - resistance to preharvest sprouting,
- To coordinate the Western Regional Nurseries.

Yield trial locations included Bickelton, Central Ferry, Connell, Harrington, Lind, Pomeroy, Pullman, and Ritzville, in Washington plus Lexington, Echo, Moro and Pendleton in Oregon. Separate disease nurseries were established to evaluate resistance to foot rot (*Tapesia yallunde*) and stripe rust (*Puccinia striiformis*). The WSU winter wheat breeding program, the WSU variety testing program, and personnel at the Columbia Basin Agricultural Research Center in Pendleton OR assisted in the planting and harvest of several nurseries.

Field plots evaluated in 2000:

Nursery	Entries	Locations
Elite	36	18
Advanced	72	12
Tall	18	6
Preliminary	180	5
F4	1,000	3
Head Rows	37,760	1
F2	190	1
Crosses	432	GH

Twenty-seven entries contributed by breeders from throughout the Pacific Northwest were evaluated in the Western Regional Hard Winter Wheat Nursery, 35 entries in The Western Regional Soft Winter Wheat Nursery, and 39 in the Western Regional Spring Wheat Nursery. The complete report for agronomic data is available at on the web through the graingenes gopher at gopher://greengenes.cit.cornell.edu/11/.Performance/.westregional.
Five ARS breeding lines were sent to the 2001 regional nurseries, 4 clubs were entered for the first time. They are: ARS 9658, ARS97119, ARS97123, and ARS98237. ARS97119 and ARS97123 are sister lines. One soft white winter ARS96277, was re-

entered. All five entries have both foot rot resistance derived from VPM (the source of resistance in Madsen), and resistance to stripe rust from various sources.

A soft white winter wheat, WA7853, approved for release and named **'Finch'**. It was released as a complement to Madsen as a second soft white wheat with resistance to foot rot and stripe rust. Finch has better end use quality and superior yields to Madsen. A white club wheat, WA7855, was approved fro pre-release seed increase and named **'Chukar'**. It was released as a high yielding club wheat for Eastern WA and Northern ID. Chukar has resistance to foot rot and stripe rust, plus good agronomic characteristics for the higher rainfall areas of the Pacific Northwest. It has excellent club wheat milling and baking quality. It has exhibited superior yields to Madsen, and to most other soft white wheat cultivars in the Palouse.

Description of new USDA-ARS Breeding Lines released, 2001

Name	Class	Thousand Kernel Weight 1997-2000	Heading Date 1997-2000	Height 1997-2000	Lodging 1998-1999
		g	*julian*	*cm*	%
CODA	CLUB	30	154	92	2.6
HILLER	CLUB	33	153	88	1.7
RELY	CLUB	32	154	91	5.1
TEMPLE	CLUB	37	150	89	4.0
CHUKAR	**CLUB**	**34**	155	88	1.1
A96105	COMMON	41	158	90	1.1
ELTAN	COMMON	35	156	88	6.9
MADSEN	COMMON	38	151	87	0.9
STEPHENS	COMMON	47	148	84	1.4
FINCH	**COMMON**	**34**	157	87	0.7
Average			153	88	3.3
LSD (0.05)		4.9			7.07

Average Yields of new ARS breeding lines, released 2001, Summarized within Years.

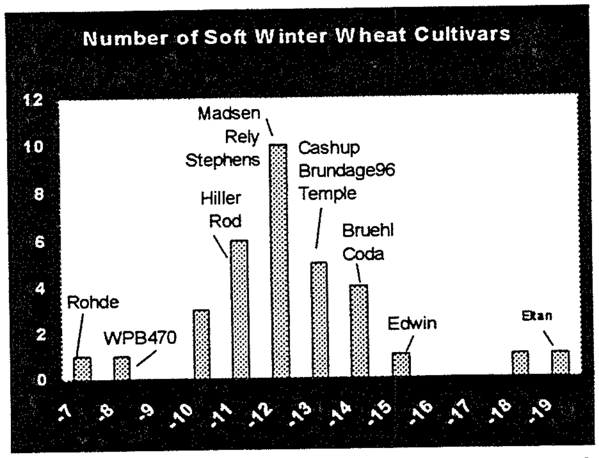
Entry	Class	1997	1998	1999	2000
CODA	Club	87	71	77	82
HILLER	Club	86	73	79	79
RELY	Club	91	69	75	78
TEMPLE	Club	---	74	70	82
CHUKAR	**Club**	**94**	**74**	**78**	**87**
ARS96105	Common	---	77	78	84
ELTAN	Common	89	62	82	80
MADSEN	Common	85	75	73	81
STEPHENS	Common	80	71	68	81
FINCH	**Common**	**91**	**75**	**74**	**88**

Cold Hardiness of new USDA-ARS Breeding Lines Released, 2001.

Entry	Class	Spring Stand Pullman 1999	Vigor Lind, Pullman 1999	Cold Hardiness Est. LT50	Est. LT50
		(%)	*(1-9=good)*	*1998*	*1999*
CODA	Club	82	7.3	-11.15	-11.21
HILLER	Club	81	5.7	-12.60	----
RELY	Club	78	6.2	-12.26	-13.17
TEMPLE	Club	81	6.0	-13.39	-12.88
CHUKAR	**Club**	**78**	**6.8**	**-13.67**	**-14.88**
ARS96105	Common	77	6.2	-12.92	-14.06
ELTAN	Common	83	7.8	-15.07	-17.92
MADSEN	Common	77	6.2	-11.81	-12.14
STEPHENS	Common	67	5.3	-11.07	-11.99
FINCH	**Common**	**76**	**6.5**	**-10.79**	**-11.04**

In our project to improve emergence of winter wheat from deep furrow seedling, we have used SSR marker, *Xgwm622* to screen advanced breeding lines for the presence of *Rht8*. We have lost *Rht8* in most lines. We suspect that it has been lost because of its linkage to *Ppd1* (which results in photoperiod insensitivity) and our tendency to select for photoperiod sensitivity in our environment. We have identified one breeding line with *Rht8* and will be evaluating it for photoperiod sensitivity this fall.

In our project to evaluate winter hardiness of winter and spring cultivars in the PNW, we are determining LT50 ratings using freeze testing. Winter cultivars commonly grown in the PNW have LT50s that range from –7°C to -18 °C . See figure:



In our project to combine rust resistance with soil borne disease resistance, we evaluated 300 breeding lines for presence of the Pch1 gene conferring resistance to strawbreaker foot rot. It is present in all of our elite breeding lines. Most of those lines also have resistance to stripe rust.

We also entered 10 breeding lines into the WSU Shadow Variety Trial that is planted at several locations throughout Eastern Washington. For 2001 we have established inoculated disease nurseries at Spillman for Cephalosporium stripe, strawbreaker foot rot, stripe rust, and leaf rust.

In 2001 we have planted:

Nursery	Entries	Locations
Elite	36	16
Advanced	36	13
Tall	25	13
Preliminary	180	9
F4 Head Rows	1510	4
F3 Head Rows	17,250	1
F2 populations	492	1

Publications in 2000

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Campbell., K.G., Pritchett, J., Little, L. 2000. Progress Report. Project 4852: Breeding Club wheat with combined resistance to rusts, strawbreaker foot rot and cephalosporium stripe. pp116-119 In: Research Review, Washington Wheat Commission and Washington Assoc. of Wheat Growers, Pullman WA., Feb. 16-17. 2000.

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STRAWBREAKER FOOT ROT, CEPHALOSPORIUM STRIPE, AND SNOW MOLD DISEASES OF WINTER WHEAT

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Strawbreaker foot rot (also known as Eyespot) and Cephalosporium stripe are two of the most important diseases of winter wheat in the Inland Pacific Northwest. These diseases are most common in the high rainfall areas (more than 18" annual precipitation), but can cause significant losses in the lower rainfall areas too. Early-seeded winter wheat has the greatest risk of being affected by these diseases, especially when planted following summer fallow. Grain yield in fields where either of these diseases is severe may be half or less than that of fields where these diseases are not serious. The snow mold diseases are limited to the northernmost wheat-producing areas of Lincoln, Douglas, and Grant Counties and southern Okanogan County where snow cover frequently persists for 100 days or more. Left uncontrolled, all of the plants in a field can be killed when snow mold is severe.

Disease-resistant varieties are the most desirable control measure for all three of these diseases. Varieties with resistance to strawbreaker foot rot and the snow molds are available and used widely. Varieties with resistance to Cephalosporium are not currently available, however.

Table 1. Cephalosporium stripe disease index, yield, and test weight of winter wheat varieties and breeding lines, Spillman Farm, 2000.

Genotype	Disease index	Yield bu/A	Test Wt. lbs/bu
WA7437	1.8	83.0	60.4
AT3425	2.3	37.2	52.0
Coda	2.3	115.0	62.6
Rod	5.2	125.7	60.8
Bruehl	6.5	123.7	58.3
Eltan	7.0	110.7	60.4
Lambert	8.8	132.6	61.0
Cashup	8.8	120.1	61.6
WA7871	9.5	119.2	59.0
Daws	10.5	97.4	61.4
Edwin	10.7	82.6	62.2
Madsen	11.0	115.3	60.9
Hiller	13.0	121.1	58.7
Albion	15.8	109.3	60.7
Hill 81	17.5	103.2	60.1
Stephens	25.6	97.9	60.4
LSD 5%	**10.9**	**29.7**	**1.1**

Disease index ranges from 0 to 100, where 0= all healthy plants with no visible symptoms and a 5= all diseased plants with stripes in the flag leaf or head. AT3425 is a wheat-wheatgrass hybrid that is perennial. LSD= least significant difference: Two figures in the same column must differ by this amount to be considered statistically different.

Cephalosporium stripe is controlled by delaying seeding in the fall (in fields seeded early relative to the production area), increasing the length of crop rotation so that winter wheat is grown one year in three, and by increasing tillage to promote decomposition of crop residue infested with the pathogen. None of these practices completely controls the disease, and all may have undesirable consequences such as increased soil erosion potential or decreased yield potential.

Resistance to Strawbreaker and Cephalosporium. Field plots to screen winter wheat cultivars and breeding lines for resistance to Cephalosporium stripe were conducted at the Spillman Agronomy Farm in 1998, 1999, and 2000 as part of our continuing effort to improve the resistance of commercial varieties to this disease (results from 1998 & 1999 were presented previously). In 2000, disease index ranged from a low of 1.8 for WA7437 to 25.6 for Stephens (Table 1). Yield and test weight ranged from 132.6 to 37.2 bu/A and 62.2 to 52.0 lb/bu, respectively. Coda had the lowest disease index for commercial varieties and WA7437 had the lowest disease index among all lines tested.

Studies are in progress to determine the number and location of genes in AT3425 conferring resistance to Cephalosporium stripe to aid in transferring resistance to adapted winter wheat lines. Ultimately, we want to develop molecular markers for these resistance genes in order to accelerate the development of Cephalosporium stripe resistant varieties. Molecular markers are tags placed on the resistance genes that allow us to follow them in crosses and determine which progeny plants have the resistance genes without the need to test them for resistance in field plots.

Resistance to strawbreaker foot rot is determined first in a seedling test conducted in a growth chamber and then under field conditions by inoculating plants with the pathogen. Growth chamber tests allow us to eliminate most of the susceptible lines before field-testing, which improves our efficiency and reduces the cost of testing.

Over 100 progeny lines from a cross between Eltan and Madsen were evaluated for resistance to strawbreaker in the greenhouse and the most resistant 30 lines were sown in the September 2000. These lines will be evaluated for disease severity and yield during summer 2001.

Resistance to snow mold. Bruehl, a new snow mold resistant club wheat variety, was approved for release in February 1999 and foundation seed was available for the 2000 planting season. Bruehl has snow mold resistance that is equal to Sprague and yield potential equal to or greater than Eltan. A continued effort is being made to develop new, more resistant varieties for the snow mold areas of the Washington State. To aid in this effort, research is in progress to develop methods of screening for resistance in the growth chambers to

Table 2. Recovery of winter wheat lines from speckled snow mold in two field plots located in Douglas County, WA in 2001.

Line	Mansfield	Waterville	Average
Bruehl	6.0	3.8	4.9
Eltan	6.5	4.3	5.4
Sprague	4.8	5.0	4.9
Stephens	3.0	2.3	2.7
VO95010	6.3	4.0	5.2
VO950114	5.3	3.5	4.4
VO96411	5.8	2.8	4.3
VO96511	6.0	3.8	4.9
J950315-001	5.8	3.5	4.7
6J950370-02	5.3	4.3	4.8

expedite the development of resistant varieties by allowing disease screening to continue throughout the year.

Presently, field tests that rely on disease development under natural conditions are used to evaluate potential new varieties. During the winter of 2000-2001, snow cover persisted for more that 120 days across much of the northern wheat-producing region of Washington and snow mold development in our field plots ranged from moderate to severe. Commercially available varieties were included as controls along with several advanced SWW selections in field plots located in Douglas County; the Tannenberg Ranch on Dyer Hill near Mansfield and the Jacobsen Ranch near Waterville. Recovery from snow mold was evaluated about one month after snowmelt on a 0 to 8 scale, which reflects the percentage of plants that regrow and the vigor of those plants (Table 2).

CONTROL OF WHEAT AND BARLEY RUSTS
2000 PROGRESS REPORT

X.M. Chen, D.A. Wood, M.K. Moore, G.P. Yan, and R.F. Line

OVERVIEW: Stripe rust, leaf rust, and stem rust affect all classes and types of wheat and occur in all agronomic zones. Without resistance, all 2,500,000 acres of winter and spring wheat in Washington can be infected. They are most destructive in the high rainfall and irrigated zones. **Stripe rust** is the most important disease of wheat in the Pacific Northwest (PNW). The PNW environment is highly favorable for severe stripe rust (losses in excess of 20%) in at least three out of four years and every year in western Washington. In the PNW, stripe rust reduced wheat yields by more than 50% in the early 1960's and by more than 20% in 1981. Without resistant cultivars and effective fungicides, losses would often exceed 80%. Susceptible cultivars such as 'Omar' (the cultivar grown in 1960 on about 70% of the Washington wheat acreage) have been often totally destroyed by stripe rust in experimental plot. The destructiveness of **leaf rust** occurs in at least two out of every four years and every year in fields with overhead irrigation. As we improve stripe rust resistance, leaf rust becomes more important because wheat crops not damaged by the early stripe rust can be damaged by leaf rust. Losses of 10 to 50% caused by leaf rust have occurred in many years since 1974. Leaf rust is more severe when the weather is most favorable for high yields. **Stem rust** is less common because it develops late in the growing season when the weather is often unfavorable for the rust. When precipitation is frequent in June and July, it can cause greater losses than stripe rust. Except a few winter wheat cultivars and some spring wheat cultivars, wheat cultivars grown in the PNW are generally susceptible to stem rust. **Barley stripe rust** is a relatively new disease that can cause widespread damage to barley. Barley stripe rust and wheat stripe rust are similar; however, they are two different diseases. Wheat stripe rust can attack some barley cultivars, but it has never severely damaged the barley crop. In contrast, barley stripe rust has reduced barley yields by 30 to 100 percent and reduced grain quality. In the United States, barley stripe rust was first detected in Texas in 1991 and is now established in the west United States. In 2000, it continued being destructive in California and western Washington. The environment in the PNW is highly favorable for barley stripe rust. If not controlled, it can be highly destructive whenever the weather is favorable for epidemics.

GOAL: Prevent losses in yield and quality of wheat caused by stripe rust, leaf rust, and stem rust and of barley caused by stripe rust, and assure stable, sustainable wheat and barley production.

APPROACH: Monitoring rusts, determining environmental and managerial factors that contribute to rust epidemics, identifying races, and characterizing rust populations; characterizing types, identifying new sources, determining inheritance, and identifying new genes of resistance; screening for resistant germplasm and testing breeding lines for new cultivars with adequate rust resistance; developing strategies and methods to improve resistance, developing molecular markers for resistance genes, and using the markers to combine genes for different types of resistance to obtain durable and high-level resistance; and determining effectiveness and use of fungicides for rust control.

ACCOMPLISHMENTS:

1. Monitored rust development, predicted rust epidemics, assessed crop losses, determined prevalent races, and identified new races

Wheat stripe rust, leaf rust, and stem rust were accurately predicted for the year 2000 using monitoring data and predictive models based on environmental factors such as temperature, precipitations, and resistance of wheat cultivars. Wheat stripe rust in the United States occurred from California and the PNW to Virginia and from Texas to North Dakota. Severe yield losses occurred in fields of susceptible wheat in California, the PNW, and the south-central states (Arkansas, Louisiana, and Texas). In Arkansas, more fungicide was sprayed than in the last five years and many fields were abandoned because of stripe rust. The severe epidemics in the south-central states and the spread of the disease to the northern and eastern states were due to the weather conditions, new races of the rust pathogen, and widely grown susceptible cultivars. Stripe rust was found early because it overwintered in many areas in the southern United States, where the winter was milder than normal. The spring weather was cooler than normal, favoring stripe rust development. California wheat also suffered severe yield losses in 2000 because of cool weather and storms that provided moisture allowing stripe rust to increase. 'RSI 5', one of the prevalent wheat cultivars in California, suffered about 50% yield loss in some areas, particularly in the Sacramento-San Joaquin Delta region. More importantly, a group of new races with virulences that were first detected in the United States were prevalent in California and east of the Rocky Mountains.

In the PNW, wheat stripe rust widely occurred, but yield losses were the minimum in 2000. The winter of 1999-2000 was mild, favoring stripe rust overwintering. More than 90% stripe rust was observed on susceptible entries in our stripe rust nurseries and on susceptible cultivars such as "Westbred 470" in commercial fields. Dry weather of May slowed the development of stripe rust. Resistant cultivars that were widely grown in the PNW provided effective control of wheat stripe rust. The durable, high-temperature, adult-plant resistance that is in most soft white winter wheats, hard red winter wheats, and spring wheats and the multiline cultivar "Rely" of club wheat with many seedling-resistance genes prevented severe stripe rust epidemics.

Because of unfavorable weather conditions, wheat leaf rust and stem rust were not significant in the PNW in 2000. Yield losses due to leaf rust were the minimum, and there were almost no yield losses due to stem rust.

In 2000, the barley stripe rust pathogen continued surviving and increasing in the west United States. In northwestern Washington, the fall, winter, and spring environments were highly favorable for establishment, survival, and increase of barley stripe rust, and when not controlled, losses exceeded 60%. In eastern Washington, the mild winter of 1999-2000 was favorable to the survival of the rust pathogen. But the dry weather in May prevented severe stripe rust. Consequently, damage from barley stripe rust was minimal.

Hundreds of stripe rust collections were evaluated to determine their virulence. These samples were increased on susceptible cultivars and tested on a set of cultivars that are used to differentiate races of wheat stripe rust in the United States. In addition to the 16 wheat differential cultivars, 'Clement', 'Compair', and the *Yr8* and *Yr9* single gene lines were also used in the tests to determine virulence of the wheat stripe rust pathogen. In 2000, the most prevalent races of wheat stripe rust in the PNW were those attacking 'Lemhi', 'Fielder', 'Produra', 'Moro', 'Paha', and seedlings of 'Druchamp' and 'Stephens'. The most prevalent races in California were "Express"-attacking races and races attacking Express and varieties with stripe rust resistance genes *Yr8* and *Yr9*. The predominant races east of the Rocky Mountains were those attacking cultivars with *Yr8*, *Yr9*, and Express. The Express-attacking races, which were first detected in California in 1998, were in all regions but predominant in California and east of the Rocky Mountains in 2000. The races attacking *Yr8* and *Yr9* were first detected in the United States and widely distributed in 2000. Twenty new races of wheat stripe rust were detected in 2000. Thus, 80 races of wheat stripe rust have been identified in the United States since 1960s. The new races especially those attacking *Yr8*, *Yr9*, and Express were not prevalent in the Pacific Northwest, but they may appear in the PNW in the future. We need to consider them in the PNW wheat breeding programs for developing stripe rust resistant cultivars.

Since we began to identify barley stripe rust races in 1993, 52 races were identified, of which seven races were identified from the samples collected in 2000. The predominant races were virulent on 'Topper', 'Hiproly', 'Abed Binder 12', and 'Trumpf'. Compared to races from 1995 to 1999, relatively few races were present in 2000 and the 2000 races were virulent on relatively few (1, 2, 3, or 4) differential cultivars. The results indicate that the barley stripe rust pathogen continues evolving and that the environmental conditions and host selections favor races attacking fewer differential cultivars. The data also indicate a potential danger that the current cultivars may push the rust population to be more aggressive on certain cultivars. The results suggest that diverse genes for race-specific resistance and genes for durable type resistance should be used to develop barley cultivars with resistance to stripe rust.

2. Tested germplasm and breeding lines for rust resistance

More than 3,200 germplasm entries of wheat and 1600 germplasm entries of barley from the National Germplasm Collection at Aberdeen, ID were evaluated in the greenhouse for resistance to the most virulence races of the wheat stripe rust pathogen and at various field sites for adult-plant resistance. More than 2,500 spring wheat and winter wheat cultivars and advanced lines from public and private wheat breeders in the western United States were evaluated in the greenhouse and at field sites in eastern and western Washington for resistance to stripe rust. Breeding lines with resistance to the rusts were identified. High-temperature, adult-plant (HTAP) resistance continues to be the most effective and durable type of stripe rust resistance. More than 95% of the wheat cultivars in Washington have stripe rust resistance, and all newly released cultivars have HTAP resistance. Seedlings of all major barley cultivars grown in the United States are vulnerable to barley stripe rust. Some cultivars have adult-plant resistance, which reduces the rate of rust increase in fields. Of the local cultivars, stripe rust is severe on 'Steptoe', 'Morex', and 'Harrington' but less severe on 'Baronesse'. New cultivars such as 'Tango' and 'Bancroft' are resistant to barley stripe rust.

3. Developed molecular markers for stripe rust resistance

To obtain superior, durable resistance against stripe rust of wheat, molecular markers were identified for genes conferring high-level seedling resistance, and durable, adult-plant resistance. The resistance gene analog polymorphism (RGAP) technique that we recently developed was used to identify markers for wheat resistance to stripe rust. Unique RGAP markers were identified for near isogenic lines with *Yr1*, *Yr5*, *Yr7*, *Yr8*, *Yr9*, *Yr10*, *Yr15*, *Yr17*, and *YrA*. We demonstrated that the co-segregating RGAP markers for *Yr9* can be efficiently used for identify the *Yr9* gene in wheat germplasm and in breeding lines. To identify markers for the *Yr5* resistance to wheat stripe rust, a BC_7:F_3 population was developed using the recurrent parent (Avocet S) and the *Yr5* near-isogenic line from the Plant Breeding Institute, Australia. Seedlings of the parents and BC_7:F_3 lines were tested with two stripe rust races under controlled greenhouse conditions. Genomic DNA was extracted from the parents and BC_7:F_3 lines. The RGAP technique and the bulk segregant analysis were used to identify markers. A linkage map was constructed for *Yr5* using 10 positive and six negative RGAP markers that were analyzed with 109 BC_7:F_3 lines. Of the 16 markers, five positive and 4 negative markers were coincident with *Yr5*. Six positive and three negative markers were verified with additional 93 BC_7:F_3 lines. Two positive and three negative markers co-segregated with *Yr5* and the other four markers were within 0.2 to 1.2 cM from *Yr5*. Analyses of the set of Chinese Spring nulli-tetrasomic lines with three negative markers confirmed that *Yr5* is on chromosome 2B. To map quantitative trait loci (QTL) for durable, high-temperature, adult-plant (HTAP) resistance, the F_7 lines of Stephens/Michigan Amber were evaluated for resistance in field plots. Molecular markers were identified by amplifying the F_8 DNA with RGA primers. Resistance QTLs that explained the most of variation were mapped on a linkage group consisting of 10 RGAP markers. These results show that the RGAP technique can be used to identify resistance genes in germplasm and may be used to help combine resistance genes. These markers can now be used to combine different genes for resistance and different types of resistance without loosing quality.

4. Determined effectiveness and use of foliar fungicides for rust control

Foliar fungicides were evaluated for control of the rusts in winter and spring plots of wheat and barley near Mt Vernon, Walla Walla, and Pullman, WA. Foliar applications of Folicur, Tilt, Quadris, or Stratego controlled stripe rusts of wheat and barley. Quadris was the most effective in the foliar fungicide tests for control of barley stripe rust. The Foliar treatments that were tested protected the crop for about one month. Protection from the boot to the milk stage of plant growth prevented most losses.

SPRING WHEAT BREEDING AND GENETICS

K. Kidwell, G. Shelton, V. DeMacon, B. Barrett, C. Bickle, J. Smith and J. Baley

The overall goal of spring wheat breeding efforts at WSU is to enhance the economic and environmental health of spring wheat production in the Pacific Northwest (PNW) by releasing genetically superior varieties for commercial production. Traditional breeding methods and molecular genetic technology are combined to reduce production risks associated with abiotic and biotic stresses by incorporating genetic insurance into adapted, elite varieties.

Variety Development

Over 350 crosses were made in 2000, and nearly 35,000 breeding lines were evaluated in field trials at 1 to 16 locations. F_1 seed from 354 lines was increased to generate segregating progenies for use in conventional breeding strategies, marker-assisted selection and genetic linkage analyses. Approximately 280 F_2 and 300 F_3 families were advanced to the next generation, and over 3,000 entries among 31,360 F_4 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 was visually evaluated for plumpness. Selections with sound grain were separated by market class, and then entries from each market class were subjected to 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 and flour swelling volume were used to assess protein and starch quality, respectively, of selected lines. The MicroMill was used to assess flour yields of early generation soft white entries. Polyphenol oxidase levels also were determined for soft white and hard white material to assess noodle color potential before selecting lines to advance to 2001 field trials. Grain samples from 765 breeding lines with superior agronomic performance were sent to the USDA-ARS Western Wheat Quality Laboratory (Pullman, WA) for milling and baking evaluations.

Variety Development Update:

Soft White

Zak (WA7850) is a high yielding, Hessian fly (HF) tolerant, stripe rust resistant variety with exceptional baking properties that is well adapted to the high rainfall regions of the PNW. It was approved for variety release in 2000 as a replacement for Wawawai, based on its improved threshability. Six cooperators (B. Nelson, K. Felgenhauer, E. Zakarison, H. Johnson, B. Stephenson and D. Harlow) grew 1 to 10 A on-farm trials of Zak to generate grain for large scale, end-use quality tests in crop year 2000. ADM (Cheney, WA) took delivery of 1500 bu of grain from these trials for pilot commercial milling tests. Resulting flour was shipped to the Nabisco factory in Portland, OR for commercial baking evaluations in January 2001. Results were encouraging, and opportunities for developing a domestic identity preserve market for Zak are being discussed. Foundation seed (246,000 lb) of Zak was sold for Registered seed production in 2001.

Hard Red

Tara (WA7824) a high yielding, HF resistant line with exceptional gluten strength that is well adapted to direct seed production, was approved for variety release in 2000 as a replacement for Westbred 926. Based on its superior baking performance, Pendleton Flour Mills (PFM; Pendleton, OR) was interested in assessing Tara for industrial baking purposes. Seven cooperators (J. Moore, J. Knodel, C. Hennings, B. Stephenson, M. Stubbs, J. Aeschliman and D. Harlow) produced 500 bu of Tara in on-farm trials for commercial milling and baking evaluations. Tara was delivered to PFM in December of 2000, and results were encouraging. A local, domestic market for this variety may evolve due to its exceptional end-use quality. Foundation seed of Tara will be produced in 2001.

Hard White

Macon (WA7899) was approved for pre-release in 2001, and represents the first hard white spring wheat variety to be released by WSU for commercial production. Macon is moderate to high yielding, is moderately resistant to stripe rust and is resistant to the Hessian fly. Macon has excellent protein quality, and has bread baking characteristic similar to those of Klasic, an exception bread wheat. Macon also has acceptable noodle color with soft noodle texture, which may be suitable for the Korean noodle market. Foundation seed of Macon will be produced in 2001. Several companies are currently assessing Macon to determine if it has potential for use in the domestic bread making industry.

Spring Club

WA7902 (tentatively named 'Eden") was approved for pre-release in 2001. The yield performance of this line equaled or exceeded that of the best soft white common entries in the 2000 variety testing trials across locations. WA7902 has excellent quality, is early maturing and is resistant to stripe rust. This variety is intended to replace 'Calorwa' in the intermediate to high rainfall zones. Breeder seed of WA7902 will be produced in 2001.

Seed of three high yielding, tall spring club lines (CLB0014, C9900008 and C9900015) with superior end-use quality was sent to New Zealand for winter seed increases in September, 2000. Foundation seed for CLB0014 will be produced in 2001.

Marker-Assisted Backcross Breeding

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 wheat microsatellite marker associated with a chromosomal segment that confers a 1-2% grain protein content (GPC) increase in two donor lines, GluPro and ND683, was identified, then a strategy was developed to rapidly move this segment into adapted germplasm through marker-assisted backcross 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_5 lines containing 99% of the genes from the WSU lines and 1% of the genes from the donor parents, including the high protein segment, have been developed using this strategy. Field evaluations of BC_1 and BC_2 lines generated in initial stages of backcrossing were conducted in crop year 2000. Twelve lines from each of 24 BC_1 families and 35 BC_2 families derived from a subset of the original BC_1s were evaluated in a non-replicated headrow field nursery in Pullman, WA. Eighty-nine percent of the lines containing the selected markers exhibited higher GPC than the recurrent parent. Fifty-nine of the high protein lines were selected for advancement to 2001 single plot yield evaluation trials.

Gene Discovery

Rhizoctonia root rot, caused by *R. solani* AG-8, is a prominent disease of spring cereal grains in direct seed management systems in the PNW. To date, genetic resistance to this disease has not been identified in cultivated wheat or barley. The objectives of this study were 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, 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. Variation for disease reaction was detected among spring wheat varieties; however, all were rated as susceptible to Rhizoctonia root rot. The addition lines, amphiploids and synthetic wheat varieties also were susceptible to infection by *Rhizoctonia*. Disease ratings for the *D. villosum* accessions were significantly lower than those for spring wheat varieties evaluated in growth chamber analyses. Although *D. villosum* can withstand *Rhizoctonia* infection, the ability to recover viable offspring from crosses between hexaploid wheat and *D. villosum* has been challenging. Unfortunately, other wild relatives evaluated in this study, that perhaps would be more compatible with hexaploid wheat for crossing purposes, were not resistant to the pathogen. We are currently assessing whether growth chamber results agree with resistance ratings and grain yields from inoculated field evaluations.

Transgene Assessment

Herbicides are an integral tool in the management of weeds in wheat production, especially in direct seeded systems. Genes are being incorporated into wheat varieties for tolerance to glyphosate (Round-up™), a widely used broad-spectrum herbicide. This technology has been quickly adopted in soybean and canola cultivation in North America, and has the same potential in wheat production. Introgressed transgenes code for an altered enzyme in the shikimic acid pathway that confers resistance to the herbicide, however, this same pathway is used by the plant for defense against soilborne pathogens. The objectives of the study are to examine the response of glyphosate tolerant and sensitive lines to three common root pathogens, *Gaeumannomyces graminis* var. *tritici*, *Rhizoctonia solani* and *Pythium* spp., in the presence and absence of glyphosate. Glyphosate can cause a synergistic reaction with soilborne pathogens, leading to a breakdown of plant defense and increased disease on sensitive plants. Dying grassy weeds and volunteers within a crop of glyphosate tolerant wheat may serve as a reservoir of inoculum, potentially increasing disease pressure on susceptible wheat. The overall goal of this research is to proactively determine the practicality of incorporating glyphosate tolerant wheat into direct seed, agricultural production systems.

WASHINGTON STATE UNIVERSITY WHEAT QUALITY PROGRAM

Principal Investigator: Brady P. Carter, Dept of Crop and Soil Sciences;

Cooperators: Tracy Harris, Research Technician; Steve Jones, Dept of Crop and Soil Sciences; Kim Kidwell, Dept of Crop and Soil Sciences; Kim Campbell, USDA-ARS; Craig Morris, USDA-ARS.

The Pacific Northwest (PNW) is a major wheat producer and a majority of the wheat produced in the PNW is exported to oversea markets. However, wheat shipments with functionality problems and a general lack of quality consistency in U.S. wheat have been blamed for recent losses in the world wheat market. The market losses have resulted in an increase in US wheat stocks and lower wheat prices. Consequently, end-use quality has become a high priority in the US wheat industry.

The PNW produces all classes of wheat, except soft red winter, and each market class is ideally suited for a specific end-use product. Flour extracted from soft white common and soft white club wheat is generally used in cookies and cakes, while flour from hard red and hard white wheat is used in pan breads, flat breads, noodles, and family flour (Morris and Rose 1996). Wheat varieties, depending on their particular quality attributes, differ in the performance of their flour in the production of an end product. Making efforts to insure that new varieties possess superior quality traits is an essential step to recapture lost markets and establish new markets. The end-use quality of new varieties is assessed using two types of tests: end-product tests and component tests (Morris and Rose 1996). End-product tests serve as a summation of all quality attributes and usually mimic the large-scale commercial process. Component tests measure individual flour characteristics in an effort to predict the overall performance of the flour in a particular end-use product. End-product tests normally require larger grain lots and are time consuming while component tests usually require very small samples and can be performed quickly. Since very little grain is available for testing in the early generations after a cross, small-scale component tests are used to predict the end-use quality of early generation lines (Carter et al. 1999). Conversely, a combination of component and end-product tests are used to assess the quality of varieties in later generations when larger grain lots are available (Morris and Rose 1996).

The Washington State University Wheat Quality Program (WSUWQP) was established in August 2000 to ensure that all varieties released by WSU possess superior quality attributes and meet the needs of Washington Wheat customers. The long-term objectives of the WSUWQPC are to become integrated with the breeding programs by establishing quality-testing priorities that are congruent with breeding objectives, providing breeders with additional early generation and market specific quality testing, and becoming a source of information about market desired end-use quality. The quality testing will be performed in cooperation with the Western Wheat Quality Lab (WWQL), utilizing the current cultivar evaluation system and facilities. The WWQL has been evaluating WSU breeder lines for many years and its existence on the WSU campus allows the WSUWQP to be an enhancement to the cultivar evaluation system, as opposed to duplicating the system. For example, the WSUWQP, as the quality arm of the breeding programs, will meet annually with the breeders before harvest to verify breeding objectives and establish a quality testing strategy for early and late generation nurseries. Then, as the results of the quality testing become available, the WSUWQP will summarize the results and make them available to breeders. Finally, when all results have been summarized, a final meeting to discuss the results will occur.

In addition, the WSUWQP will begin utilizing several new component and end-product tests in addition to the current testing strategy being used by the WWQL. Solvent retention capacity (SRC) (Gaines 2000), a relatively new test that has shown great promise as a small-scale component test, will be performed for first time on breeders' samples in 2001 by the WSUWQP. This test is used routinely by the domestic industry to analyze the starch and protein quality attributes of flour. In addition, breeders' samples will be analyzed for noodle texture for first time in 2001 by the WSUWQP. Noodle color has been analyzed routinely by the WWQL using reflectance colorimeters to measure brightness and yellowness. However, due to time and resource constraints, the WWQL has not analyzed noodle texture. The WSUWQP will utilize a TA.XT2*i* Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK) to assess the noodle quality of breeder lines. Noodle quality analysis is still in its infancy and research to determine the most appropriate methods to use in assessing noodle quality is being planned. Also, in an effort to increase effectiveness and efficiency, additional market specific and early generation tests are currently being researched by WSUWQP.

The WSUWQP also is the growers' extension source for information about wheat quality and a liaison to domestic and foreign markets for Washington State University. The WSUWQP is available to discuss quality issues with growers and give presentations at grower meetings. In addition, the WSUWQP has established lines of communications with representatives of domestic wheat markets in the PNW and will be source of information about wheat varieties from WSU. Wheat varieties that have the potential for release are currently evaluated prior to final release by the domestic industry through the PNW Wheat Quality Council. The WSUWQP will follow up with domestic markets to determine their level of interest in specific varieties and relate that information to the growers. Efforts also are being made to establish communication with representatives of foreign markets to discuss the quality attributes they consider most desirable in the wheat they purchase. A system has been established that utilizes the US Wheat Associates' Asian Collaborative to allow representatives of foreign markets to assess the quality of WSU varieties prior to release. The WSUWQP is working to broaden the system to include intense market specific end-product testing by the Wheat Marketing Center on larger groups of varieties prior to submittal to the Asian Collaborative. Only varieties with superior performance will be submitted to the collaborative, such that foreign customers evaluate only those varieties showing the greatest potential. Decision on final release will continue to be based on the results of both domestic and foreign evaluations.

In the global market, wheat buyers have imposed tighter quality specifications and are demanding wheat varieties that posses flour functionality characteristics that ideally suit them for use in specific products (Kerns 2000). The current wheat marketing system in the US allows wheat varieties of the same market class with variable functionality to be grouped together with no penalty for low quality. The result is a lack of consistency in the quality of US wheat. By developing new varieties that are agronomically superior, as well as superior for quality, the WSU breeding programs, in cooperation with the WSUWQP, can help eliminate the lack of consistency at no risk to the grower. When the highest yielding varieties also are the highest quality varieties, the grower doesn't have to choose between quality and yield. Domestic and foreign markets will continue to demand increased quality consistency and the future success of the wheat industry in Washington depends on cooperation by the researcher, grower, and end-user to produce a wheat crop that requires less input and possesses superior, consistent end-use quality.

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BARLEY IMPROVEMENT RESEARCH

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Collaborators: A. Kleinhofs, D. von Wettstein, J.W. Burns, P.E. Reisenauer, J. Kuehner, R.J. Cook, R.L. Line, X. Chen, and B.-K. Baik

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 and/or waxy, and winter types.

The latest release (2001) from the Barley Improvement Program is the new two-row spring feed barley cultivar 'Farmington'. It is a semidwarf selection from the cross WA7190-86/Maresi. Maresi is a European two-row malting type. WA7190-90 is from the cross: WA10698-76 (Klages/WA8189-69) / WA8517-74 (Piroline Mutant/Valticky Mutant). Farmington was tested as WA9504-94. It is adapted to the mid to high rainfall areas of eastern Washington (Table 1) and has partial resistance or tolerance to barley stripe rust (BSR) based on tests in Bolivia, Mexico, California, and western and eastern Washington state. It is expected to compete with Baronesse in some areas in eastern Washington and with other BSR resistance cultivars recently released. It has potential malting quality based on micro-malt data, but needs further testing on the pilot scale level. Foundation seed of Farmington will be produced in 2001. A description of Farmington was published in the May 2001 issue of *Wheat Life*.

Six advanced breeding lines have been identified as potential variety release candidates; three "conventional" (WA8682-96, WA8709-96, WA10147-96) and three proanthocyanidin-free types (98NZ223, 98NZ015, 98NZ533) developed in collaboration with D. von Wettstein. All six lines have shown exceptional yield potential (Table 2) and WA8682-96 has a relatively high level of stripe rust resistance. WA8682-96, WA8709-96, and WA10147-96 have been approved for pre-release seed increase, and breeder's seed of these lines will be produced in 2001.

For spring barley in 2000, 160 crosses were made. There were 150 F_2 plus 150 F_3 single-seed descent populations (~100/population) in the greenhouse. Lines were selected from approximately 15,000 head rows. There were approximately 2,100 single replication evaluation plots planted at Spillman Farm and Ritzville or Royal Slope in 2000; the entries of which came from 1999 or 1999-2000 (New Zealand) head/plant rows. The more advanced lines are tested in thirty 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, Royal Slope, and Ritzville – and the state uniform trial of 39 entries planted at 14 locations (eight extension/Burns, Reisenauer, Kuehner). Barley performance in 2000 was presented in the Nov. 22, 2000 *Green Sheet* and in the Jan. 2001 *Wheat Life*. There were four grower-conducted on-farm tests with six entries (including 'Farmington') in Columbia and Whitman counties in 2000 coordinated by Kevin Anderson of Great Western Malting Company and Roland Schirman and John Burns, of

Cooperative Extension. The average yield of Farmington (5136 lb/a) and Baronesse (5113 lb/a) were essentially equal, and represented the highest yielding entries.

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. A new study was initiated this year with Byung-Kee Baik in the Dept. of Food Science and Human Nutrition to exam barley flour and barley product color and discoloration. Color is an important sensory quality component for foods, and this work could lead to a new barley breeding selection criterium and better acceptance of barley as a human food component.

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. **Barley stripe rust** (BSR) is a new disease to the PNW and little resistance exists in currently grown barley cultivars. Rollie Line has and Xianming Chen is currently collaborating on monitoring and testing for this disease. We have had germplasm screened for barley strip rust reaction the past several years in Bolivia, Colorado, California, Mexico, and Washington. There appears to be good resistance in a relatively large number of WSU breeding lines including Farmington (WA9504-94) and WA8682-96 described above. A new backcross program to incorporate various sources of resistance into PNW adapted cultivars and lines was initiated in 2001 with Xianming Chen. **Soil borne pathogens** probably affect barley production more than we realize especially in reduced tillage cropping systems. Efforts were initiation in 1994 in collaboration with Jim Cook to screen for reaction to soil borne pathogens in the field and growth chamber. Field testing for soil borne pathogen reaction has been expanding over the past few years with nurseries planted variously at Spillman Farm, Dusty, Ralston, Ritzville, Bickelton, and most recently at the WSU Cunningham Farm. Carolyn Kruger's M.S. thesis research involves direct-seeded barley and soil borne disease reactions in the field and growth chamber. Backcross breeding projects are underway for Russian wheat aphid, barley stripe rust, and *Rhizoctonia* resistance. Backcross progeny will be 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. 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 and others. The comprehensive genome 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, and barley stripe rust resistance from several sources. Mapping populations from the Harrington/TR306 and Harrington/Morex crosses have also been evaluated. The incorporation of yield QTL from Baronesse into Harrington is a collaborative project with Andy Kleinhofs, Dave Kudrna, and Deric Schmierer, a 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 (kernel, feed, 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 his research group. The transformation project will see transformed plants in the field for the sixth year in 2001. 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. Several new lines are described above

Table 1. Farmington relative yields (% Baronesse).

Year	Locations						
	Pomeroy	**Fairfield**	**Pullman**	**Farmington**	**R. Slope**	**Lind**	**Ritzville**
1996			98				
1997	91*		82*		83*	97	95
1998	100	102	106	115*	104	93	90*
1999	90*	108	99	94*	88	101	93
2000	108	83*	93*	107	123*		90*
Avg.	97	95	95	105	98	96	91*

Year	Locations						
	Dusty	**Reardan**	**Asotin**	**Bickelton**	**Lamont**	**Dayton**	**St. John**
1996							
1997	94	87*		90	75*	99	86*
1998	86*	93*		85*	74*	88*	88*
1999	83*	97	82*		87*	85*	89*
2000	93	96	87*	87	86*	89*	109
Avg.	89*	94*	85*	87*	81*	90*	92*

* - indicates significant difference from Baronesse, alpha=0.10

Table 2. Relative Yield of Breeding Lines (% Baronesse). Nursery yield means in lb/a.

Lines	Locations													
	Asotin	Bickelton	Ritzville	Pomeroy	Dusty	St.John	Dayton	Fairfield	Farmington	Lamont	Reardan	R. Slope	Pullman	Average
1998														
8682-96													98	98
10147-96													100	100
8709-96													101	101
Nurs. Mean													4724	4724
1999														
8682-96			95					118*					99	104
10147-96			95					105					112*	105
8709-96			94					117					115*	110
Nurs. Mean			2180					2724					3750	2885
98NZ533												104	106*	105
98NZ015												104	106*	105
98NZ233												102	101	102
Nur. Mean												6962	4551	5756
2000														
8682-96	105	123	109*	108*	102	100	86*	94	105	100	95	107	89*	100
10147-96	103	121	99	103	100	86	95	90*	97	92	95	127*	98	99
8709-96	101	126*	106	102	101	92	93	78*	105	99	81*	121*	95	98
Nurs. Mean	2267	2795	3498	3836	4159	4520	5213	5740	5760	5882	6478	6549	6843	4888
98NZ233	96	123	102	100	108	107	95	91*	101	108	93	101	101	101
98NZ015	79*	119	106	105	92*	98	85*	93	103	99	96	134*	99	101
98NZ533	91*	121	87	92*	98	85	93	87*	98	99	91	119*	100	97

* - indicates significant difference from Baronesse, alpha=0.10

THE BARLEY BREEDING ACTIVITIES OF THE R.A. NILAN PROFESSORSHIP

Diter von Wettstein

Today mankind produces enough safe food for feeding the world's 6 billion people. But with the present population increase we have to satisfy every day over the next 25 years 200,000 more hungry stomachs than the previous day. The basis for this is precarious. An uncontrollable disease in wheat, barley, corn or rice can suddenly cause a global shortage situation. Similarly, natural climatic changes and environmental changes caused by human activities can damage crop production.

Presently the industrial production methods and biotechnology are scrutinized with many legitimate, critical questions. There are people that believe that ecological productions will solve all problems, others propagate the idea that gene technology will revolutionize production of food and raw materials. The truth is that there are no easy solutions for solving the global situation. If the future production of food and raw materials shall fulfill our requirements for sustainability, amounts and quality, it is necessary to combine the best aspects of conventional and ecologically sound agriculture with the best sides of classical plant breeding and rationally targeted gene technology.

There are seven tasks of high priority, in which combinations of classical plant breeding and gene technology can make important contributions prior to 2025.

- The yield of our crop plants has to be increased, so that marginal soil and environmentally valuable nature can remain free from crop production
- The basis of productions should be diversified by utilizing additional crop plants
- The quality of existing crop plants has to be improved, e.g. by an increase of nutritional contents and removal of allergens
- Requirement for fertilizer and water has to be reduced by developing plants, which take up more efficiently the nutrient salts from the soil and are resistant to desiccation
- Crop plants have to be made resistant to diseases and herbicides, in order to increase food production and quality
- Petrochemical products shall be replaced by plant based materials, e.g. novel biodegradable plastics
- Risks for infection with undesirable virus diseases shall be reduced by an increased production of pharmaceuticals and feed ingredients from plants

Accordingly our barley-breeding program is two-legged. With one leg we breed for barley with high yield stability and improved quality using classical methods. After 21 years of efforts - with forceful input by Bob Nilan, Judy Cochran and shifting barley crews- the two excellent two-row barley selections 98NZ223 and 98NZ015 were obtained. In their first year test at 13 locations of the State Uniform Nursery they ranked overall in 1st and 2nd place and surpassed Baronesse by 1%. In these lines the proanthocyanidins of the seed coat, also called condensed tannins, have been removed by mutations that block their synthesis. These flavonoid compounds, which are for instance not present in the seed coat of wheat or rye grains, are removed with polyvinyl-polypyrollidone filter sheets or by precipitation with tannin extracts of the sumac plant in the brewing of brilliant clear beer. Unless removed in the brewhouse prior to bottling the beer, they cause chill haze by precipitating the beer's proteins, a property detrimental to the shelf life of the beer. As has been shown in full scale trials, these steps in the production process can be omitted by using the new barley cultivars. But it has also been shown by cattle feeding trials that the proanthocyanidin-free barley lines do not differ from other cultivars in their feed value of the grain. While further tests of the yield stability are required, the results demonstrate that modification of metabolic pathways by targeted mutations provide value added characteristics to the crop. The yield depressions commonly experienced with biochemical mutants can be overcome by efficient recombination breeding and selection.

The other leg of our breeding programs concerns evaluation of the use of genetically engineered barley plants in crop improvements. These projects are carried out with permits from APHIS according to protocols approved by this regulatory arm of the US Department of Agriculture. The genetically engineered barley plants are scientifically designated transgenic plants and popularly called GMO for genetically modified organism. In this procedure a single or a few carefully characterized genes are inserted into the chromosomes of the barley plant. We are using the *Agrobacterium* mediated transformation procedure to transfer the genes into the plant. In barley this is done by co-cultivation of immature zygotic embryos with the bacterium carrying the gene to be inserted. This genetic transformation procedure is not an invention by scientists. They learned it from studying how *Agrobacterium tumefaciens*, a commonly occurring soil bacterium causes the crowngall tumor disease. This bacterium transfers three hormone genes into the chromosomes of many plant species. The genes are expressed by the plant and the resulting hormones suppress root and shoot growth leading to uncontrolled cancerous cell proliferations. But the bacteria also transfer genes that make the tumor plant cells produce special amino acids, opines that are secreted and used by *Agrobacterium* as food. In this natural ecological system of plant microbe interaction the agrobacteria live among the tumor cells, which they have recruited into their service for production of their speciality gourmet food. The agrobacteria used for transformation in crop plant breeding have been disarmed by deleting the genes for hormone and opine production, but employ the machinery of the bacterium to transfer desirable genes into the crop.

Over the last 4 years we have demonstrated that genetic transformation of barley is a viable procedure to breed feed barley with value added characteristics. The following results have been obtained:

1) A routine procedure to generate gene transfer by co-cultivation of immature zygotic barley embryos with *Agrobacterium* was established permitting transgenic plants to be regenerated via somatic embryos from callus developing from transformed scutellum cells [Horvath, Huang, Wong & von Wettstein, 2001].
2) Transgenic plants have been obtained that synthesize during malting or during grain maturation one of the following recombinant proteins: thermotolerant (1,3-1,4)-β-glucanase, human antithrombin III, α_1-antitrypsin, lactoferrin, lysozyme and serum

albumin. Tissue specific expression during malting is provided with the promoter of the gene for an aleurone specific α-amylase. Export of the recombinant protein into the endosperm is effected by the signal peptide of the α-amylase precursor. Endosperm specific deposition of the recombinant proteins during grain maturation is accomplished with the promoter of the barley D-hordein storage protein gene. The signal peptide of the D-hordein precursor is employed to target the recombinant proteins into the storage vacuoles, where they are protected from degradation by the programmed cell death that destroys all endosperm DNA, nuclei, membranes and cytosol during the last stages of grain maturation in the field. With the latter system 1g recombinant protein per kg of mature grain can be produced [Horvath, Huang, Wong, Kohl, Okita, Kannangara & von Wettstein, 2000].

3) The high production of recombinant proteins from microbial or human origin requires codon optimization of the DNA to a guanine + cytosine content of more than 60%. Thus the target genes used in our transgenic plants are synthesized from appropriate synthetic oligonucleotides.
4) The genetically stable transformants have generally decreased grain production and thousand-grain weights. As with induced mutations, the decreased agronomic performance can be rectified by standard recombination breeding with modern cultivars [Horvath, Jensen, Wong, Kohl, Ullrich, Cochran, Kannangara & von Wettstein, 2000].
5) The low nutrional value of barley for poultry is because of the absence of an intestinal enzyme for efficient depolymerization of (1,3-1,4)-β-glucans, the major polysaccharide of the endosperm cell walls. This leads to a high viscosity in the intestine, limited nutrient uptake, decreased growth rate, and unhygienic sticky droppings adhering to the chickens and floors of the production cages. Consequently, the 7.5 billion broiler chickens produced annually in the US are raised on corn-soybean diets. In a trial with 240 chickens it was shown that addition to normal barley of 6.2% transgenic malt containing a thermotolerant (1,3-1,4)-β-glucanase [4.28 $\mu g \cdot g^{-1}$ soluble protein] provides a weight gain equivalent to corn diets. The number of birds with adhering sticky droppings is drastically reduced. Intestines and excrements of chickens fed the barley control diet contained large amounts of soluble (1,3-1,4)-β-glucans, which was reduced by 75% and 50%, respectively, by adding transgenic malt to the diet. The amount of active recombinant enzyme in the small intestine corresponded to that present in the feed, whereas an 11-fold concentration of the enzyme was observed in the ceca and a 7.5 fold concentration occurred in the excrement. Glycosylation of the β-glucanase isolated from the ceca testified to its origin from the transgenic barley. Analysis of the data from this trial demonstrates the possibility of introducing individual recombinant enzymes into various parts of the gastrointestinal tract of chickens with transgenic malt and thereby the possibility of evaluating their effect on the metabolism of a given ingredient targeted by the enzyme [von Wettstein, Mikhaylenko, Froseth & Kannangara, 2000]. In a recently conducted second chicken trial the formation of sticky droppings by increasing the amount of transgenic malt in the feed was entirely avoided.
6) We have recently developed a technology, that allows the determination of the transgene insertion site in the barley chromosomes at the nucleotide sequence level. From the identified barley sequences next to the insertion site oligonucleotide primers

are designed and used by PCR (polymerase chain reaction) to distinguish uniquely any transformant from any other transformant as well as any cultivar. It is thus possible to satisfy FDA's request for unique identification of a barley cultivar to be marketed. The technique also allows to detect and trace contaminants in grain samples.

Economic perspectives.
Advantages in using the transgenic malt containing the thermostable (1,3-1,4)-β-glucanase for chicken feed are several. The required malt corresponding in amount to the feed ingredients such as fish meal, beef tallow or dicalcium phosphate can be added to normal barley in areas that have to import grain corn and there constitute the major basis of the feed. It provides an alternative to the use of corn grain, which is more extensively used and needed as food for humans than barley. Corn grain is also at times 30-50% more expensive. Only 10% of the barley harvest in the US is used as malt for beer and less than 1% for production of ingredients in human food (Washington Agricultural Statistics 1997-1998). The State of Washington produces annually 40 million broilers with imported corn grain. If barley is to be used for raising this number of broiler chickens it would require 3,400 t of presently available transgenic malt and 280,000 t of normal barley i.e. ~ 1/3 of the barley harvest of the State. Barley is needed in Washington agriculture for crop rotation.

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MOLECULAR MARKER-ASSISTED SELECTION FOR IMPROVED YIELD IN TRADITIONAL MALTING BARLEY CULTIVARS

Deric Schmierer, Dave Kudrna, Andris Kleinhofs, and Steve Ullrich

The American malting industry two-row malting barley standard cv. Harrington tends to yield significantly lower than cv. Baronesse, especially in dryland growing conditions. Baronesse, a high yielding two-row feed barley, was originally developed in Europe, but has adapted very well to the growing conditions in the PNW. Baronesse has accounted for approximately 70-75% of the total barley acreage grown in Washington over the last three years (1998-2000) covering nearly 370,000 acres in all years. This cultivar is the leading feed barley grown in the state. Harrington was developed in Canada and accounted for almost 7% of the total barely acreage in the state for 1998-2000. It is the leading malting barley grown in Washington, consistently planted on about 35,000 acres in each year. Similar numbers have been reported in Oregon, Idaho, and Montana, with Harrington and Baronesse being the top malting and feed barleys, respectively. Washington State is capable of growing high quality malting barley, but lacks the high yielding cultivars with malting qualities desired by the brewers. For this reason, our goal is to introduce the good yield and adaptability characteristics of Baronesse into new lines while maintaining the good malting characteristics of Harrington.

Baronesse yield QTL (quantitative trait loci) were mapped to the long arm of barley chromosome 2-(2HL) and chromosome 3-(3HL) (T. Blake, personal commun.). A population of near isogenic lines (NILs) were produced from a Harrington x Baronesse cross. A molecular marker-assisted (MAS) backcross breeding scheme was used with Harrington as the recurrent parent. Two experiments were conducted involving two and three backcross schemes, respectively. After each backcross and selfing operation, progeny were selected based on their genotypes using molecular markers in the chromosome 2HL and 3HL regions.

In 1999, 110 BC_2F_4 lines were planted in replicated yield trials at Spillman Farm in Pullman, WA. Fifty-three lines produced yields similar to Baronesse. Of these 53 lines, 28 were selected and carried to the next generation. These lines were planted in replicated yield trials in summer 2000 at Pullman and the National Small Grains Germplasm Research Facility in Aberdeen, ID. Eight lines showing yield similar to Baronesse in the 2000 trials were selected and planted in spring 2001 in regional nurseries across E. Washington at Pullman, Royal Slope, and Fairfield.

The second experiment consisted of a BC_3 population. Eighty-four lines from this population were planted in yield trials at Pullman and Aberdeen in summer 2000. Twenty high yielding lines from these 2000 trials were also planted with the 8 BC_2 lines this spring (2001) in the regional trials.

Based on the genotypes of all lines and the past two years yield data, we have targeted two regions on chromosome 2HL as well as one region on 3HL that potentially carry yield related QTL. Distinctive molecular markers bracket each chromosomal region. At least one of these regions has been integrated into each high yielding line. Malting data is pending.

WSU EXTENSION CEREAL VARIETY TESTING PROGRAM – 2000

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The goal of the WSU Extension Cereal Variety Testing Program is to provide comprehensive, objective and readily available information on the performance of public and private cereal varieties to Washington growers. Wheat and barley variety testing is a cooperative effort. The WSU Winter Wheat, WSU Spring Wheat, WSU Spring Barley and USDA-ARS Winter Club breeding programs work in cooperation with the WSU Extension Cereal Variety Testing Program in design, establishment, harvest, and data analysis from the variety testing nurseries. Varieties submitted by private companies are on a fee-for-entry basis. In order to obtain a uniform data set of comparisons all entries are grown at all locations.

The diverse growing condition characteristic of Eastern Washington necessitates using a large number of testing sites. There were 18-winter wheat, 14-spring wheat and 13-spring barley nurseries grown in 2000. The WSU Winter Wheat Breeding Program provided data for hard red winter nurseries. Growing conditions for winter wheat during crop year 2000 were ideal and resulted in above average yields for both winter and spring cereals. The average yield for all winter wheat varieties in the trials combined across all locations was nearly 30% higher (25.1 bu/ac) than the previous year (1999). Average nursery yields for spring wheat and spring barley were 20% and 39% higher in 2000 than the previous year, respectively.

A complete listing for each testing location is available on a web site maintained by the WSU Extension Variety Testing Program: http://variety.swu.edu Included in the web site are 3-5 year average yields for each variety at each testing location. Following are summary tables of the 2000 WSU Extension variety trials, as well as "acres planted" tables from the Washington Agricultural Statistics Service.

Acknowledgements: This program is made possible by funding provided by the WSU College of Agriculture and Home Economics (Agricultural Research Center, Department of Crop & Soil Sciences, Cooperative Extension) in cooperation with the Washington Wheat Commission, Washington Barley Commission, Washington State Crop Improvement Association and fees paid by private companies. The cornerstone of the program is the contributions from farm cooperators who provide land, fertility and pest management products and other assistance required to grow and maintain the trials.

2000 WSU WINTER WHEAT VARIETY TRIAL SUMMARY

September 18, 2000

YIELD (BU/A)

VARIETY NAME	COULEE CITY	BICKLETON	LIND DRY	ASOTIN	DUSTY	RITZVILLE	POMEROY	HARRINGTON	LAMONT	FAIRFIELD	REARDAN	FARMINGTON	CRESTON	MAYVIEW	PULLMAN	ST. JOHN	DAYTON	MOSES LAKE	VARIETY MEAN
Soft White Common																			
ALBION	49.6	58.2	60.8	77.5	92.8	92.9	90.4	96.8	109.3	118.8	138.7	119.5	125.2	133.7	134.4	163.0	162.7	171.7	110.9
BEAMER	55.2	57.7	56.0	82.8	79.8	90.7	98.3	95.8	102.3	123.9	125.8	140.8	130.1	130.6	148.8	167.8	154.6	175.7	112.0
CASHUP	52.6	44.5	56.0	76.3	97.5	86.0	94.6	95.3	95.4	124.6	127.4	133.9	131.2	131.2	136.6	150.8	162.5	164.1	108.9
ELTAN	57.5	55.5	60.8	84.6	100.0	82.0	92.9	96.5	121.8	125.8	127.9	121.6	135.6	135.6	138.7	98.1	126.8	179.8	107.9
ELTAN-MADSEN	51.4	48.2	60.7	85.4	83.4	89.8	94.6	95.0	101.8	122.3	116.6	122.7	129.2	127.7	134.3	127.0	136.0	158.0	104.7
HILL 81	48.5	43.8	57.1	80.1	83.4	85.9	82.1	95.5	113.1	129.0	119.7	124.9	121.6	133.6	126.2	163.4	151.1	179.7	107.7
ID - B96	56.9	58.3	59.1	92.6	85.4	89.2	96.4	97.2	117.1	129.3	125.9	136.3	132.3	129.0	129.3	147.5	155.3	157.8	110.8
ID 10085-5	48.8	47.4	51.5	89.6	75.6	84.2	76.7	103.2	93.7	120.9	116.8	136.5	121.9	122.1	128.3	135.8	113.3	198.5	103.6
ID52814A	53.4	62.7	59.6	88.9	91.1	92.9	91.9	97.7	114.2	122.4	126.3	131.4	127.3	120.2	131.1	135.1	155.0	185.8	110.4
LAMBERT	45.7	48.0	56.1	65.7	82.7	84.4	90.8	85.8	98.7	104.5	104.6	119.0	103.1	104.2	114.0	131.3	134.0	142.9	95.3
LEWJAIN	58.9	53.6	64.0	80.8	99.2	86.2	94.7	89.2	111.9	113.9	124.0	117.4	132.4	130.8	135.6	130.0	156.4	174.0	108.5
MACVICAR	47.0	53.3	47.8	83.8	69.6	87.6	89.2	93.3	106.1	124.0	117.7	129.7	125.3	139.2	129.3	138.5	164.2	172.2	106.5
MADSEN	45.0	50.4	55.6	77.3	86.9	91.4	86.1	92.7	111.4	123.5	126.1	129.4	119.8	119.3	134.0	143.9	145.3	163.3	105.6
MADSEN-ROD	57.3	50.7	62.4	86.3	92.0	92.4	101.1	101.2	116.3	123.9	115.7	131.8	129.8	140.3	143.7	140.7	156.2	175.5	112.1
MADSEN-STEPHENS	52.1	53.6	56.2	81.6	80.6	92.1	79.7	105.7	98.4	116.1	114.0	142.0	123.3	123.8	130.7	148.4	147.5	176.3	106.8
MJ-4	48.2	51.8	67.4	82.6	96.8	97.7	112.6	98.0	104.7	132.0	131.1	123.7	140.4	135.1	143.5	144.1	167.6	175.5	114.1
OR939526	51.4	60.6	65.3	89.9	91.8	97.8	108.3	103.1	114.8	129.0	123.8	131.4	141.1	145.1	144.3	163.1	164.5	180.8	117.0
OR939528	45.4	62.4	54.8	91.1	81.5	88.0	101.6	106.1	113.7	125.9	122.1	131.9	131.6	145.8	145.5	159.9	161.6	192.1	114.5
Q. HYBRID 5019	61.8	55.4	59.8	91.5	87.1	94.5	70.3	109.5	106.1	128.0	124.8	140.7	137.2	133.9	140.6	166.5	137.6	181.5	112.6
Q. HYBRID 7415	58.7	50.7	58.6	91.1	84.6	91.4	81.3	106.0	100.6	122.6	135.9	133.5	139.2	138.5	145.4	146.8	144.5	168.6	111.0
ROD	61.6	55.2	66.6	87.3	98.6	92.9	90.8	103.0	130.6	130.8	131.0	145.6	144.6	139.4	144.9	117.6	169.2	190.8	116.7
STEPHENS	51.2	51.9	57.9	87.0	77.9	84.0	96.5	99.5	115.4	117.7	115.0	134.3	123.3	131.5	128.0	140.6	149.5	192.8	108.6
WA7853	49.5	60.8	68.4	88.0	92.5	93.6	109.0	103.2	126.2	124.8	123.5	130.9	140.9	135.0	138.2	153.2	164.3	181.1	115.7
WEATHERFORD	48.8	57.3	60.0	84.3	87.6	91.5	95.0	95.7	117.8	122.9	121.1	124.2	125.4	135.4	136.6	155.9	153.5	186.2	111.1
WESTBRED 470	54.2	56.0	51.4	77.2	63.7	81.7	84.8	85.6	93.8	108.5	129.5	126.0	132.8	121.1	135.5	142.5	138.9	141.2	101.4
WESTBRED 477	53.5	53.9	62.2	95.1	83.2	96.7	98.2	104.4	105.6	124.5	121.3	137.6	132.2	133.4	137.7	138.0	141.2	179.7	111.0
Soft White Club																			
BRUEHL	59.6	48.7	67.6	92.2	98.6	98.3	92.7	109.1	128.0	126.6	138.2	132.8	133.7	142.7	134.8	105.9	153.9	170.7	113.0
CODA	49.5	48.7	54.8	76.7	96.2	88.3	91.3	98.6	102.6	128.3	136.2	132.5	126.0	132.6	138.5	125.6	141.4	176.2	108.0
EDWIN	47.1	45.5	60.4	74.6	84.5	83.3	77.5	86.7	100.5	118.4	118.1	116.0	116.6	117.7	123.9	97.0	105.4	158.6	96.2
HILLER	57.6	62.6	56.6	88.7	98.8	92.8	82.3	105.6	109.0	124.1	134.4	139.2	142.5	141.4	139.4	102.2	136.6	187.2	111.2
RELY	58.5	50.7	53.0	69.9	95.8	84.2	78.3	103.1	104.5	118.8	129.5	134.0	143.9	130.7	142.0	118.8	117.4	165.0	105.5
ROHDE	44.9	50.8	51.0	79.6	86.5	80.8	65.5	97.4	86.8	114.0	125.3	123.1	131.0	127.9	128.0	123.3	132.9	165.4	100.8
TEMPLE	53.2	53.9	58.8	76.4	89.1	89.1	84.5	98.6	112.2	131.6	138.1	136.8	138.9	134.0	142.7	115.2	117.1	160.5	107.3
WA7855	48.5	49.5	62.6	72.8	109.8	95.3	115.8	108.2	115.3	129.7	121.7	126.9	138.1	140.7	143.7	140.9	157.3	171.6	113.8
Hard Red Common																			
ESTICA	48.0	63.6	62.1	87.5	95.8	96.5	89.7	104.6	111.5	129.1	129.6	130.2	132.9	139.2	145.8	151.3	171.7	169.8	114.4
NURSERY MEAN	52.3	53.6	59.0	83.3	88.6	89.9	91.0	99.1	108.9	123.2	125.1	130.5	130.9	132.1	136.4	138.0	147.1	173.4	109.0
CV %	18.0	16.6	8.5	9.5	9.1	6.2	11.7	6.6	8.4	5.8	9.8	6.2	6.8	7.3	4.3	11.8	6.2	8.2	8.7
LSD @ .10	11.0	10.5	5.9	9.3	9.5	6.5	12.5	7.7	10.8	8.4	14.4	9.4	10.4	10.9	6.9	19.2	10.7	16.7	2.6

2000 WSU WINTER WHEAT VARIETY TRIAL SUMMARY

September 18, 2000

PROTEIN (%)

VARIETY NAME	COULEE CITY	BICKLETON	LIND DRY	ASOTIN	DUSTY	RITZVILLE	POMEROY	HARRINGTON	LAMONT	FAIRFIELD	REARDAN	FARMINGTON	CRESTON	MAYVIEW	PULLMAN	ST. JOHN	DAYTON	MOSES LAKE	VARIETY MEAN
Soft White Common																			
ALBION	8.8	7.2	11.0	8.5	8.1	8.8	7.4	9.3	8.2	10.5	8.5	9.1	8.2	10.1	8.0	10.5	8.9	9.4	8.9
BEAMER	9.0	6.5	9.6	7.9	8.1	8.7	7.7	9.8	7.3	10.0	7.6	9.0	8.0	9.4	8.2	10.2	9.2	9.3	8.7
CASHUP	8.9	7.8	8.7	9.2	7.8	8.9	7.6	8.7	7.7	10.1	8.1	9.2	8.0	9.9	8.6	10.9	9.0	9.7	8.8
ELTAN	8.2	6.6	9.0	7.2	7.2	8.8	7.3	8.7	7.2	10.2	7.2	8.5	7.7	9.7	7.4	10.5	9.2	9.1	8.3
ELTAN-MADSEN	8.1	7.1	9.6	8.3	7.8	8.8	7.8	9.2	8.0	10.2	7.9	9.3	7.9	9.4	8.1	10.6	9.2	9.1	8.7
HILL 81	8.8	7.3	9.7	8.4	8.0	8.7	7.9	8.8	8.1	10.3	8.3	9.0	7.9	10.3	8.5	11.0	9.6	9.6	8.9
ID - B96	9.2	7.0	9.1	7.9	8.2	9.2	7.8	9.2	9.3	10.1	8.4	8.9	8.4	9.7	8.4	10.9	9.9	10.2	9.0
ID 10085-5	9.0	7.2	11.1	8.8	9.6	10.1	9.0	10.0	8.9	10.8	8.8	9.5	8.9	10.3	8.5	11.4	10.5	9.9	9.6
ID52814A	8.3	7.1	8.4	8.0	7.6	9.0	7.4	8.6	7.9	9.9	7.7	8.4	7.8	10.0	7.8	10.4	8.6	9.0	8.5
LAMBERT	10.2	8.0	10.6	8.9	8.8	9.6	8.3	9.9	8.5	10.7	9.5	9.7	8.9	9.9	8.6	12.0	10.3	10.1	9.6
LEWJAIN	9.2	6.9	8.8	8.2	7.7	8.7	7.5	8.9	7.6	10.2	7.3	8.7	8.3	9.8	7.8	10.8	9.0	9.8	8.6
MACVICAR	8.9	7.0	9.9	8.6	8.8	9.0	7.8	9.4	7.9	10.3	8.4	9.0	8.1	9.6	8.3	10.7	9.0	9.3	8.9
MADSEN	9.8	7.4	10.5	8.1	8.2	9.4	8.5	10.0	8.3	10.3	9.4	9.2	8.4	9.7	8.6	11.3	9.8	9.6	9.3
MADSEN-ROD	9.4	6.9	9.4	7.8	8.2	8.5	7.8	8.8	8.2	10.1	8.1	8.9	8.6	9.7	8.4	10.9	9.4	9.9	8.8
MADSEN-STEPHENS	8.7	7.4	10.1	8.4	8.7	9.3	8.2	9.5	8.3	10.4	8.8	9.4	9.0	9.8	8.5	11.5	10.0	10.0	9.2
MJ-4	9.2	7.1	10.1	7.8	8.1	9.0	8.1	8.9	7.3	10.1	8.3	9.5	8.6	9.4	8.5	11.0	9.4	9.9	8.9
OR939526	8.6	6.9	9.8	8.3	8.2	9.2	7.7	9.1	8.1	9.9	8.4	8.5	8.2	10.1	8.2	10.6	9.2	9.5	8.8
OR939528	9.6	7.8	9.9	8.9	8.6	9.1	8.2	9.4	8.3	10.3	8.5	9.2	8.3	9.8	8.4	10.4	9.4	9.6	9.1
Q. HYBRID 5019	9.2	7.5	9.5	8.2	8.5	8.7	8.3	9.2	7.9	10.2	8.1	9.0	8.3	10.0	8.6	10.6	9.4	9.6	8.9
Q. HYBRID 7415	8.7	7.2	11.7	8.1	9.8	9.6	8.7	9.7	9.4	10.5	8.5	9.3	8.5	9.8	8.9	11.3	10.2	10.2	9.4
ROD	8.3	6.3	9.0	7.6	7.2	9.1	7.8	8.6	8.2	9.8	8.1	8.7	8.1	9.2	8.0	10.9	8.9	9.7	8.5
STEPHENS	8.8	7.4	10.3	8.6	9.4	9.7	9.2	9.7	9.1	10.7	8.9	9.4	8.6	9.5	8.7	11.5	10.1	10.0	9.4
WA7853	8.1	6.3	9.5	7.7	7.6	9.0	7.3	8.2	8.2	10.2	8.0	8.7	8.2	9.3	7.9	10.5	9.2	9.9	8.6
WEATHERFORD	9.9	6.9	10.5	8.1	8.8	9.3	8.1	9.2	8.6	10.2	8.5	9.3	8.5	9.7	8.7	11.0	9.7	10.2	9.2
WESTBRED 470	9.1	7.2	12.3	8.6	10.0	9.7	9.2	10.5	9.1	10.3	9.0	9.2	8.9	9.5	9.1	10.6	10.2	11.1	9.7
WESTBRED 477	7.9	7.3	9.3	8.2	8.1	9.0	7.2	8.6	7.9	10.3	8.0	8.8	8.1	9.6	8.1	10.8	9.0	9.1	8.6
Soft White Club																			
BRUEHL	8.0	6.8	9.8	7.4	7.5	9.1	7.3	8.4	8.3	10.5	9.2	8.6	8.0	9.7	8.1	11.9	9.2	10.0	8.8
CODA	8.7	7.5	8.9	7.9	7.9	9.2	7.9	8.9	7.8	10.5	8.4	8.9	8.1	10.2	8.8	12.5	9.7	9.7	9.0
EDWIN	8.8	7.1	9.5	7.8	8.7	9.3	8.7	9.4	8.1	10.7	8.5	9.2	8.4	9.3	8.3	11.5	10.9	9.8	9.1
HILLER	8.4	6.5	9.4	7.9	8.1	8.8	7.4	8.1	7.5	9.8	8.1	8.7	8.5	9.2	8.3	11.2	9.4	10.2	8.6
RELY	8.7	6.9	8.3	7.1	7.6	8.7	8.6	8.2	8.2	10.3	7.5	8.4	7.8	9.5	8.2	10.7	9.7	9.3	8.5
ROHDE	8.5	6.8	10.4	7.9	9.0	9.8	8.4	9.2	8.1	10.8	8.5	8.0	8.4	9.4	8.4	12.1	10.5	10.1	9.2
TEMPLE	8.6	6.4	9.2	7.5	8.1	9.1	8.6	8.5	8.6	9.9	7.8	8.8	7.7	9.6	8.4	10.5	10.0	9.3	8.7
WA7855	8.1	7.3	8.2	7.0	7.4	7.8	7.4	8.2	7.2	9.7	7.3	8.6	8.5	9.6	7.7	11.2	8.8	9.6	8.3
Hard Red Common																			
ESTICA	7.6	6.5	9.1	7.3	8.0	8.1	7.0	9.1	6.7	10.3	7.9	8.9	7.7	9.7	8.4	10.6	9.1	10.0	8.5
NURSERY MEAN	8.8	7.1	9.7	8.1	8.3	9.1	8.0	9.1	8.1	10.3	8.3	9.0	8.3	9.7	8.3	11.0	9.5	9.8	8.9
CV %	7.5	10.2	6.8	7.4	3.7	8.0	7.0	4.7	10.4	2.9	8.7	4.0	5.5	7.1	2.2	6.3	5.4	6.6	6.6
LSD @ .10	0.8	0.8	0.8	0.7	0.4	0.9	0.6	0.5	1.0	0.4	0.8	0.4	0.5	0.8	0.2	0.8	0.6	0.8	0.2

2000 WSU WINTER WHEAT VARIETY TRIAL SUMMARY

September 18, 2000

TEST WEIGHT (LB/BU)

VARIETY NAME	COULEE CITY	BICKLETON	LIND DRY	ASOTIN	DUSTY	RITZVILLE	POMEROY	HARRINGTON	LAMONT	FAIRFIELD	REARDAN	FARMINGTON	CRESTON	MAYVIEW	PULLMAN	ST. JOHN	DAYTON	MOSES LAKE	VARIETY MEAN
Soft White Common																			
ALBION	60.4	58.6	59.6	59.9	60.0	60.7	60.6	59.5	60.8	60.1	59.9	58.7	59.9	60.8	59.1	60.1	61.3	60.0	60.0
BEAMER	60.3	59.1	61.5	60.4	60.5	61.9	62.3	60.9	61.1	61.1	60.1	60.6	60.5	61.8	60.6	62.6	63.0	61.9	61.1
CASHUP	61.5	59.7	60.6	61.2	60.4	61.7	61.3	61.0	60.9	60.5	60.2	60.1	60.1	61.9	60.1	62.0	61.9	60.7	60.9
ELTAN	62.0	58.8	60.5	59.5	59.9	60.4	59.9	60.5	59.6	59.4	59.3	59.4	60.0	60.9	58.4	58.2	60.5	59.7	59.8
ELTAN-MADSEN	61.3	59.6	60.5	60.2	60.3	61.3	60.9	60.5	60.3	60.4	59.5	59.8	59.8	61.0	58.0	60.7	61.6	59.7	60.3
HILL 81	61.6	59.2	61.1	60.9	59.8	61.2	61.3	60.7	61.5	61.1	59.6	60.0	59.4	61.9	59.4	62.3	62.5	60.9	60.8
ID - B96	60.9	59.0	60.9	57.5	59.8	61.8	62.1	61.1	61.9	60.5	59.9	60.0	59.9	61.5	59.0	61.5	62.6	60.4	60.6
ID 10085-5	60.6	59.4	60.4	59.6	60.2	61.3	61.4	62.1	61.0	60.3	59.5	60.1	60.3	61.2	59.3	61.2	62.9	61.7	60.7
ID52814A	62.5	60.5	61.3	61.6	61.0	61.6	61.9	60.7	61.7	62.0	60.8	60.5	61.0	63.1	60.0	60.9	62.9	60.8	61.4
LAMBERT	61.5	58.8	60.8	60.6	60.4	61.3	62.1	60.3	61.2	60.3	60.8	60.0	60.2	61.2	59.0	61.1	62.2	60.5	60.7
LEWJAIN	62.7	60.9	61.8	61.4	60.8	61.4	61.7	60.4	61.1	61.3	60.0	59.8	60.6	62.1	59.6	60.6	62.0	59.9	61.0
MACVICAR	60.4	59.2	59.9	60.5	59.5	61.6	62.0	61.3	61.3	60.2	60.0	59.3	60.4	62.2	60.3	59.6	62.5	60.1	60.6
MADSEN	61.6	59.3	60.9	60.6	60.2	61.6	62.0	60.5	61.1	59.9	60.1	60.1	61.3	61.2	59.1	60.9	62.4	60.7	60.8
MADSEN-ROD	61.2	58.7	60.4	59.5	59.9	60.9	61.5	60.1	61.3	60.4	59.3	59.4	59.4	60.8	59.2	60.5	61.9	60.5	60.3
MADSEN-STEPHENS	60.4	58.8	60.3	59.7	60.3	61.8	62.2	61.3	61.2	60.4	59.7	60.2	60.4	61.0	59.3	61.2	62.9	61.1	60.7
MJ-4	59.6	57.8	59.3	59.0	59.1	59.6	60.9	59.0	60.0	59.2	59.1	58.5	59.7	59.9	58.9	59.9	61.3	59.0	59.5
OR939526	59.9	58.6	60.2	59.6	59.8	61.0	61.9	60.1	60.9	60.0	59.2	59.0	59.7	61.0	59.4	60.9	62.2	59.9	60.2
OR939528	60.5	59.7	60.0	59.7	59.7	61.1	62.4	59.9	61.1	59.9	59.3	58.6	59.2	61.0	59.4	61.2	62.4	59.9	60.3
Q. HYBRID 5019	58.9	58.3	59.2	58.8	59.0	60.1	61.1	59.4	60.0	59.5	58.7	58.4	58.5	60.2	58.6	60.9	61.5	60.5	59.6
Q. HYBRID 7415	62.2	61.2	61.9	61.5	61.4	62.9	62.9	63.3	62.8	61.6	61.3	61.1	61.6	63.1	61.4	61.9	63.7	63.0	62.2
ROD	60.1	57.7	59.6	59.2	59.4	60.3	61.0	58.7	60.9	59.9	58.8	58.8	59.1	60.4	59.1	59.8	61.4	59.5	59.7
STEPHENS	59.7	58.6	59.7	59.2	59.7	61.7	62.4	61.5	61.7	60.3	59.2	60.1	59.9	61.3	59.2	61.2	62.8	61.0	60.5
WA7853	62.6	60.7	62.1	61.7	61.2	62.3	62.4	62.2	62.2	61.9	61.1	60.9	61.4	62.5	60.2	62.2	62.9	60.9	61.8
WEATHERFORD	61.4	59.3	60.4	60.2	60.3	61.6	62.0	60.7	61.5	60.5	60.1	60.0	60.1	61.3	59.7	61.3	62.3	61.1	60.8
WESTBRED 470	63.4	63.1	63.1	63.2	62.6	64.0	64.1	64.1	63.9	62.5	62.9	62.5	63.3	64.0	62.7	62.0	64.5	63.9	63.3
WESTBRED 477	60.1	59.9	61.0	60.5	60.1	61.9	62.1	61.4	61.3	61.4	59.4	60.0	60.0	62.0	59.7	61.5	62.9	61.5	60.9
Soft White Club																			
BRUEHL	59.6	56.8	59.9	58.3	57.8	58.0	57.8	57.7	58.5	58.0	56.4	57.6	58.0	59.0	56.8	56.2	58.3	56.9	57.9
CODA	62.3	60.4	61.4	61.3	61.1	60.9	62.7	61.9	60.8	60.9	61.5	61.2	61.0	62.9	60.5	60.5	63.1	62.5	61.5
EDWIN	62.4	59.1	61.3	61.1	61.2	61.9	62.3	61.2	61.8	61.7	61.0	61.1	61.2	62.7	59.4	62.2	63.1	62.8	61.5
HILLER	58.3	56.1	58.9	57.7	57.1	59.0	59.3	58.1	57.4	58.3	57.1	57.0	57.5	58.8	56.4	58.6	59.5	58.3	58.0
RELY	61.1	58.0	59.2	59.5	59.2	60.1	61.5	59.6	60.7	60.3	59.0	59.2	59.6	61.0	58.7	60.3	61.6	60.9	60.0
ROHDE	62.8	59.8	61.5	61.3	61.3	62.2	62.1	62.4	61.6	61.8	60.9	60.6	61.0	63.0	60.1	62.1	63.8	62.0	61.7
TEMPLE	60.9	59.1	60.5	60.1	59.6	61.2	61.7	61.3	61.0	60.6	59.5	60.1	59.7	62.2	59.3	61.1	62.6	61.3	60.7
WA7855	60.2	57.3	58.3	58.6	58.7	59.7	60.2	58.9	59.2	59.3	58.3	58.7	59.1	60.4	57.7	60.2	60.9	59.7	59.2
Hard Red Common																			
ESTICA	58.0	55.5	56.7	56.4	57.8	57.6	58.0	57.6	58.1	58.6	58.0	57.6	57.8	58.7	56.1	59.8	60.3	58.2	57.8
NURSERY MEAN	61.0	59.1	60.4	60.0	60.0	61.1	61.5	60.6	60.9	60.4	59.7	59.7	60.0	61.4	59.3	60.8	62.1	60.6	60.5
CV %	0.9	1.5	0.8	1.6	0.9	0.8	0.9	0.7	1.2	0.9	1.4	0.6	1.0	0.6	0.7	1.5	0.5	1.0	1.0
LSD @ .10	0.7	1.0	0.5	1.1	0.6	0.6	0.6	0.5	0.9	0.6	1.0	0.4	0.7	0.4	0.5	1.0	0.4	0.7	0.2

2000 WSU HARD RED WINTER WHEAT VARIETY TRIAL

VARIETY	YIELD (BU/A) LIND	YIELD (BU/A) CONNELL	YIELD (BU/A) PULLMAN	TEST WEIGHT (LBS/BU) LIND	TEST WEIGHT (LBS/BU) CONNELL	TEST WEIGHT (LBS/BU) PULLMAN	PROTEIN (%) LIND	PROTEIN (%) CONNELL	PROTEIN (%) PULLMAN
BLIZZARD	69.0	39.8	61.0	63.3	62.7	61.0	13.2	10.6	10.5
BOUNDARY	79.5	34.2	111.6	61.7	60.5	61.8	12.4	11.5	9.3
BUCHANAN	69.3	37.1	67.2	63.0	60.7	59.8	12.4	10.3	9.5
ESTICA	79.9	40.4	125.2	58.0	56.2	58.9	12.0	10.9	9.2
FINLEY	66.8	41.6	54.0	63.4	64.0	61.3	13.0	10.3	11.2
HATTON	65.9	43.1	57.4	64.0	64.2	62.1	12.8	10.4	9.9
N9502203	60.2	38.2	44.1	64.0	63.2	60.2	12.5	9.5	9.9
N9502601	62.9	41.6	45.5	62.9	62.6	61.0	13.2	11.8	10.9
N9502606	59.2	41.3	49.8	63.3	62.0	59.3	12.9	11.7	10.8
N9502802	59.2	29.8	63.0	62.6	61.5	60.9	13.2	13.0	8.8
N9504703	60.4	28.5	61.3	62.6	61.4	60.7	13.0	12.4	9.9
N9505403	60.1	41.0	58.4	63.1	62.7	60.4	13.0	10.2	10.7
N9988067	56.5	37.2	59.1	62.7	62.9	62.4	13.7	10.7	10.4
N9988120	75.9	41.1	67.6	63.3	61.9	61.6	12.4	11.3	10.4
N9988121	65.3	40.0	68.9	62.9	62.2	61.7	12.6	10.8	10.9
N9988138	63.7	43.7	51.0	62.5	62.5	61.3	13.2	10.7	10.3
PILLAR	46.2	22.1	100.6	60.9	59.3	61.8	16.2	13.9	11.4
Q HYB 1779	59.1	38.3	85.4	62.5	62.5	60.7	12.8	10.1	8.7
Q HYB 542	70.8	44.1	86.0	63.3	62.9	63.0	13.0	11.5	10.3
Q HYB 9803	68.6	38.6	83.8	63.1	62.6	61.0	12.6	10.0	8.8
SYMPHONY	70.1	38.4	106.9	61.3	60.2	60.5	13.0	12.6	10.5
WANSER	54.8	36.9	45.8	63.0	62.2	59.4	13.1	11.4	10.6
WESTON	61.1	32.3	79.1	63.7	63.7	63.4	13.4	11.1	11.5
ELTAN (SW CHECK)	75.7	46.9	74.1	62.2	60.8	59.9	12.3	10.5	9.2
Mean	65.0	38.2	71.1	62.6	61.9	61.0	13.0	11.1	10.2
CV%	8.0	14.3	17.5	0.4	0.9	1.6	2.2	10.2	5.4
LSD @ .10	62.0	6.5	14.7	0.3	0.6	1.2	0.3	1.3	0.7

2000 WSU SPRING WHEAT VARIETY TRIAL SUMMARY

October 16, 2000

YIELD (BU/A)

VARIETY NAME	HORSE HEAVEN	LIND FALLOW	BICKLETON	RITZVILLE	LAMONT	POMEROY	DUSTY	ST. JOHN	DAYTON	FARMINGTON	PULLMAN	FAIRFIELD	REARDAN	ROYAL SLOPE	VARIETY MEAN
Soft White Common															
ALPOWA	34.8	34.5	31.7	51.3	61.5	60.0	57.7	70.8	77.1	80.2	96.9	94.0	116.2	131.5	68.3
CHALLIS	32.5	36.0	34.3	51.1	61.3	57.5	67.4	75.2	75.7	73.2	97.3	102.6	113.4	140.3	69.6
EDWALL	30.2	31.9	30.4	51.2	53.7	61.9	65.7	67.0	71.8	65.6	84.2	87.8	101.1	112.3	62.7
FIELDER	31.5	31.2	32.7	49.0	60.0	54.3	64.6	67.9	70.8	46.4	69.7	73.3	103.8	116.1	59.8
ID506	34.3	35.6	29.6	51.0	62.8	50.6	63.6	74.6	72.6	84.6	96.9	104.3	112.6	128.3	68.4
ID525	31.6	34.0	31.1	50.2	60.7	57.8	64.2	71.5	75.6	91.6	90.7	98.1	99.6	125.6	67.3
ID526	34.6	39.2	29.1	51.1	73.0	55.3	68.5	75.2	79.6	84.6	95.7	105.5	107.0	125.2	69.9
ML 037,(C6-2)	29.6	35.0	28.9	46.2	69.6	42.5	56.0	55.7	71.0	86.4	95.3	97.3	101.5	144.0	65.7
ML66A(14-4)	.	.	.	.	.	.	.	.	.	.	.	.	.	145.3	145.3
PENAWAWA	30.9	32.5	35.3	45.3	61.2	56.2	63.9	71.1	76.3	67.4	85.4	86.7	119.0	136.6	66.1
WA7864	32.7	37.6	34.7	48.6	71.7	59.1	63.3	68.8	76.4	89.0	97.4	101.3	118.3	122.8	69.7
WA7867	33.8	39.3	34.4	48.1	64.4	62.5	61.5	65.2	75.3	86.2	100.8	102.1	102.3	126.2	68.7
WA7877	31.7	36.6	40.4	50.0	67.6	52.6	61.3	70.2	79.5	86.1	99.2	105.9	114.7	132.9	70.5
WA7879	31.5	36.0	31.2	49.8	52.6	48.2	60.5	57.4	77.6	82.8	104.6	100.1	98.6	133.3	65.9
WA7883	31.5	33.5	34.8	49.3	62.1	59.4	65.3	71.6	75.9	91.7	102.7	96.7	108.8	120.8	68.7
WA7884	31.9	36.4	32.6	52.6	57.2	51.7	63.0	69.9	81.4	98.0	111.8	103.6	115.3	158.7	72.8
WAWAWAI	34.8	36.4	36.1	51.9	69.0	54.4	60.2	79.8	77.4	93.6	93.5	108.8	109.7	128.7	70.7
ZAK	34.4	33.7	34.0	49.6	56.7	49.0	62.7	67.5	72.5	89.4	100.4	105.2	111.3	127.1	68.1
Soft White Club															
CALORWA	26.9	32.9	29.0	45.2	60.6	49.0	61.1	58.1	70.4	76.3	89.3	88.3	103.3	113.2	61.8
WA7902 (S9700431)	29.9	38.8	36.3	54.9	60.1	57.0	66.7	65.5	77.8	92.7	100.9	95.5	106.9	126.0	69.0
WA7903 (S9700459)	26.2	33.9	38.7	50.4	55.1	49.1	59.4	59.0	73.9	89.8	97.2	94.5	117.3	121.6	66.1
Hard Red Common															
96W51213	.	.	.	.	.	.	.	.	.	.	.	.	.	130.7	130.7
96W51402	.	.	.	.	.	.	.	.	.	.	.	.	.	121.4	121.4
BONUS	.	.	.	.	.	.	.	.	.	.	.	.	.	122.6	122.6
BUTTE 86	29.6	33.5	39.4	43.1	45.5	50.9	58.2	74.8	78.3	77.9	92.9	96.9	86.8	112.4	63.0
BZ 994-484	22.9	28.0	29.4	36.8	53.8	55.9	63.0	66.4	76.8	82.6	103.5	96.2	95.4	120.6	63.7
EXPRESS	.	.	.	.	.	.	.	.	.	.	.	.	.	125.1	125.1
HANK	24.9	31.0	39.1	43.9	54.1	59.1	67.1	61.5	78.0	92.6	107.6	102.7	101.9	121.3	67.2
JEFFERSON	26.5	32.8	45.7	46.2	66.0	63.3	65.6	62.7	81.4	91.2	106.0	103.7	93.5	131.7	69.4
SCARLET	31.3	32.0	38.2	47.8	51.2	49.8	62.9	71.7	73.1	82.6	92.5	100.5	94.1	125.5	65.3
SLW 97606	28.8	30.9	34.9	42.6	49.1	54.8	53.7	55.4	71.1	79.0	90.8	91.0	86.3	116.4	60.8
SPILLMAN	26.9	30.7	36.2	48.7	40.8	51.0	43.2	53.4	63.9	62.2	92.4	92.3	90.2	119.2	58.4
STANDER	.	.	.	.	.	.	.	.	.	.	.	.	.	111.4	111.4
WA7824	24.1	30.3	38.2	42.9	44.6	56.9	56.2	68.1	81.0	87.2	106.1	101.2	101.5	117.5	65.3
WA7839	23.2	29.2	38.0	42.8	55.3	58.9	57.9	69.4	78.3	88.7	107.9	97.5	90.4	110.6	64.7
WA7859	29.1	32.9	38.9	42.4	51.7	56.4	57.3	69.3	76.9	86.3	93.0	96.2	95.0	112.7	64.3
WA7860	27.4	33.4	33.6	38.2	52.3	53.1	63.4	69.8	77.7	79.3	96.9	94.5	95.9	124.8	64.5
WA7872	26.1	31.6	31.4	41.5	45.8	52.0	57.0	58.1	73.8	81.5	99.7	94.9	88.5	112.3	61.3
WA7874	23.8	27.6	39.3	38.8	48.7	57.5	61.4	61.8	77.8	82.3	101.7	100.7	91.7	118.2	63.7
WA7875	26.8	33.5	35.2	44.9	57.7	54.6	57.0	63.8	79.0	96.6	102.4	104.7	95.5	120.0	66.5
WPB 926	21.6	24.4	32.6	41.2	45.7	57.3	54.8	65.6	71.6	80.8	97.9	90.1	89.7	102.7	59.9
Spring Durum															
KRONOS	.	.	.	.	.	.	.	.	.	.	.	.	.	146.5	146.5
NPB871104E	.	.	.	.	.	.	.	.	.	.	.	.	.	132.9	132.9
Hard White Common															
ID377S	30.8	34.4	41.0	48.9	44.3	53.6	65.5	75.4	80.5	81.8	108.2	105.8	102.7	130.3	68.6
ID533	34.3	34.2	41.5	48.2	52.0	59.1	60.1	70.6	77.9	89.1	114.3	107.6	107.8	130.7	70.3
ID560	31.3	38.3	39.9	51.1	47.5	55.4	65.7	70.6	76.9	86.7	95.5	109.8	102.8	143.0	69.5
ML107455	29.2	31.2	37.0	51.1	49.2	50.7	60.6	67.5	67.9	86.7	102.7	92.8	105.3	137.9	66.1
PRISTINE	25.5	27.9	33.7	34.3	34.2	52.8	61.3	75.7	77.1	70.3	93.7	93.8	96.7	113.0	60.9
WA7899 (HW000021)	26.5	32.2	37.5	42.7	40.5	60.6	57.4	71.4	79.3	83.2	95.8	95.8	94.0	122.6	64.2
WA7900 (HW000034)	28.8	34.2	35.6	46.5	46.9	59.9	64.7	70.6	80.4	65.5	95.3	93.9	100.7	127.1	64.9
WA7901 (HW000098)	32.9	31.5	33.4	45.9	40.0	58.1	61.8	71.8	77.0	96.4	101.7	102.7	112.1	115.7	67.0
WINSOME	29.5	33.6	38.8	48.7	43.1	51.4	61.3	66.4	69.9	81.2	96.0	105.1	100.0	143.4	66.4
NURSERY MEAN	29.5	33.3	35.3	46.7	54.6	55.0	61.2	67.6	75.8	82.9	97.8	98.2	102.3	125.7	66.8
CV %	6.7	6.0	11.1	4.8	13.2	11.1	7.1	14.2	5.9	10.2	5.0	5.6	6.7	7.5	8.9
LSD @ .10	2.7	2.7	5.3	3.0	9.8	8.3	5.9	13.0	6.1	11.6	6.6	7.5	9.2	12.8	3.8

2000 WSU SPRING WHEAT VARIETY TRIAL SUMMARY

October 16, 2000

PROTEIN (%)

VARIETY NAME	HORSE HEAVEN	LIND FALLOW	BICKLETON	RITZVILLE	LAMONT	POMEROY	DUSTY	ST. JOHN	DAYTON	FARMINGTON	PULLMAN	FAIRFIELD	REARDAN	ROYAL SLOPE	VARIETY MEAN
Soft White Common															
ALPOWA	13.6	13.6	10.8	9.5	11.7	11.5	13.5	12.3	9.6	9.2	9.7	9.4	9.6	11.5	11.3
CHALLIS	13.6	13.0	10.8	10.3	11.6	11.5	13.2	12.2	9.0	9.8	10.5	9.4	10.2	10.8	11.3
EDWALL	13.8	13.9	10.8	10.5	12.3	10.8	13.0	12.4	10.0	10.1	10.7	9.0	10.1	11.4	11.5
FIELDER	14.2	14.4	11.1	10.9	12.2	11.4	13.6	12.4	9.9	10.1	10.7	10.0	9.5	11.9	11.7
ID506	15.0	14.8	11.6	11.0	12.1	12.1	13.9	13.0	10.3	10.9	10.8	10.3	10.6	11.5	12.1
ID525	13.9	14.2	11.4	10.4	12.2	11.7	13.4	12.3	10.2	10.8	10.7	9.7	9.7	11.8	11.7
ID526	13.5	13.6	10.8	10.1	12.0	11.1	12.9	12.1	10.0	10.1	10.4	9.5	9.8	11.0	11.3
ML 037,(C6-2)	15.8	15.3	11.9	10.3	13.1	13.6	15.4	14.7	11.4	11.6	11.4	9.8	10.6	12.1	12.8
ML66A(14-4)	.	.	.	.	.	.	.	.	.	.	.	.	.	12.7	12.7
PENAWAWA	14.4	14.1	10.5	10.9	11.9	12.2	13.9	12.1	9.8	10.0	11.1	8.5	10.0	12.1	11.7
WA7864	14.9	14.5	11.1	9.7	12.5	12.0	14.4	12.3	10.6	10.8	10.7	10.1	11.1	11.9	12.1
WA7867	13.7	13.3	10.6	9.5	11.8	11.6	13.6	12.6	10.6	10.5	10.7	10.2	10.7	11.2	11.6
WA7877	15.3	14.6	10.5	10.2	12.4	12.3	15.5	12.6	10.2	10.8	10.8	9.3	10.2	12.2	12.1
WA7879	14.0	13.7	11.0	9.3	11.9	11.4	13.4	12.4	10.3	10.6	10.6	9.9	10.0	10.8	11.5
WA7883	14.0	14.0	11.0	10.0	12.3	11.2	13.9	12.1	10.2	10.7	10.7	9.8	10.2	11.2	11.7
WA7884	14.0	13.2	10.5	8.9	11.6	12.1	13.5	12.0	9.7	10.3	10.5	8.7	10.5	11.4	11.3
WAWAWAI	14.0	13.9	11.4	10.2	12.8	11.8	13.8	12.2	10.3	10.6	10.7	10.4	10.0	12.0	11.9
ZAK	14.8	14.4	10.9	9.8	12.6	12.5	14.6	13.4	10.5	10.7	11.1	10.3	10.2	11.4	12.1
Soft White Club															
CALORWA	14.8	14.2	11.2	11.0	12.3	12.4	14.0	13.2	10.6	10.7	10.9	9.4	10.8	11.1	12.1
WA7902 (S9700431)	13.6	12.6	10.4	9.8	11.4	11.4	12.6	12.3	10.2	10.6	10.2	8.9	9.5	10.9	11.2
WA7903 (S9700459)	14.8	13.8	10.5	9.8	12.1	12.8	14.7	13.4	10.6	11.0	10.8	10.3	9.5	11.3	11.9
Hard Red Common															
96W51213	.	.	.	.	.	.	.	.	.	.	.	.	.	12.8	12.8
96W51402	.	.	.	.	.	.	.	.	.	.	.	.	.	12.6	12.6
BONUS	.	.	.	.	.	.	.	.	.	.	.	.	.	12.7	12.7
BUTTE 86	16.1	15.5	11.3	12.5	15.8	12.0	15.7	14.6	12.9	14.1	12.8	13.3	11.8	15.1	13.9
BZ 994-484	17.7	16.8	13.3	13.3	15.5	15.0	16.2	15.0	12.6	14.0	13.8	13.5	11.0	14.6	14.6
EXPRESS	.	.	.	.	.	.	.	.	.	.	.	.	.	13.9	13.9
HANK	16.7	16.3	11.6	11.8	15.3	14.0	15.3	14.9	12.6	13.4	12.8	13.6	10.5	14.2	13.9
JEFFERSON	16.9	15.6	10.8	10.9	14.4	13.7	15.1	14.9	12.5	13.9	13.1	13.1	11.1	13.5	13.7
SCARLET	16.4	16.5	11.6	11.4	15.6	14.9	15.1	14.3	12.5	14.0	13.3	13.2	11.1	14.4	14.0
SLW 97606	16.9	16.5	13.2	12.1	16.3	16.2	16.8	15.9	14.2	15.1	14.9	14.3	11.6	16.1	15.1
SPILLMAN	16.5	16.5	11.7	11.5	15.1	14.0	16.4	15.5	13.1	14.2	13.2	12.9	11.6	13.7	14.1
STANDER	.	.	.	.	.	.	.	.	.	.	.	.	.	12.7	12.7
WA7824	17.2	15.4	11.8	12.9	14.8	14.0	15.7	14.3	12.6	14.0	12.9	13.3	10.0	14.0	13.9
WA7839	17.1	16.0	12.2	11.9	14.8	13.4	15.5	14.8	12.5	13.9	13.0	13.2	10.4	13.8	13.9
WA7859	16.8	15.9	12.0	12.3	15.6	13.0	15.9	15.1	13.0	13.8	12.4	12.8	11.3	14.2	14.0
WA7860	16.8	15.2	11.7	12.4	15.0	13.8	15.1	14.4	12.7	13.8	13.1	12.1	10.4	13.5	13.7
WA7872	17.2	16.5	12.7	12.1	15.6	13.2	16.2	15.4	12.1	14.7	13.7	13.3	11.7	15.2	14.4
WA7874	17.1	16.5	11.9	11.5	14.7	13.9	15.3	14.7	12.4	13.7	12.9	12.5	11.2	13.9	13.9
WA7875	16.3	15.9	11.6	11.4	14.7	13.4	15.7	14.5	12.6	13.6	12.8	13.3	10.7	14.8	13.8
WPB 926	17.4	16.5	12.7	12.9	15.0	13.4	15.8	14.9	13.1	14.3	13.8	13.5	11.2	14.5	14.4
Spring Durum															
KRONOS	.	.	.	.	.	.	.	.	.	.	.	.	.	13.7	13.7
NPB871104E	.	.	.	.	.	.	.	.	.	.	.	.	.	13.7	13.7
Hard White Common															
ID377S	16.1	15.9	11.3	11.1	14.5	13.4	14.7	13.8	11.1	13.0	12.2	12.0	10.4	12.5	13.1
ID533	15.4	15.4	11.3	11.5	14.1	12.7	13.8	13.7	11.4	12.0	11.9	11.2	10.7	12.4	12.8
ID560	14.6	14.1	10.7	10.1	13.6	12.8	13.8	13.9	11.2	11.9	11.1	11.4	10.1	12.0	12.4
ML107455	15.4	15.2	11.6	10.6	14.0	12.7	13.9	13.9	11.5	11.7	11.9	12.0	10.1	12.0	12.8
PRISTINE	16.7	16.3	12.7	13.7	15.1	13.8	15.5	13.3	12.5	13.0	12.2	12.3	11.4	13.2	13.8
WA7899 (HW000021)	15.7	15.3	11.5	11.2	14.2	13.1	14.5	13.5	11.6	12.7	12.0	11.9	10.1	12.1	12.9
WA7900 (HW000034)	15.8	15.5	11.5	11.5	14.2	12.8	13.8	13.2	11.4	11.7	11.4	10.7	10.5	12.1	12.7
WA7901 (HW000098)	15.4	15.4	11.7	11.0	14.0	13.3	14.4	13.6	11.7	11.9	11.6	11.5	10.3	12.4	12.9
WINSOME	14.9	14.6	10.9	10.2	13.8	13.1	14.2	14.2	11.4	11.9	11.5	11.8	10.5	11.9	12.6
NURSERY MEAN	15.4	15.0	11.4	11.0	13.6	12.8	14.6	13.6	11.4	12.0	11.8	11.3	10.5	12.7	12.8
CV %	1.2	2.7	4.2	7.3	3.5	6.0	1.9	4.3	4.6	4.1	32.0	4.9	7.0	2.5	4.0
LSD @ .10	0.3	0.6	0.7	1.1	0.6	1.1	0.4	0.8	0.7	0.7	0.5	0.8	1.0	0.4	0.3

2000 WSU SPRING WHEAT VARIETY TRIAL SUMMARY

October 16, 2000

TEST WEIGHT (LBS/BU)

VARIETY NAME	HORSE HEAVEN	LIND FALLOW	BICKLETON	RITZVILLE	LAMONT	POMEROY	DUSTY	ST. JOHN	DAYTON	FARMINGTON	PULLMAN	FAIRFIELD	REARDAN	ROYAL SLOPE	VARIETY MEAN
Soft White Common															
ALPOWA	60.6	62.2	62.3	61.9	62.1	59.7	57.8	58.2	61.3	60.7	61.3	61.5	61.7	64.1	61.1
CHALLIS	59.4	61.2	60.9	60.5	60.2	56.9	57.4	58.0	59.8	59.4	59.6	61.1	59.4	63.1	59.6
EDWALL	56.5	59.2	58.8	58.8	58.3	55.5	55.0	54.7	58.2	56.4	56.5	59.0	56.7	61.3	57.4
FIELDER	59.8	60.8	60.7	61.4	60.4	57.0	57.7	57.7	60.3	56.8	58.0	59.0	59.9	63.3	59.5
ID506	59.3	61.4	61.0	60.8	58.9	57.0	58.3	58.3	59.8	59.4	60.0	61.1	59.0	61.9	59.7
ID525	61.4	61.8	61.4	62.0	60.9	59.0	58.1	59.4	60.4	60.3	60.8	61.7	60.1	63.5	60.8
ID526	59.9	61.3	60.5	61.2	61.1	58.8	58.3	58.9	60.6	60.0	60.1	61.2	60.0	63.2	60.4
ML 037,(C6-2)	57.5	60.7	60.2	60.9	60.5	55.8	55.5	55.4	59.6	58.4	60.2	61.0	57.5	62.5	59.0
ML66A(14-4)	.	.	.	.	.	.	.	.	.	.	.	.	.	63.1	63.1
PENAWAWA	59.3	61.1	61.3	61.1	61.2	57.9	57.8	59.1	61.7	59.8	60.1	61.5	61.0	63.9	60.3
WA7864	57.7	60.6	60.0	60.9	61.0	57.2	55.7	58.2	59.9	59.7	60.3	61.9	60.3	62.5	59.5
WA7867	58.2	59.4	59.9	60.0	59.4	58.0	54.9	56.7	59.2	58.7	60.6	61.1	58.9	61.3	58.9
WA7877	57.2	61.0	61.5	60.0	61.0	57.5	54.4	57.6	59.9	60.1	60.9	61.3	60.0	63.1	59.6
WA7879	60.1	62.2	61.6	62.0	60.8	57.8	58.5	58.3	61.6	61.5	62.3	62.9	61.0	64.1	61.0
WA7883	59.4	60.4	61.3	61.6	61.2	60.2	58.5	58.8	61.2	60.8	62.0	61.7	60.8	63.5	60.7
WA7884	59.5	61.8	61.4	61.4	60.2	57.4	56.6	58.5	60.3	61.2	61.1	62.0	58.7	63.8	60.3
WAWAWAI	59.7	61.6	62.0	62.2	60.8	58.5	57.0	59.2	61.1	61.8	61.5	62.9	60.3	63.8	60.8
ZAK	59.5	61.1	61.3	61.0	60.0	57.9	57.0	58.0	60.3	60.0	60.7	61.7	59.6	62.8	60.1
Soft White Club															
CALORWA	58.7	60.7	62.0	62.6	61.0	56.4	59.6	57.4	60.7	60.4	60.5	61.8	60.5	62.6	60.2
WA7902 (S9700431)	59.8	62.7	61.7	62.2	61.3	59.9	61.5	58.8	60.6	61.8	61.7	61.2	57.6	62.5	60.9
WA7903 (S9700459)	58.7	61.2	60.4	60.6	60.0	56.8	56.8	57.2	60.5	60.6	61.5	61.8	59.9	62.3	59.9
Hard Red Common															
96W51213	.	.	.	.	.	.	.	.	.	.	.	.	.	63.0	63.0
96W51402	.	.	.	.	.	.	.	.	.	.	.	.	.	65.0	65.0
BONUS	.	.	.	.	.	.	.	.	.	.	.	.	.	62.1	62.1
BUTTE 86	61.1	61.5	62.5	61.7	59.1	58.1	59.1	59.5	61.6	59.9	62.2	61.9	61.2	64.0	60.9
BZ 994-484	60.7	61.4	63.9	62.7	60.7	57.7	59.6	58.9	62.4	59.8	61.8	62.8	62.6	65.3	61.4
EXPRESS	.	.	.	.	.	.	.	.	.	.	.	.	.	63.7	63.7
HANK	60.3	61.1	62.0	61.9	59.2	56.3	58.1	56.6	60.1	57.6	60.4	60.2	60.8	63.0	59.8
JEFFERSON	60.7	61.3	62.4	61.9	60.4	59.0	58.7	57.5	61.2	58.7	61.2	61.2	60.9	63.6	60.6
SCARLET	60.2	60.1	61.8	61.2	58.7	55.6	57.5	57.4	60.7	58.6	59.9	60.6	60.6	63.5	59.7
SLW 97606	61.3	62.6	63.8	63.7	60.8	61.8	60.8	61.2	63.3	62.4	64.1	64.2	63.4	65.9	62.8
SPILLMAN	57.7	58.7	60.1	59.4	58.0	54.3	50.2	53.1	57.8	56.8	58.3	60.0	58.9	62.8	57.7
STANDER	.	.	.	.	.	.	.	.	.	.	.	.	.	63.7	63.7
WA7824	59.4	59.8	62.3	61.8	58.6	57.6	58.6	58.2	61.1	59.1	61.4	61.2	61.4	63.1	60.2
WA7839	60.5	60.6	62.2	61.9	59.4	58.7	59.8	58.0	61.0	58.5	61.6	61.4	61.0	63.6	60.6
WA7859	60.1	61.1	61.8	60.8	57.9	57.6	57.9	57.8	60.5	59.2	61.7	61.2	61.0	64.1	60.2
WA7860	60.5	61.1	62.2	62.1	58.9	58.5	59.2	59.0	62.0	59.0	61.5	62.0	62.2	64.2	60.8
WA7872	60.9	61.1	62.5	61.9	59.9	58.9	59.4	57.7	61.0	58.9	61.3	61.3	60.8	63.6	60.7
WA7874	60.4	60.3	62.0	61.2	59.1	57.3	58.4	57.3	60.3	58.1	60.7	60.9	60.0	63.4	59.9
WA7875	60.7	61.5	62.3	62.1	60.4	58.2	58.0	58.7	62.1	60.5	62.4	62.3	62.4	64.2	61.1
WPB 926	60.2	60.5	62.0	61.1	58.3	58.3	58.2	57.0	60.3	56.8	59.5	60.4	60.1	62.8	59.7
Spring Durum															
KRONOS	.	.	.	.	.	.	.	.	.	.	.	.	.	63.0	63.0
NPB871104E	.	.	.	.	.	.	.	.	.	.	.	.	.	62.9	62.9
Hard White Common															
ID377S	59.4	61.6	61.5	62.1	57.6	56.9	58.4	58.0	62.2	59.4	61.3	61.2	62.7	64.7	60.5
ID533	61.4	61.9	62.5	62.0	58.4	58.9	58.9	58.4	61.9	61.2	62.5	62.4	61.9	64.7	61.2
ID560	61.4	62.0	61.2	62.0	58.7	57.4	56.0	56.2	60.1	58.8	59.5	60.2	60.7	64.0	60.0
ML107455	58.1	60.4	61.2	60.9	57.4	55.8	56.2	55.4	58.4	57.7	59.8	59.4	60.4	63.3	58.8
PRISTINE	61.5	62.0	62.6	63.0	56.9	59.1	62.0	61.1	62.2	60.1	62.5	62.8	62.6	64.4	61.6
WA7899 (HW000021)	59.8	60.6	61.0	61.8	57.4	56.8	57.1	57.7	60.6	58.0	59.5	59.9	61.2	63.9	59.6
WA7900 (HW000034)	61.0	61.7	61.5	62.7	58.7	57.5	59.2	58.3	61.5	58.7	61.3	61.9	62.3	65.0	60.8
WA7901 (HW000098)	60.5	61.8	61.3	62.6	59.3	58.3	58.2	58.8	60.9	60.5	61.7	61.7	62.6	64.7	60.9
WINSOME	60.9	61.3	60.5	61.3	57.9	55.8	54.3	55.0	58.7	57.8	58.6	59.3	60.0	63.8	59.0
NURSERY MEAN	59.8	61.1	61.5	61.5	59.6	57.7	57.7	57.8	60.7	59.4	60.8	61.3	60.6	63.5	60.2
CV %	0.7	0.7	0.9	0.6	2.0	2.3	1.4	2.0	1.2	1.3	0.9	1.1	1.3	0.7	1.3
LSD @ .10	0.6	0.6	0.8	0.5	1.7	1.8	1.1	1.6	1.0	1.0	0.7	0.9	1.1	0.6	3.3

2000 WSU SPRING BARLEY VARIETY TRIAL SUMMARY

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YIELD (LBS/A)

VARIETY NAME	ASOTIN	BICKLETON	RITZVILLE	POMEROY	DUSTY	ST. JOHN	DAYTON	FAIRFIELD	FARMINGTON	LAMONT	REARDAN	ROYAL SLOPE	PULLMAN	VARIETY MEAN
2-ROW														
98NZ223	2298	3199	3731	3973	4734	5316	5715	6248	6148	7657	6720	5950	7499	5322
98NZ015	1891	3115	3899	4178	4028	4886	5110	6359	6241	7015	6916	7924	7331	5299
BARONESSE	2392	2609	3669	3961	4395	4991	5986	6843	6087	7062	7210	5900	7392	5269
WA 8682-96	2500	3220	3984	4283	4472	4993	5142	6443	6379	7024	6851	6337	6594	5248
PONGO	2163	2797	3647	3893	4023	5143	5169	6249	6563	5932	7047	7762	7534	5225
XENA	2597	3040	3551	4201	4574	5346	5564	6352	5249	6315	7075	6456	7609	5225
WA 10147-96	2474	3148	3635	4067	4401	4277	5682	6153	5887	6458	6834	7298	7269	5199
WA 8709-96	2407	3289	3894	4027	4426	4569	5586	5364	6418	7006	5864	7149	7031	5156
98NZ533	2174	3165	3486	3652	4304	4258	5576	5987	5991	6961	6565	7022	7420	5120
JERSEY	2323	2865	3593	4057	4155	4360	5275	6584	6376	5616	6347	7649	7161	5105
WA 10138-96	2427	2733	3736	4231	4670	3504	5607	6266	6131	5491	7133	7024	6958	5070
WA 9504-94	2078	2262	3286	4270	4069	5418	5311	5646	6540	6044	6885	7264	6843	5070
H3869224	2291	3285	3731	3851	4431	4872	5544	6516	5512	5262	6783	6287	6743	5008
WA 11825-95	2205	2785	3573	3869	4328	4636	5449	5985	6070	6092	6882	6146	7007	5002
WA 8718-96	2431	3314	3709	3966	3971	3238	5229	6774	5874	6613	6525	5849	7344	4987
WA 8710-96	2339	2839	3772	4086	4272	3955	5183	6466	5627	6581	6328	6439	6917	4985
98NZ234	2065	2443	3473	3600	3987	5647	5117	5898	5843	7171	6329	6253	6873	4977
WA 11832-95	2285	3120	3659	4374	4421	4349	5591	6264	5983	5553	6315	5622	6791	4948
WA 12953-95	2307	3136	3602	3819	4020	4804	5227	5364	5723	6502	6314	6225	7284	4948
WA 11801-95	2198	3154	3416	3740	4194	3974	5506	6171	5706	5726	6364	7135	7000	4945
CAMELOT	2377	2953	3572	4272	4277	5129	5411	5559	5510	5405	6332	6536	6768	4931
CA 803803	2077	2933	3488	3799	4087	3078	5456	5607	5860	5951	6780	7904	6933	4919
BANCROFT	2250	3101	3394	3936	4286	5625	4967	5733	5286	5705	6451	6336	6496	4890
98NZ532	2117	2511	3224	3309	4165	4252	4962	6123	5587	6342	6849	7011	6887	4872
MENTOR	2283	2820	3756	3805	4451	4435	5337	5805	6005	5244	6841	5196	6943	4840
WA 8831-96	2342	2637	3318	3671	4443	4216	5394	5511	5819	6162	6335	6657	6375	4837
98NZ226	2092	2459	3554	3626	4076	4725	5058	5194	5580	6613	6282	5945	7043	4788
VALIER	2307	2734	3694	3958	4416	5125	4784	5772	4975	4957	6515	6033	6740	4770
HARRINGTON	2339	1870	3129	3952	3964	4986	4794	5495	6181	5640	6214	6406	6717	4745
GALLATIN	2115	2799	3713	3896	4109	4604	5088	5808	5391	5208	6097	6165	6424	4724
WA 12223-95	2081	2590	3179	3560	3789	3152	5166	5707	5636	6039	6607	6595	7233	4718
CREST	2282	2862	3207	3706	3989	4523	5351	5502	6265	5453	5551	5427	6674	4676
ORCA	2332	2785	3113	3337	3666	4784	4914	4536	5143	5483	6217	7204	5886	4569
BCD 47	2133	3093	3148	4155	3883	4819	4719	4191	5526	5510	5776	5857	6559	4567
WA 7942-96	2254	2698	3388	3741	3886	4234	4780	4493	5439	4424	6265	7092	6523	4555
6-ROW														
STEPTOE	2629	2613	3563	3933	4572	4502	5426	5831	5514	5442	7338	7351	7159	5067
TANGO	2322	2909	3532	3678	4136	4988	5025	4622	5292	4657	6129	6762	6655	4670
MOREX	2620	2275	2891	2732	3303	3741	4422	5136	5199	4703	5887	5164	6007	4160
HULLESS														
CONDOR	1947	1959	3076	3340	3646	3408	4576	4614	5124	4078	5817	6375	5560	4117
BEAR	1941	1668	2916	2911	3386	3979	4338	4416	4744	4194	5594	6248	5533	3990
NURSERY MEAN	2267	2795	3498	3835	4160	4521	5213	5740	5760	5882	6479	6549	6843	4888
CV %	6.3	16.3	6.9	7.0	6.3	15.6	7.7	9.8	7.6	11.5	9.5	10.0	5.0	9.8
LSD @ .10	193	620	328	364	357	958	543	761	597	918	840	886	466	178

2000 WSU SPRING BARLEY VARIETY TRIAL SUMMARY

October 12, 2000

TEST WEIGHT (LBS/BU)

VARIETY NAME	ASOTIN	BICKLETON	RITZVILLE	POMEROY	DUSTY	ST. JOHN	DAYTON	FAIRFIELD	FARMINGTON	LAMONT	REARDAN	ROYAL SLOPE	PULLMAN	VARIETY MEAN
2-ROW														
98NZ223	46.4	50.8	51.7	50.9	48.0	50.3	54.0	53.9	53.0	53.0	52.2	52.0	54.9	51.6
98NZ015	47.3	49.0	50.5	50.1	43.8	50.0	50.8	52.9	50.9	52.5	50.1	52.8	53.1	50.3
BARONESSE	48.5	49.9	51.7	50.7	48.4	51.1	54.3	54.8	53.0	52.3	54.1	53.4	54.7	52.1
WA 8682-96	48.7	50.9	53.7	52.5	49.7	51.6	53.4	54.9	53.9	52.9	53.8	53.2	55.4	52.7
PONGO	45.5	47.6	50.0	47.7	43.4	47.7	48.9	51.7	49.8	49.1	47.3	51.7	51.8	48.6
XENA	49.1	50.8	52.4	52.2	50.0	51.3	54.4	54.9	53.9	52.3	53.5	53.9	54.9	52.6
WA 10147-96	47.6	50.2	51.9	50.1	45.6	51.3	54.0	54.7	53.2	52.2	52.4	54.2	54.5	51.7
WA 8709-96	48.6	49.9	51.7	51.4	45.3	50.8	54.2	55.3	54.2	53.9	52.0	54.2	55.4	52.1
98NZ533	46.1	50.4	51.1	49.2	44.1	49.3	52.1	53.3	51.5	51.8	51.1	52.9	53.6	50.5
JERSEY	49.7	50.8	52.3	50.5	48.4	50.6	52.3	53.9	52.8	52.8	50.7	52.4	54.0	51.6
WA 10138-96	48.5	50.2	52.6	52.6	48.2	48.7	54.3	54.5	53.3	52.4	52.8	54.3	54.7	52.1
WA 9504-94	47.2	48.5	51.2	51.4	46.8	51.2	51.6	53.5	52.3	52.1	52.6	54.0	54.8	51.3
H3869224	48.2	51.5	52.3	51.5	48.5	51.6	54.2	55.2	53.1	52.5	52.7	54.6	54.3	52.3
WA 11825-95	46.1	49.5	50.9	51.2	45.7	49.9	52.8	53.7	52.7	52.5	51.6	53.2	53.7	51.0
WA 8718-96	48.4	51.5	51.6	50.7	45.3	47.7	53.4	55.4	54.4	53.1	52.4	53.8	55.3	51.8
WA 8710-96	48.2	50.9	52.4	52.2	47.7	49.5	54.4	55.6	54.4	53.4	52.6	53.9	55.5	52.4
98NZ234	46.8	49.6	51.0	50.5	45.8	51.0	51.8	53.5	52.1	53.1	51.4	53.7	54.1	51.1
WA 11832-95	46.9	48.9	51.5	52.5	48.1	49.5	53.7	53.5	52.8	51.8	51.2	52.5	53.6	51.3
WA 12953-95	45.9	48.8	50.2	47.7	46.4	49.1	51.3	52.6	52.0	51.4	49.7	51.5	52.7	49.9
WA 11801-95	47.3	50.7	51.8	50.4	46.5	48.1	53.9	54.2	52.6	52.5	51.9	54.0	54.3	51.4
CAMELOT	49.0	51.9	53.3	53.9	51.3	53.2	54.2	55.3	53.8	53.6	54.0	54.5	55.4	53.3
CA 803803	48.5	51.6	52.0	51.0	48.4	48.2	53.7	54.2	52.1	51.4	52.6	54.9	54.8	51.8
BANCROFT	46.0	50.4	51.4	50.4	47.8	51.5	52.2	53.5	52.1	51.7	52.0	52.2	53.2	51.1
98NZ532	45.7	49.8	51.0	48.3	47.0	47.6	52.3	53.1	52.3	51.5	52.9	54.3	53.8	50.7
MENTOR	47.0	49.8	52.0	49.3	47.2	48.8	52.9	53.3	51.9	49.7	52.6	51.9	53.8	50.8
WA 8831-96	46.3	50.0	52.3	51.5	50.0	49.8	53.1	54.3	53.0	53.1	53.7	53.3	54.2	51.9
98NZ226	46.3	49.7	50.8	48.6	45.7	48.3	51.2	53.0	51.8	52.4	52.2	53.3	53.2	50.5
VALIER	48.7	51.9	52.6	52.6	50.7	52.9	54.4	54.6	52.8	52.1	53.2	53.0	54.8	52.6
HARRINGTON	46.6	47.4	51.4	50.6	46.3	49.8	51.0	52.6	51.9	50.9	51.8	53.2	53.0	50.5
GALLATIN	47.6	51.0	53.2	54.2	49.8	53.0	54.6	55.5	54.2	52.9	53.2	54.6	55.9	53.0
WA 12223-95	45.7	50.0	52.1	48.0	44.4	45.8	52.1	53.3	52.5	52.6	51.7	52.5	54.1	50.4
CREST	48.4	51.4	52.9	51.1	50.6	51.8	54.0	54.5	53.5	52.9	50.9	52.3	54.6	52.2
ORCA	48.0	51.1	50.1	52.3	51.9	52.3	54.2	53.6	53.5	51.3	53.4	55.1	53.6	52.3
BCD 47	47.9	51.6	53.6	51.3	49.8	51.1	52.3	53.4	52.7	53.0	52.6	50.9	54.4	51.9
WA 7942-96	47.4	48.3	50.0	50.5	47.1	48.2	51.0	51.9	50.3	49.2	51.7	53.6	52.4	50.1
6-ROW														
STEPTOE	43.9	46.8	48.2	46.3	46.5	46.4	48.6	47.2	46.8	46.3	49.3	50.0	48.3	47.3
TANGO	43.2	47.8	48.2	46.9	46.8	47.0	49.5	48.2	48.0	47.4	50.7	50.8	50.2	48.0
MOREX	46.0	48.9	51.1	48.4	48.7	49.7	52.1	51.6	51.5	50.5	51.6	51.3	52.0	50.3
HULLESS														
CONDOR	59.2	60.4	62.5	62.0	54.9	57.0	61.3	63.3	60.3	60.0	62.5	63.2	63.7	60.8
BEAR	55.7	57.4	59.9	59.9	49.7	56.5	59.3	60.8	59.2	55.9	59.8	60.7	61.8	58.2
NURSERY MEAN	47.7	50.4	52.0	51.1	47.8	50.2	53.1	54.0	52.7	52.1	52.5	53.5	54.3	51.7
CV %	1.6	2.0	1.1	2.7	1.9	3.1	1.3	1.1	1.4	1.9	2.5	1.7	0.8	1.9
LSD @ .10	1.0	1.4	0.8	1.9	1.3	2.1	1.0	0.8	1.0	1.4	1.8	1.2	0.6	0.4

2000 WSU SPRING BARLEY VARIETY TRIAL SUMMARY

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PRODUCTION ZONE (LBS/A)

	<3500		3500-5000		5000-6000		>6000		OVERALL	
VARIETY	YIELD LBS/A	TEST WT LBS/BU	YIELD LBS/A	TEST WT LBS/BU	YIELD LBS/A	TEST WT LBS/BU	YIELD LBS/A	TEST WT LBS/BU	YIELD LBS/A	TEST WT LBS/BU
2-row										
98NZ223	2748	48.6	4438	50.2	6442	53.5	6723	53.0	5322	51.6
98NZ015	2503	48.2	4248	48.6	6181	51.7	7390	52.0	5299	50.3
BARONESSE	2500	49.2	4254	50.5	6494	53.6	6834	54.1	5269	52.1
WA 8682-96	2860	49.8	4433	51.9	6247	53.8	6594	54.2	5248	52.7
PONGO	2480	46.5	4176	47.2	5978	49.9	7447	50.3	5225	48.6
XENA	2818	49.9	4418	51.5	5870	53.9	7046	54.1	5225	52.6
WA 10147-96	2811	48.9	4095	49.7	6045	53.5	7134	53.7	5199	51.7
WA 8709-96	2848	49.3	4229	49.8	6093	54.4	6681	53.9	5156	52.1
98NZ533	2669	48.2	3925	48.4	6129	52.2	7002	52.5	5120	50.5
JERSEY	2594	50.2	4041	50.4	5962	52.9	7052	52.4	5105	51.6
WA 10138-96	2580	49.3	4035	50.5	5874	53.6	7038	53.9	5070	52.1
WA 9504-94	2170	47.9	4261	50.2	5885	52.4	6997	53.8	5070	51.3
H3869224	2788	49.8	4221	51.0	5708	53.7	6604	53.9	5008	52.3
WA 11825-95	2495	47.8	4101	49.4	5899	53.0	6678	52.8	5002	51.0
WA 8718-96	2872	49.9	3721	48.8	6122	54.1	6573	53.8	4987	51.8
WA 8710-96	2589	49.6	4021	50.5	5964	54.4	6561	54.0	4985	52.4
98NZ234	2254	48.2	4177	49.6	6007	52.6	6485	53.0	4977	51.1
WA 11832-95	2702	47.9	4201	50.4	5848	52.9	6242	52.4	4948	51.3
WA 12953-95	2721	47.3	4061	48.3	5704	51.8	6608	51.3	4948	49.9
WA 11801-95	2676	49.0	3831	49.2	5777	53.3	6833	53.4	4945	51.4
CAMELOT	2665	50.4	4312	52.9	5471	54.2	6545	54.6	4931	53.3
CA 803803	2505	50.0	3613	49.9	5718	52.8	7206	54.1	4919	51.8
BANCROFT	2676	48.2	4310	50.3	5422	52.4	6428	52.5	4890	51.1
98NZ532	2314	47.7	3737	48.5	5753	52.3	6915	53.7	4872	50.7
MENTOR	2551	48.4	4111	49.3	5598	52.0	6327	52.8	4840	50.8
WA 8831-96	2489	48.2	3912	50.9	5721	53.4	6456	53.7	4837	51.9
98NZ226	2275	48.0	3995	48.3	5611	52.1	6423	52.9	4788	50.5
VALIER	2521	50.3	4298	52.2	5122	53.5	6429	53.7	4770	52.6
HARRINGTON	2105	47.0	4008	49.5	5527	51.6	6446	52.7	4745	50.5
GALLATIN	2457	49.3	4080	52.5	5374	54.3	6229	54.6	4724	53.0
WA 12223-95	2336	47.8	3420	47.6	5637	52.6	6812	52.8	4718	50.4
CREST	2572	49.9	3856	51.6	5642	53.7	5884	52.6	4676	52.2
ORCA	2558	49.5	3725	51.6	5019	53.1	6436	54.0	4569	52.3
BCD 47	2613	49.7	4001	51.5	4986	52.8	6064	52.6	4567	51.9
WA 7942-96	2476	47.8	3812	49.0	4784	50.6	6627	52.6	4555	50.1
6-row										
STEPTOE	2621	45.3	4142	46.9	5553	47.2	7283	49.2	5067	47.3
TANGO	2615	45.5	4083	47.2	4899	48.3	6515	50.5	4670	48.0
MOREX	2447	47.4	3167	49.5	4865	51.4	5686	51.6	4160	50.3
Hulless										
CONDOR	1953	59.8	3367	59.1	4598	61.2	5917	63.1	4117	60.8
BEAR	1804	56.5	3298	56.5	4423	58.8	5792	60.8	3990	58.2
GRAND MEAN	2531	49.1	4003	50.3	5649	53.0	6624	53.4	4888	51.7
CV %	13.4	1.8	10.4	2.3	9.4	1.5	8.4	1.8	9.8	1.9
LSD @ .10	323	0.9	281	0.8	357	0.5	432	0.7	178	0.4
# LOCATIONS	2		4		4		3		13	
	Asotin Bickleton		Dusty Pomeroy Ritzville St. John		Dayton Fairfield Farmington Lamont		Pullman Reardan Royal Slope		All Locations	

Winter Wheat: Acres Planted by Variety, By Agricultural Districts, Washington, 1998-2000

Class and	Variety	1998 Total	1999 Total	2000 Total 1/	2000 West	2000 Central	2000 N. East	2000 E.Central	2000 S. East
		Acres	Acres	Acres			Acres		
COMMON WHITE	Madsen	590,000	535,500	455,800	800	11,900	72,400	69,400	301,300
	Eltan	510,600	402,300	403,600	-	14,400	1,300	380,600	7,300
	Madsen-Rod*	108,700	121,200	124,300	-	-	-	20,500	102,700
	Stephens	163,000	123,400	98,200	3,000	19,000	-	25,200	51,000
	Cashup	56,000	57,400	75,100	1,900	-	-	6,300	66,900
	Eltan-Madsen*	50,700	72,400	56,800	-	-	2,300	52,300	-
	Lewjain	56,500	51,300	33,400	-	-	4,100	26,900	2,200
	Lambert	19,500	22,100	28,900	-	-	800	1,900	26,200
	Rod	70,100	37,400	25,000	-	-	-	6,400	18,400
	Hill 81	23,100	13,900	14,600	-	-	4,000	1,400	9,200
	Malcolm	8,700	18,400	14,500	-	-	-	-	-
	WPB 470	18,000	18,500	13,700	-	-	-	3,400	9,700
	Lambert-Madsen*	2,400	2,200	13,100	-	-	-	-	13,100
	Hill 81-Madsen-Rod*	11,300	8,300	10,000	-	-	-	-	9,400
	Rod-Stephens*	3,600	2,000	8,500	-	-	-	-	8,500
	Madsen-Stephens*	9,000	14,700	8,000	-	1,600	-	-	6,400
	Madsen-Rod-Stephens*	8,500	5,700	7,100	-	-	-	-	7,100
	Madsen-Rod-Eltan	4,300	3,900	6,000	-	-	-	2,800	-
	Cashup-Rod*	-	700	5,800	-	-	-	-	2,600
	Eltan-Lewjain*	-	6,000	5,500	-	-	-	5,100	-
	Daws	12,200	8,600	5,300	-	-	1,700	2,000	1,400
	MacVicar	13,900	4,200	5,300	-	-	-	-	3,900
	Cashup-Madsen*	-	-	3,900	-	-	-	-	3,900
	Lambert-Rod*	-	2,500	3,800	-	-	-	-	-
	Lewjain-Madsen*	4,500	5,300	3,500	-	-	-	3,500	-
	Hill 81-Madsen*	2,300	1,900	2,800	-	-	-	-	1,700
	Basin	4,400	1,600	2,000	-	-	-	600	1,300
	Eltan-Rod*	-	-	1,900	-	-	-	1,900	-
	Lambert-Madsen-Rod*	-	3,400	1,700	-	-	-	-	1,700
	Sprague	5,300	5,100	1,500	-	-	-	1,300	-
	Quantum 7817	-	900	1,100	-	-	-	-	-
	Gene	-	-	1,000	-	-	-	-	-
	Other Common White	34,700	24,300	13,700	300	17,100	6,800	11,500	13,100
	Total Common White	**1,806,000**	**1,589,000**	**1,455,400**	**6,000**	**64,000**	**93,400**	**623,000**	**669,000**
WHITE CLUB	Rely	151,400	101,800	163,300	-	2,400	100	156,800	4,000
	Coda	-	400	22,900	-	-	-	22,000	700
	Moro	10,400	8,100	21,300	-	-	-	21,100	-
	Hiller	5,400	7,700	11,700	-	3,000	-	6,300	2,400
	Rohde	18,900	6,700	7,700	-	-	400	3,300	4,000
	Crew	-	-	2,600	-	-	-	-	-
	Tres	8,600	8,800	1,500	-	-	-	-	-
	Hyak	1,900	4,600	500	-	-	-	-	-
	Other White Club	2,400	4,500	3,500	-	600	100	5,300	2,300
	Total White Club	**199,000**	**142,600**	**235,000**	**-**	**6,000**	**600**	**215,000**	**13,400**
HARD RED	Hatton	47,300	30,400	37,800	-	6,500	-	30,200	-
	Buchanan	9,300	17,500	31,400	-	27,200	-	4,200	-
	Finley	-	7,400	31,400	-	27,600	-	3,800	-
	Quantum (Q542)	36,400	27,200	22,400	-	3,100	-	18,100	-
	Symphony	29,100	26,400	15,000	-	5,000	-	9,700	-
	Weston	38,700	35,100	7,300	-	-	-	-	-
	Estica	500	4,200	4,100	-	-	-	4,000	-
	Other Hard Red	18,200	8,600	10,200	-	10,600	2,000	7,000	600
	Total Hard Red	**195,000**	**168,400**	**159,600**	**-**	**80,000**	**2,000**	**77,000**	**600**
TOTAL WINTER WHEAT		**2,200,000**	**1,900,000**	**1,850,000**	**6,000**	**150,000**	**96,000**	**915,000**	**683,000**

1/ *The sum of the districts by variety may not add to the state total to avoid disclosure of individual operations.*
* *Denotes mixtures.*
\- *Not estimated or combined with the "Other" category.*

Spring Wheat: Acres Planted by Variety, By Agricultural Districts, Washington, 1998-2000

Class and Variety	1998 Total	1999 Total	2000 Total 1/	2000 West	2000 Central	2000 N. East	2000 E. Central	2000 S. East
	Acres	Acres	Acres	Acres				
COMMON WHITE								
Alpowa	145,300	220,900	283,400	-	23,700	18,600	161,100	80,000
Wawawai	67,600	95,500	40,600	-	-	1,800	9,900	27,500
Penawawa	44,900	63,300	24,600	-	6,100	-	11,800	4,100
Westbred Vanna	13,400	10,400	22,600	-	-	-	-	20,000
Wakanz	7,600	5,200	19,000	-	-	-	-	18,000
Edwall	39,200	20,800	16,300	-	-	4,700	5,600	6,000
Wadual	8,800	5,700	3,600	-	-	-	3,600	-
Vanna-Westbred Sprite*	-	-	800	-	-	-	-	500
White Club	-	1,500	7,500	-	-	-	6,900	-
Other Common White 2/	25,300	5,300	9,700	1,000	4,000	2,500	6,200	4,500
Total Common White 2/	**352,100**	**448,500**	**428,100**	**1,000**	**33,800**	**27,600**	**205,100**	**160,600**
HARD RED								
Westbred 926	33,500	41,600	69,800	-	3,800	4,500	4,600	56,900
Westbred Express	25,100	35,400	45,400	-	-	-	36,600	7,500
Butte 86	12,500	18,500	18,000	-	10,000	-	8,000	-
Spillman	4,400	15,700	16,400	-	2,400	-	14,000	-
Scarlet	-	-	7,300	-	5,600	-	1,700	-
Westbred 936	4,600	11,600	4,600	-	1,000	-	-	1,600
Westbred 906R	5,100	3,100	3,700	-	-	-	-	2,400
Kulm	13,700	16,600	2,700	-	-	-	2,700	-
Yecora Rojo	5,000	3,200	2,000	-	700	-	1,300	-
Wampum	-	3,100	1,400	-	1,400	-	-	-
Amidon	-	-	800	-	-	-	-	-
Other Hard Red	14,000	7,900	500	-	1,300	1,400	3,200	-
Total Hard Red	**117,900**	**165,800**	**172,600**	**0**	**26,200**	**5,900**	**72,100**	**68,400**
HARD WHITE								
ID 377	-	8,400	20,200	-	-	2,300	5,100	12,800
Winsome	-	-	3,800	-	-	-	-	-
Other Hard White	**-**	**2,300**	**300**	**-**	**-**	**200**	**700**	**3,200**
Total Hard White	**-**	**10,700**	**24,300**	**-**	**-**	**2,500**	**5,800**	**16,000**
TOTAL SPRING WHEAT	**470,000**	**625,000**	**625,000**	**1,000**	**60,000**	**36,000**	**283,000**	**245,000**

1/ *The sum of the districts by variety may not add to the state total to avoid disclosure of individual operations.*
2/ *"Total Common White" includes an estimated 1,500 acres of White Club spring varieties in 1999 and 7,500 acres in 2000, at both District and State levels.*
* *Denotes mixtures.*
\- *Not estimated or combined with the "Other" category.*

Barley: Acres Planted By Variety, By Agricultural District, Washington, 2000

Type/Variety	West	Central	Northeast	East Central	Southeast	State Total 1/	% of Total 2/
	Acres						Percent
FEED BARLEY							
Westbred Baronesse	500	2,300	33,800	121,800	220,900	379,300	75.9
Camelot	400	600	4,200	18,700	3,900	27,800	5.6
Gallatin	-	-	400	13,300	7,200	21,300	4.3
Lewis	-	9,900	-	700	-	10,600	2.1
Steptoe	1,200	2,800	200	3,100	1,700	9,000	1.8
Meltan	-	-	1100	2,200	-	3,300	0.7
Belford	-	400	-	-	300	1,200	0.2
Xena	-	-	-	300	-	1,000	0.2
Kamiak	-	-	-	-	-	800	0.2
Hesk	-	-	-	-	-	600	0.1
Columbia	-	200	-	-	-	200	-
Westford	-	-	-	-	-	200	-
Other Feed Barley	500	1,200	1,300	3,400	1,500	4,700	0.9
Total Feed Barley	**2,600**	**17,400**	**41,000**	**163,500**	**235,500**	**460,000**	**92.0**
MALTING BARLEY							
Harrington	-	-	5,200	1,500	25,800	32,500	6.5
Morex	-	-	2,700	-	1,700	4,900	1.0
Chinook	-	-	-	-	-	900	0.2
Stander	-	-	-	-	-	400	0.1
Other Malting Barley	-	300	400	600	1,800	1,300	0.3
Total Malting Barley	**-**	**300**	**8,300**	**2,100**	**29,300**	**40,000**	**8.0**
TOTAL ALL BARLEY	**2,600**	**17,700**	**49,300**	**165,600**	**264,800**	**500,000**	**100.0**

1/ The sum of the district may not add to the state total to avoid disclosure of individual operations.
2/ Sum of the percentages may not add due to rounding.
- Not estimated or combined with the "Other Barley" category.

NEW DIRECTIONS OF THE GRAIN LEGUME BREEDING PROGRAM

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

The grain legume breeding program is focused on producing new improved cultivars of spring-sown dry pea, lentil, chickpea and winterhardy pea and lentil. Emphasis has been placed on the development of edible types of winter peas and winter lentils that can be fall sown into cereal stubble. All types of edible grain legumes must be environmentally adapted, high yielding and market acceptable. Meeting these demands has necessitated accelerating the breeding process. An increased use of greenhouse screening for early generation breeding material coupled with intense field screening of selected material has resulted in dramatically reducing the overall time from initial parental selection and cross pollinations through to cultivar release. Promising selections are often increased during the winter months in Arizona to shorten the time from variety release to field production. 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. Progress has been made under previous industry supported projects in the development of dry pea lines with multiple disease resistance, particularly to root rot, wilt, powdery mildew and viruses (mainly bean leaf roll and pea enation mosaic).

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 in East Asia they are used in the snack food industry. 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. Market requirements include extremely large seed size, dark green color (<30% bleach) and excellent seed coat integrity.

The dry pea breeding program has recently been expanded to include the orange 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 have been evaluated in the field since that time.

In 2000, two new cultivars were released, 'Lifter' and 'Franklin'. They both have the semi-dwarf growth habit and normal leaf morphology. Yield potential of Lifter and Franklin is superior to 'Joel' and 'Columbian' and they have durable, green cotyledon color which is resistant seed bleaching. Due to the normal leaf morphology and poor stem structure lodging will occur prior to harvest.

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. Several lines are currently in the advanced yield trials at four locations and are being considered for release. One line in particular, PS610152, has shown excellent yield potential, resistance to seed bleach and maintains an upright growth habit through harvest. This line has been approved through the Washington State University Legume Variety Release Committee for preliminary increase of breeder seed. Full release is expected in 2002.

Future objectives of the dry pea breeding program include continued increases in yield potential, bleach resistance, upright growth habit and multiple disease resistance. Development of an orange-seeded pea that is adapted to the Pacific Northwest and a marrowfat cultivar suited to the snack food industry are currently a major focus of the program.

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 now are that several types can be produced and sold in various markets both domestically and worldwide. 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. Recently, two new lentil varieties were proposed for release and include 'Pennell', a large-seeded type with good standing ability, large non-mottled seeds and higher yields and 'Merrit', a large-seeded high yielding variety that is intended as a replacement for 'Brewer'. Additional work toward an 8-9 mm diameter lentil is underway. Improved selections are being tested in 1999 and one or more will be proposed for release to the industry this fall. The improved selection will have better standing ability, higher yields and increased amounts of residues.

Winter lentil:

A breeding program for winter lentil has been established and many breeding lines have been identified with excellent winter hardiness. Three main types of winter lentil are being developed, large red, large yellow and small yellow cotyledon types. We are currently increasing several winter lentils selections for possible release in the near future. These have proven to have good winter hardiness, high yielding and acceptable quality traits. Samples were taken to India and have acceptable quality in that market. The lines are small seeded and similar to 'Crimson' and should fit well in the decortication and splitting process.

Chickpea (Garbanzo beans):

Ascochyta blight is a devastating disease of chickpea in the Palouse area and has caused serious problems with crop production. Success in the early 1990s led to the development of cultivars such as 'Dwelley' and 'Sanford' making it possible to grow the crop with some assurance that the disease would not be as devastating. In 1997, 'Evans' was 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 characterized by exceptionally large white seeds. Numerous crosses were made to incorporate Ascochyta blight resistance into the Spanish White type. During the 2000-01 winter season, three Spanish White type selections were increased at Yuma, Arizona to provide additional seed for yield testing and reduce the time required for release to producers. A decision to release one or more of the lines will be made following the 2001 field season.

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. This past winter, a 'Café' type chickpea with good resistance to blight, large seed size and a reduction of 2 to 3 days to flower and maturity was proposed for release. This selection has been named 'Sierra' and should be available to producers in small quantities for the 2002 growing season.

Winter Peas:

Two types of winter peas are currently being developed. The first is the Austrian winter pea and the second is a white-flowered, clear-seeded pea that is edible and is similar to the Alaska type. The Austrian winter peas are an alternative legume crop on the Camas Prairie of northern Idaho and to a limited extent in southeastern Washington and eastern Oregon. A relatively high proportion of hard seed in the Austrian winter pea has limited its use in the Palouse region. Development of the clear-seeded types will not only reduce the hard seed problem but will allow greater yields to be attained from the pea crop. Several promising lines have been evaluated for yield potential and seed quality. The more winterhardy lines were evaluated and generally well received in overseas markets.

Root and foliar diseases have caused a decline in production over the past 10 years. The most serious diseases include soil borne Aphanomyces root rot and infestations of Ascochyta blight and Sclerotinia white mold. The foliar disease problems can be solved through the use of upright plant types that increase air movement through the canopy 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. Development of multiple disease resistant varieties is needed if this crop is to continue as an integral part of the cropping systems in the Camas prairie and for expanded production in the Palouse region. The most urgent need is to develop cultivars with resistance to these diseases and with sufficient winterhardiness to be grown over a wide area. Many crosses have been made with these objectives in mind and are expected to yield superior breeding lines.

2000 DRY BEAN PERFORMANCE EVALUATION

An N. Hang and Virginia I. Prest
Washington State University - Prosser

Bean became an important rotation crop in Washington after the expansion of irrigated acreage when the Coulee Dam and diversions from the Yakima River were completed in the 1940's. Washington State University scientists, in cooperation with ARS scientists, have participated in National Cooperative Dry Bean Nursery program for many years. Washington has released numerous bean cultivars that provide the bean industry with virus-free, high quality pinto, small red, navy, pink and kidney. These bean lines were also tested in 20 other locations nation wide.

Materials and Methods

The trial was located at the Othello Research Farm, Irrigated Agricultural Research and Extension Center, Washington State University. The soil is a Shano silt loam soil and previously cropped with seed potato. Plots were pre-irrigated and a pre-plant herbicide application of 2 qt/a of Eptam and 1 qt/a of Sonalan was incorporated on May 3. Plots consisted of 4 rows (22" apart) of 25 ft long and the harvest area was 2 middle rows of 19 ft. Bean plots were planted in randomized complete block design with 4 replications using cone seeder on a John Deere Flex planter to place seed at 3" apart. Cultivation and hand weeded as needed during the growing season. Furrow irrigation was applied as needed starting a month after seeding. Seedling vigor, 50 % bloom and 50 % maturity were recorded. Ten plants from each plot were pulled, air dry, weighed and threshed by a bundle thresher for harvest index as plants reaching maturity (August 23 to September 6). Plots were blocked and two middle rows of each plot were cut then threshed by a small plot thresher (one replication) and other replications were threshed by Hege, small plot combine.

Results and Discussion

Seed emergence of all lines was excellent. Yields, Harvest Index, Seed Weight, Bloom and Maturation were reported in Table 1. Great northern and kidney market classes are early maturing bean varieties but all reached maturity in less than 100 days. Yields across entries averaged 3,167 lb/a, and ranged from 1905 lb/a (WK 380) to 3952 lb/a (Buster). Seed loss at harvest is minimal so no data is recorded. Seed moisture at harvest is less than 12%.

Table 1. 2000 Advanced Variety Trial - Dry Bean Nursery Data Evaluated at Othello, WA, USA.

Line	Market Class	Seed Yield lb/A	100-Seed Weight grams	50% Bloom days	50% Maturity days	BioMass Yield lb/A	Harvest Index lb/A/day
I9606-6	Black	3273	22	55	87	6202	52.8
ICB-10	Black	2344	22	55	87	4649	50.5
JAGUARS	Black	3362	19	55	90	6684	50.4
SHINY CROW	Black	3346	23	54	87	5949	56.2
AC CALMONT	Dark Red Kidney	2101	43	45	82	4130	51.0
RED HAWK	Dark Red Kidney	1918	44	51	82	3882	49.6
USWA-39	Dark Red Kidney	2681	46	42	87	4234	54.7
CDC CROCUS	Great Northern	3105	40	48	82	5405	57.7
MATTERHORN	Great Northern	3601	35	51	82	6969	51.7
WEIHING	Great Northern	2877	36	52	82	5483	52.5
CHINOOK 2000	Light Red Kidney	2458	48	45	82	4664	52.9
USWA-33	Light Red Kidney	2553	52	43	82	4752	56.7
AC COMPASS	Navy	3115	22	43	87	4491	56.9
AC MAST	Navy	3272	21	53	87	6464	50.6
AC TRIDENT	Navy	3340	19	51	95	6374	52.4
ARTHUR	Navy	3402	19	55	95	6604	51.6
ISB 1252	Navy	2694	19	54	95	5303	50.9
ISB 1256	Navy	3604	20	51	95	6824	53.1
ISB 3156	Navy	2921	24	53	95	5511	53.2
MACKINAC	Navy	3025	18	55	94	5998	52.3
OAC GRYPHON	Navy	3197	19	54	94	6439	48.8
OAC LASER	Navy	2971	20	53	95	5897	50.5
OAC THUNDER	Navy	2990	21	44	92	5604	53.4
AC PINTOBA	Pinto	3275	43	51	92	5338	61.4
BUSTER	Pinto	3952	43	52	82	6858	58.5
CDC PINNACLE	Pinto	3920	44	50	82	6458	61.3
ELIZABETH	Pinto	3501	44	54	82	5822	60.2
ISB 5893	Pinto	3902	41	54	94	6437	60.7
KODIAK	Pinto	3389	42	54	87	5796	58.5
MONTROSE	Pinto	3910	40	55	82	6097	64.2
OTHELLO	Pinto	3768	39	46	82	6078	64.5
BURKE	Pinto	3568	43	49	87	5577	61.6
USPT 73	Pinto	3815	41	53	88	5250	62.3
R 93-365	Small Red	2667	33	49	84	5268	50.7
LEBARON	Small Red	2909	37	43	75	5064	57.3
BELUGA	White Kidney	2242	45	44	82	4510	50.3
WK 380	White Kidney	1905	45	51	82	3540	54.1
USWA-70	White Kidney	2208	54	43	82	5288	42.3
Site Mean:		**3233**	**33**	**51**	**88**	**5705**	**55.1**
LSD (5%):		**440.01**	**2.641**	**1.040**		**1217.4**	**5.230**
CV%:		**9.550**	**4.365**	**1.470**		**13.330**	**6.200**

Table 2. Annual Weather Summary for WSU- OTHELLO, 8 MI ESE of Othello, Wa

Lat:46.7 Lng:119.0 elevation:1154
Dates Range From 1989-01-01 To 2000-12-31

Year	Max Air Temp (F)	Min Air Temp (F)	Avg Air Temp (F)	Total Precip Inches	Total ETr Inches	Total ETo Inches	Wind Run Miles	Solar Rad Langley
1989	96.53	-4.54	49.91	4.58	54.11	50.53	52724	122148
1990	103.78	-9.58	51.04	5.29	55.95	54.02	57199	120665
1991	96.15	-1.66	50.2	7.21	51.88	48.99	48833	120459
1992	103.62	7.16	51.77	7.52	49.38	45.85	44977	116045
1993	96.58	-8.32	47.63	7.59	47.87	45.26	45672	116200
1994	100.76	5.72	51.62	8.8	55.17	53.27	45079	122699
1995	97.38	6.8	50.31	11.46	48.89	46.39	45562	117481
1996	99.75	-19.48	47.69	12.9	47.61	44.27	42867	123045
1997	95.97	5.36	49.86	21.74	45.18	42.64	43724	117327
1998	106.12	0.23	51.81	13.95	49.43	47.16	42435	120199
1999	97.75	23.22	50.71	7.75	52.05	50.22	48419	120480
2000	99.23	10.29	48.99	13.49	47.97	45.01	39685	122204

Information provided by WSU Public Agricultural Weather System

RELEASE OF 'ROJO CHIQUITO' SMALL RED DRY BEAN

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

1. Unique Cultivar Characteristics: Rojo Chiquito is derived from the cross 'K42'/Pompadour. It has moderate resistance to curly top virus (CTV). Although neither parent has a small red seed type, Rojo Chiquito is closer to a small red than any commercial dry bean class, but is different in several respects. It has a much smaller seed size than typical small reds. This smaller size is characteristic of the 'Central American' small red market class. This Rojo Chiquito will be grown primarily for export to Central America and for US consumption by ethnic niche markets. Rojo Chiquito will be the first small red cultivar release to possess dominant *I* gene resistance to seed borne bean common mosaic virus (BCMV). This gene restricts seed transmission of the virus, which has plagued seed production of most small red cultivars in the Pacific Northwest. The plant has a more upright plant habit (IIA) than typical commercial small reds such that narrow row spacing may be used to increase yield. Pods are borne high enough (mid to top plant) to be directly harvested. Rojo Chiquito has a small shiny dark red seed when mature.

2. Use Type: Rojo Chiquito seed has a very shiny and attractive dark red appearance. It retains very attractive bright red color after cooking and good texture. Its canning quality is equal or higher than the standard commercial small red cultivars. In summary, it will be useful as a dry pack or canned product.

3. Description: Rojo Chiquito is an upright short vine bean. It is taller then NW-63 and LeBaron, with smooth ovate leaf morphology and resistance to lodging. It adapts to the Pacific Northwest where red bean is grown commercially. Yield is comparable to LeBaron but lower than NW-63. Seed of Rojo Chiquito is much smaller than LeBaron and NW-63 (20g/100 seeds vs. 32 g/100 seed) (Table 1 and 2), and is characteristic of the 'Central American' small red market class. It has excellent seed and canning quality with good appearance. Splitting is not a problem with this cultivar (Table 3 and 4).

4. **To Supplant:** Rojo Chiquito will be the first US-bred cultivar for the Central American small red market class.

Performance Evaluation:

1. Agronomic: Yield is comparable to LeBaron, small red variety released in 1999. Maturity for Washington state is in the medium-late class (100 to 105 days) and is 5 days later than NW-63 and about 11 days later than LeBaron. However, in other states maturity is comparable to NW-63 (Table 1).

2. Quality: Excellent canning quality, retains very bright red color with good texture. It received perfect canning scores in a New York canning trial of small reds (Tables 2,3, and 4).

3. Resistance to Diseases, Insects, Other: Rojo Chiquito has *I* gene resistance to BCMV and moderate resistance to curly top virus.

4. Area of adaptation: Rojo Chiquito is widely adapted to the bean growing areas of the Northwest. It out yields NW-63 in Sidney, Montana, Guelph, Ontario and Columbia, Missouri.

Table 1. Yield, Harvest Maturity and Lodging Data for Rojo Chiquito and other Small Red Cultivars.

Cultivar	Othello, Washington Yield lbs/a	Maturity day	Lodging 1 to 9	Kimberly, Idaho Yield lbs/a	Maturity day	Lodging 1 to 9	Parma, Idaho Yield lbs/a	Maturity day	Lodging 1 to 9	Twenty locations across US and Canada Yield lbs/a	Maturity day	Lodging 1 to 9
1995												
Rojo Chiquito	**1964**	**101**	**1.2**	**1433**	**95**	**2.3**	**2036**	**88**	**2.0**	**2048**	**96**	**2.5**
UI 239	3074	101	2.0	2918	89	3.6	2700	84	4.0	2445	94	3.3
NW-63	2430	100	2.0	2934	87	3.5	3030	82	3.4	2350	95	3.5
LeBaron	2280	100	1.0	2619	82	2.8	2109	80	2.5	2155	89	2.6
1996												
Rojo Chiquito	**2765**	**100**	**1.0**									
UI 239	3467	100	4.0									
NW-63	3493	100	4.0									
LeBaron	2786	89	1.0									
Rufus	3202	95	4.0									
1998												
Rojo Chiquito	**2086**	**90**	**3.0**									
UI 239	3239	84	7.0									
NW-63	3013	86	8.0									
UI 259	2767	85	8.0									
LeBaron	2728	76	7.0									
Rufus	2429	86	9.0									

Lodging: scale 1 to 9: 1= no lodging and 9 = prostrate.

Table 2. Canning Evaluation for Rojo Chiquito and other Small Red Cultivars Grown and Rated in New York ,1995.

Entry	Uniformity of Size	Uniformity of Color	General Appearance
Rojo Poquito	**2.00**	**2.00**	**2.00**
NW-63	2.00	2.00	1.13
LeBaron	2.00	2.00	2.00

Scores from 0 to 2 with 0= unacceptable and 2= perfect
Data from the Fruit and Vegetable Science Report No.59. Cornell University. March 1996.

Table 3. Canning evaluation for Rojo Chiquito and other Small Red Cultivars Grown in Othello, WA and Rated at MSU-East Lansing, MI in 1997.

Entry	Clumps	Splits	General Appearance	Overall Seed Characteristics	PQI*
R93-365	4.4	4.3	4.4	4.3	38.5
Rufus	4.3	5.1	4.1	4.4	34.1
UI 239	4.1	3.6	3.9	4.1	33.0
Rojo Chiquito	**4.0**	**4.6**	**4.0**	**4.0**	**31.8**

Each number is the average of 7 rating scores.
* PQI the higher the value the more visually appealing is a sample
Comment from Dr. G.L. Hosfield, Bean geneticist working on improvement of bean quality: "Rojo Chiquito has an excellent appearance but what market class it belongs to".

Table 4. Canning Evaluation for Rojo Chiquito and other Small Red Cultivars Grown in Othello, WA and Rated at Prosser, WA in 1997.

Entry	Overall Appearance
Rojo Chiquito	**1.8**
R93-365	1.8
Rufus	2.6
UI 239	2.7

Each value is the average of 10 rating scores. * Scale 1 to 5 where by 1 = best and 5= worst

2000 SUGARBEET VARIETY TRIAL PERFORMANCE EVALUATION

An N. Hang and Virginia I. Prest
Washington State University – Prosser

Thirty-seven sugarbeet varieties were seeded in randomized complete plot experiment with eight replications at two locations with different soil types and microclimates. These two locations represent a majority of the growing conditions of sugarbeet production acreage in Washington State. The variety trials were managed the same as the remainder of the field, receiving the same fertilizer, pest management and cultivation inputs by the grower (Table 1). Washington State University planted, thinned, harvested and collected data for beet yield and sugar concentration for final reports.

Planting

At Ephrata plots, the top of the bed was knocked of to clear away volunteer winter wheat used as ground 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 feet in length. Following planting, the grower made a Roundup Ultra application to control wheat and other weeds.

At the Moses Lake location, beet seeds were seeded with the same planter using the same plot dimensions. Beds were built up over the season with cultivation operations.

In-Season

All research plots were thinned at the 6 to 8 leaf stage to a plant population of 170 beets per 100 feet. At all locations, the beets grew well but at Moses Lake the seedlings were about two to three weeks behind those at Ephrata even though all trials were planted within a week of each other. No bolting was observed in the trials this season. At Moses Lake 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 one day prior to digging. One full row was taken from the middle of each plot. All beets were counted, weighed and sub-sampled. The samples were taken to the Pacific Northwest Sugar Company's laboratory for tare, sugar concentration and nitrate-N determinations.

Results

Mean yield of 37 varieties at Ephrata was 50.2 and Moses Lake was 37.3 T/A, a difference of 12.9 T/A (Tables 2). The Moses Lake plots were planted six days after the Ephrata plots; but plant growth and development were lagged three to four weeks. Additionally, the beets at Moses Lake were harvested three weeks prior to Ephrata. The weather at planting, during the growing season and the delay in harvesting contributed a lot to yield at Ephrata. Warmer sandy soil and loose soil may also contribute to the high yield in Ephrata. However, the average sugar concentration was 0.4% lower at Ephrata than that of Moses Lake (17.0 and 17.4%).

Table 1. Field Specification and Grower Management Practices

Trial Location	Ephrata	Moses Lake
Soil Type	Quincy Fine Sand	Shano Silt Loam
Planting date Grower field	April 4	April 10
Variety Trial	April 6	April 12
Grower Variety	Blazer	Sierra and Oasis
Field History	1999 Crop: wheat Followed by wheat For winter cover	______________
Fertilizer	Fall fertilizer, Pre plant and in season fertilizer	85N-20S-1B 30-30-0-4S (June 7) 20-0-0-4S (June 15)
Weed Control	Combination of Upbeet, Assure II and Progress Cultivation and followed by dammer-diker	Two micro sprays Assure II + Crop oil
Harvest	October 24-25	October 2-3

Table 2. 2000 Field Performance of Commercial Sugarbeet Varieties in Washington

Line	Moses Lake Beet Yield (T/A)	Moses Lake Sugar (%)	Moses Lake Sugar Yield lb/A	Moses Lake Rank by Sugar Yield	Ephrata Beet Yield (T/A)	Ephrata Sugar (%)	Ephrata Sugar Yield lb/A	Ephrata Rank by Sugar Yield
Novartis								
HM Canyon	35.9	17.2	12303	25	49.6	16.3	16658	26
HM Oasis	38.4	17.1	13173	20	51.1	16.6	17022	22
HM PM21	38.7	17.5	13503	16	48.7	17.6	17012	24
HM Owyhee	34.0	17.5	11821	28	51.4	16.9	17184	17
HM Dillon	40.7	17.4	14287	7	54.3	16.7	18321	4
HM 1642	43.8	17.8	15566	1	50.5	17.4	17901	10
HM 2983Rz	40.1	16.7	13391	18	47.9	17.0	16308	30
HM 2984RZ	41.1	17.4	14272	8	50.7	17.0	17233	16
ACH								
Mustang	41.3	17.4	14481	5	52.7	17.1	18007	8
Tomcat	40.6	17.6	14335	6	49.5	16.7	16416	29
Crystal 9908	39.2	17.5	13718	14	51.7	16.5	17056	19
Crystal 0002	41.0	17.8	14527	4	51.5	17.6	18126	6
Crystal 0003	40.4	17.5	14084	10	50.3	17.3	17670	12
Beta								
Beta 8118	37.4	17.7	13014	24	49.4	17.4	17020	23
Beta 8220B	38.3	16.3	12252	26	55.7	16.9	18765	2
Beta 8348	41.0	17.5	14225	9	49.6	16.5	16426	28
Beta 8468	31.3	17.1	10706	34	49.8	17.2	17046	21
Beta 8757	39.6	17.7	14020	11	52.4	17.5	18315	5
Beta 8919	37.7	17.4	13036	23	49.4	17.9	17830	11
Beta 7KJ5109	37.2	17.5	13051	21	45.3	17.2	15605	35
Beta 7CG5936	41.3	18.4	15255	2	50.4	17.5	17599	13
Beta 8CG7305	31.7	17.3	10835	32	54.8	17.6	19610	1
Beta 8KG6976	41.5	17.4	14661	3	46.8	17.1	16117	33
Holly								
HH 111	28.3	17.9	10142	36	52.2	17.6	18439	3
HH 119	36.8	16.2	11280	31	47.0	15.4	14372	37
HH 120	34.2	17.2	11679	30	52.6	17.2	18066	7
97HX706	23.8	17.7	8353	37	46.0	17.6	16148	32
98HX802	32.1	16.2	10237	35	49.4	16.9	16611	27
99HX961	30.3	17.8	10742	33	50.2	17.1	17342	14
00HX15	36.3	18.0	13038	22	47.5	17.0	16071	34
00HX34	41.4	16.8	13697	15	52.9	15.9	17051	20
00HX35	38.0	17.7	13446	17	52.0	17.2	17938	9
Seedex								
SX Ranger	34.3	17.2	11813	29	48.6	16.8	16298	31
SX Puma	39.4	17.8	13948	12	50.3	17.3	17322	15
SX Bronco	35.7	16.6	11828	27	45.9	16.3	14989	36
SX Chinook	39.0	17.0	13299	19	51.8	16.6	17152	18
SX Blazer	39.3	17.5	13777	13	48.9	17.0	16689	25
Mean	**37.3**	**17.4**	**12922**		**50.2**	**17.0**	**17140**	
Pr>F	**0.0001**	**0.0001**	**0.0001**		**0.0372**	**0.0001**	**0.0006**	
C.V.	**10.76**	**3.91**	**11.41**		**9.71**	**3.06**	**10.11**	
LSD 0.5	**4.58**	**0.67**	**1688.4**		**5.53**	**0.51**	**1972.1**	

PNW WEB SITE PROVIDES DIRECT SEED TECHNOLOGY ACCESS

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist, Moscow/Pullman; **Don Wysocki,** OSU Extension Soil Scientist, Pendleton; **Russ Karow,** OSU Extension Agronomist, Corvallis; **Stephen Guy,** UI Extension Crop Management Specialist, Moscow; **Bill Schillinger,** WSU Dryland Agronomist, Lind; **Joe Yenish,** WSU Extension Weeds Specialist, Pullman; **John Burns,** WSU Extension Agronomist, Pullman; **Greg Schwab,** WSU Extension Soils Specialist, Pullman; **Larry Robertson,** UI Extension Crop Management Specialist, Aberdeen; **Brad Brown,** UI Extension Crop Management Specialist, Parma

The Growing PNW Internet / E-Mail Connection

The Internet and e-mail are rapidly becoming major technology access and communications tools for Pacific Northwest growers and Ag support personnel. 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 1999 USDA Agricultural Statistics Service survey of growers study showed that 40% of PNW growers had Internet / e-mail access, up dramatically from 18% in 1997. Washington growers lead the NW and were second in the nation at 50%. The portion of PNW growers with Internet access today is likely around 75% or more. As growers are moving towards direct seeding and more intensive cropping systems to improve productions efficiency and profitability, cropland productivity, and environmental protection.... they are expanding their use of the Internet to search for technologies they need to help make the transition.

A PNW Web site and PNW Direct Seed List E-Mail Server are helping meet this expanding PNW demand for computer technology access and an improved communications network on direct seed cropping systems. The Web site (http://pnwsteep.wsu.edu) "PNW Conservation Tillage Systems Technology Source" was initiated in 1997 as part of an educational effort by the PNW 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 effort under the Columbia Plateau Wind Erosion / Air Quality Project.

The Web site contains a wealth of technology resources and communication links. Averaging more than 100 hits per day, the Web site is becoming an increasingly important information source. Electronic access through the Internet is a low cost, effective means of providing unlimited access to the latest technologies and communications networks. The following are brief descriptions of some of the major Web site features.

NW Direct Seed Cropping Systems Conferences

You can select the 1998, 1999, 2000, 2001 and 2002 Conferences on the Web site. These Conference pages help publicize the Conferences and providing later access to the proceedings and conference video information. In advance of the conferences, the conference pages include: a conference overview; agenda; sponsorship prospectus; registration form; and hotel information. Conference sponsorship prospectus and conference registration forms include templates that can be completed online, printed and mailed, or submitted directly via e-mail.

PNW Extension Conservation Tillage Update

This newsletter provides a timely and effective technology transfer tool for STEEP and related PNW research projects. The current mailing list is over 2,800, including primarily PNW producers (about 1,950), county Extension agents, Conservation Districts, NRCS staff, and Ag service industry, Ag media and other support personnel. Issues have also been posted on the Web site since 1995 to greatly expand the potential audience. Update issues highlight new research technologies, information resources and upcoming events related to direct seed cropping systems.

PNW Conservation Tillage Handbook Series

This PNW Extension Handbook is a major reference on Northwest research developments for direct seed / conservation tillage systems. It currently contains 168 Handbook Series publications that are now available on the Web site. Since the *Handbook* was published in1990, 70 new Series publications have been completed. Print copies of new Handbook Series publications are distributed through the PNW Conservation Tillage Update newsletter.

Direct Seed Resource Directories

The first two editions of the Directories in May 1997 and May 1999 are on the Web site and are also part of the PNW Conservation Tillage Handbook Series. They describe and provide access information on more than 42 publications, videos, and other Web sites with additional information on direct seed cropping systems.

PNW Direct Seed Internet / E-Mail List Server

This List Server was initiated in October 1999 and 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 also helps provide access to direct seed systems technology from other regions and countries that could be adapted to Northwest production conditions. Messages are received by e-mail and also stored on the List Server Web site for later access by those added to the List Server over time. The initial address list of 230 included PNW university and USDA-ARS researchers, Extension specialists, county/area Ag Extension educators, Conservation Districts, USDA-NRCS staff, PNW grower organizations, Ag industries representatives and growers from across the dryland cropping areas of the Inland Northwest. The List Server has grown to over 330 participants. More than 130 messages have been posted since it was initiated.

PNW Grower Direct Seed Discussion Forum

This "threaded discussion" page was initiated at the request of NW growers in March 2000 as a new feature of the Web site to facilitate more in-depth discussions on direct seeding and more intensive cropping systems and technologies among growers and Ag support personnel. The format allows participants to follow and participate in progressive discussions in 6 "conference" topic areas starting with the original messages and continuing with successive responses.

STEEP Annual Research Reports
These Reports provide detailed summaries of new developments in current research through the PNW STEEP conservation tillage systems research program in Idaho, Oregon and Washington. They are being added to the Web site beginning with the 1998 issue.

Northwest Direct Seed Case Study Series
The goal of this new PNW Extension publication series is to facilitate grower-to-grower learning to enhance Northwest grower adaptation of direct seed systems. The series of 16, full-color, 8-page publications were completed in January 2001 with 3000 print copies of each. The 16 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 also utilize a variety of equipment and cropping systems. Copies 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. The Case Studies are also accessible on the PNW Web site (click on Direct Seed Case Studies), where you can view and print copies as they look from the publisher.

On-Farm Testing
The results of over 200 grower on-farm trials on direct seed systems and a variety of related topics are posted on the Web site. It also includes a number of "how-to" resource publications on on-farm testing.

Web Resource Links
A preliminary compilation of PNW, national and international Web sites with new technologies and resources for direct seed cropping systems is being added to the Web site. Web users are encouraged to submit their favorite Web sites related to direct seed cropping systems for everyone's benefit.

Coming Events
Announcements of upcoming conferences, field days, tours and other events related to direct seed systems are continually added to the Web site's "Coming Events."

Search Engine
A search engine has been installed which provides extensive key-word searches within the entire Web site.

Your Input Will Be Appreciated --- Your requests and suggestions will help expand this Web site to better serve NW growers and Ag support personnel in developing successful direct seed cropping systems in the region. Contact Roger Veseth by e-mail (rveseth@uidaho.edu), phone 208-885-6386 or Fax 208-885-7760.

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CUNNINGHAM AGRONOMY FARM–SERVING NW AGRICULTURE THROUGH DIRECT-SEED AND PRECISION AGRICULTURE TECHNOLOGIES

R. James Cook, David R. Huggins, Joseph P. Yenish

In 1998, a team of Washington State University and USDA-ARS scientists and engineers launched a long-term direct-seed cropping systems study on 140 acres of the WSU-owned Cunningham Agronomy Farm located about 5 miles NE of Pullman, WA. The team consists of faculty, graduate students and technicians from the Departments of Crop and Soil Sciences, Plant Pathology, Agricultural Economics, Biosystems Engineering, Center for Precision Agriculture Systems, Program in Statistics, and the USDA Agricultural Research Service in the CAHE and Department of Geology. The work on this farm is intended to help growers and the supporting-area infrastructure adjust to and profit from some of the greatest technological changes for Northwest agriculture since the introduction of mechanization early in the 20th century. The Washington Wheat Commission provided $120,000 as the start-up budget for the first three years 1998/99, 1999/00, and 2000/01.

The broad goals of the work on this new WSU agronomy farm are to:

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

- Develop the agronomics for alternate crops as components of more diverse crop rotations to better manage weeds, diseases, and crop residue while maintaining a strong emphasis on wheat and a balance between fall- and spring-sown crops;

- Obtain base data and understanding needed to model and predict carbon sequestration over a Palouse landscape in response to different crop rotations; and

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

Over the past 3 years, from early 1998 to early 2001, the team has converted this 140-acre farm into what promises to be scientifically the most comprehensive, field-scale cropping systems study in the United States if not the world. A 90-acre portion of this 140-acre field is already probably the most intensively mapped, sampled, and characterized 90 acres of land anywhere in the state of Washington if not the entire Northwest. Specifically, the team has:

- Acquired the equipment needed to farm the land, including, a prototype, 15-foot no-till drill manufactured by the Great Plains Co, a used 2-5-ton International truck with auger to transfer seed from the truck to the drill, a new 40-foot-wide McGregor-built sprayer, weather station, tank and trailer for hauling water to the farm, transfer pump for water and fertilizer solution, and a John Deere 95H combine;

- Developed detailed maps, including a digital elevation map and detailed physical map of aspect, elevation, and slope of the field, referenced by GPS (global positioning system) and remote sensing;

- Established a detailed baseline using a nonaligned grid of 369 GPS-referenced sites representing 90 of the 140 acres for soil characteristics, soil carbon storage, weed seed bank and populations of soilborne pathogens, and historical biomass production, yield and grain protein;

- Developed a close cooperative working relationship and coordination of research with the Palouse Conservation Field Station and Spillman Agronomy Farm that includes sharing of equipment;

- Developed and submitted a general plan for either the creation or purchase of a 5-acre site for facilities with a well and electricity needed to store equipment and for teaching and field research;

- Established the Cunningham Agronomy Farm as a WSU Service Center, entitling the collection of receipts for the sale of products from the farm;

- Appointed and met four times with a 12-member advisory committee consisting of growers, agribusiness representatives, an area environmental group representative, and two federal regulatory agencies ;

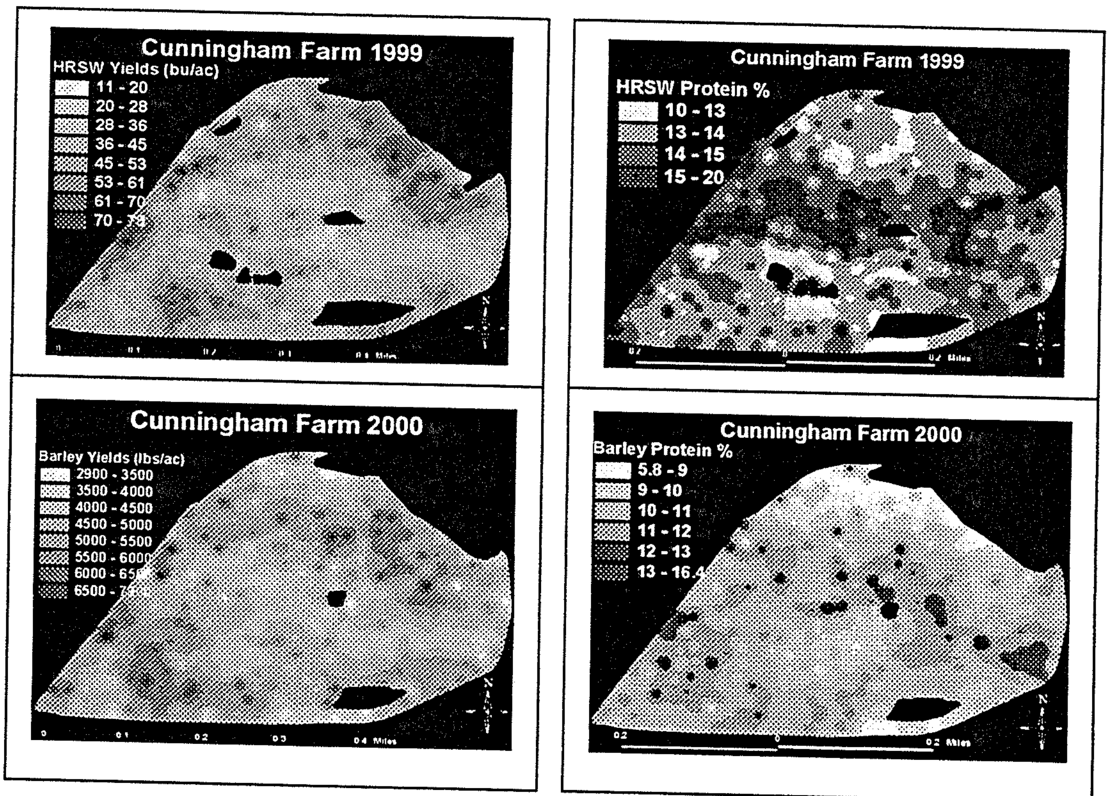
- Initiated a project on water quality using the herbicide Fargo as a monitoring tool.

- Produced two crops on the land, namely hard red spring wheat (WPB 926) in 1999 and spring barley (Baronesse) in 2000;

- Launched field-scale six-rotation cropping systems experiment in the fall of 2000 where each rotation includes spring wheat followed by winter wheat followed by one of six crops, namely winter barely, spring barley, winter canola, spring canola, winter peas, and spring peas. Small replicated variety trials are included within the corresponding fields of these crops.

Some early results:

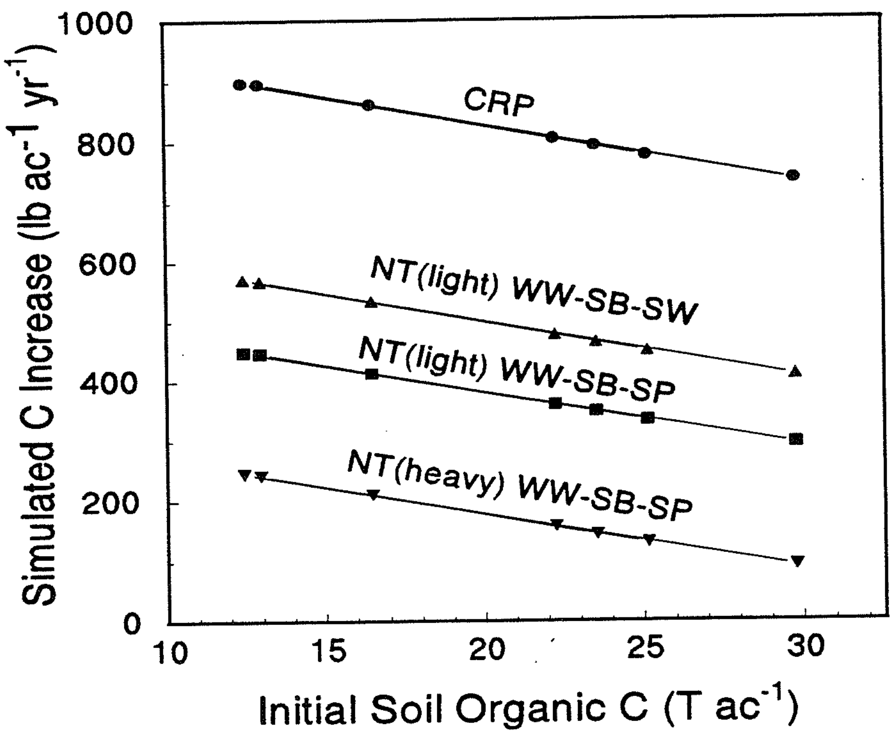
Yields and grain protein were determined by hand harvesting at all 369 GPS-referenced sites for both the hard red spring wheat in 1999 and the spring barley in 2000. For the hard red spring wheat, the yield averaged only 44 bu/A, with just under 14% protein, but the yields over the 90 intensively sampled acres ranged from a low of 20 to a high of 80 bu/ac and a low of 11 to a high of 18% protein. We found all combinations of high yield and high grain protein, low yield and high grain protein, high yield and low grain protein, and low yield and low grain protein. Likewise with the Baronesse spring barley the following year, the yield averaged about 4,700 lbs/A but varied across the landscape from a low of 2,500 lbs to a high of 6,200 lbs. Barley grain protein also varied considerably across the landscape ranging from 5.9 to 16.3%. Field patterns of barley grain protein were similar to those found with hard red spring wheat the previous year. These data suggest that site-specific field locations have very different capabilities for achieving cereal grain yield and quality goals. Therefore, suitability zones for different wheat (hard red, soft and hard white, club) or barley (feed, malting) classes could be established on a field basis as well as N management zones for obtaining greater N use efficiency.



Hard red spring wheat (WB926R) and spring barley (Baronesse) grain yield and protein percentage across 92 acre portion of the Cunningham Agronomy Farm.

Current and future research efforts are exploring soil (water, rooting depth, N cycling) crop (environmental stress, disease and other pests) and management factors that are causing field variability in grain yield and quality to devise practices that are more profitable, efficient and environmentally sound.

Soil carbon sequestration is another research focus. Management effects on soil carbon storage are being explored through direct soil measurements and carbon modeling using the CQESTR model developed by USDA-ARS scientist Ron Rickman. Early modeling efforts show that initial soil carbon levels and management practices (disturbance level, crop rotation) will greatly influence carbon sequestration. The following figure shows model simulated increases in soil carbon under Conservation Reserve Program land (CRP at high management level), no-tillage with low disturbance drill (NT light) *versus* a high disturbance drill (NT heavy) and rotations of winter wheat-spring barley-spring wheat compared to winter wheat-spring barley-spring pea.



Preliminary CQESTR simulations of crop rotation, no-till drill disturbance and initial soil carbon level effects on annual soil carbon increases.

In-kind support from area agribusinesses and other interest groups: To make this work useful to the widest possible group of stakeholders, while maximizing what can be accomplished with a limited budget, we have solicited help from agribusinesses, grower organizations, environmental groups, and government regulatory agencies to provide in-kind support for this work in return for regular and early access to results of this research, participation in the planning, and recognition by the WSU. We very much appreciate the responses provided as equipment, chemicals, seed, and in-kind services from the following area agribusinesses: BASF, Bayer, Columbia Grain, DuPont, Farm & Home Supply, Great Plains, McGregor Co., McKay Seeds, Monsanto Co., Pioneer Seeds, Syngenta, Western Plant Breeders, and Whitman County Grain Growers.

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LANDSCAPE MODELING OF THE CUNNINGHAM FARM

Mark Wardell, Bruce Frazier, Dave Huggins

Introduction

The Cunningham Farm, located approximately 5 miles north of Pullman, is a site used by the USDA-ARS and the Department of Crop and Soil Sciences (CSS) for direct seed and precision agriculture research. One of the goals of this research is to produce site-specific information about the Palouse landscape and use it to achieve crop production goals for the region. Detailed information on soil morphological, physical, and chemical properties, as well as the spatial patterns of those properties, will help assess the suitability and best management practices for a given field. Currently, the Cunningham Farm research group is developing a soil landscape database and performing digital terrain analysis to relate soil properties to the needs of site-specific management.

Soil Collection and Terrain Analysis

184 soil cores were collected in the fall seasons of 1998 and 1999 over 92 acres. A 5-foot Giddings probe mounted on a tracked vehicle was used to collect the soil cores. Detailed profile descriptions of each soil core were then made, and input to a spreadsheet for use in the digital terrain analysis of the Cunningham Farm landscape, as well as for use by other members of the research group. From these descriptions, and using ESRI's ArcView and ArcInfo GIS programs, we can display certain soil properties such as argillic (clay) layers or varying topsoil depths on the landscape (Figs. 1 & 2, respectively). Clay layers tend to have low fertility, restrict root growth, and promote lateral flow of water within the soil. Thus, agricultural producers and other land managers can see where problem areas are and where certain practices need to be modified.

Digital Elevation Model

Digital Elevation Models (DEMs) are useful in terrain analysis because they can be used in calculating attributes such as slope and aspect, and predicting areas of wetness on a landscape. Fig. 3 shows the results of a Wetness Index (WI) calculation for the Cunningham Farm.

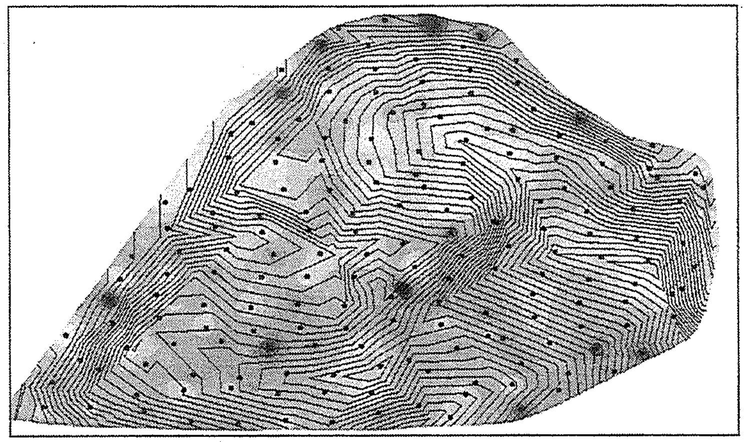

Figure 1 - Topsoil (A horizon) depths; Darker areas indicate deeper A horizons. Solid lines are elevation contours in meters, and points show soil core locations.

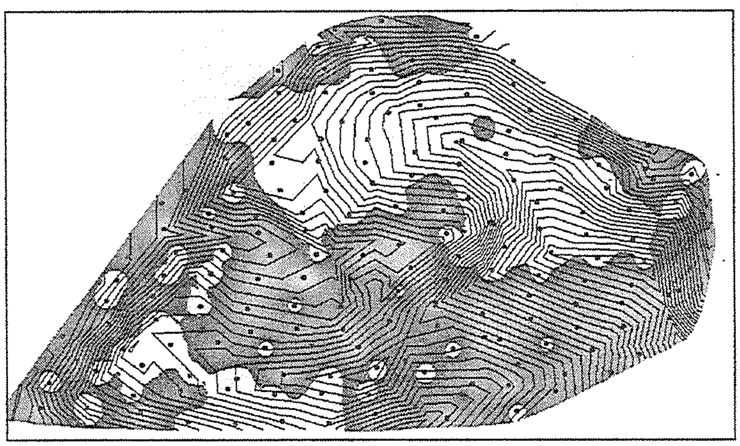

Figure 2 - Argillic horizon depths; White areas have no argillic horizon within 5 feet of the surface. Lighter areas within the shaded zones indicate shallower argillic horizons, and dark areas indicate deep argillic horizons.

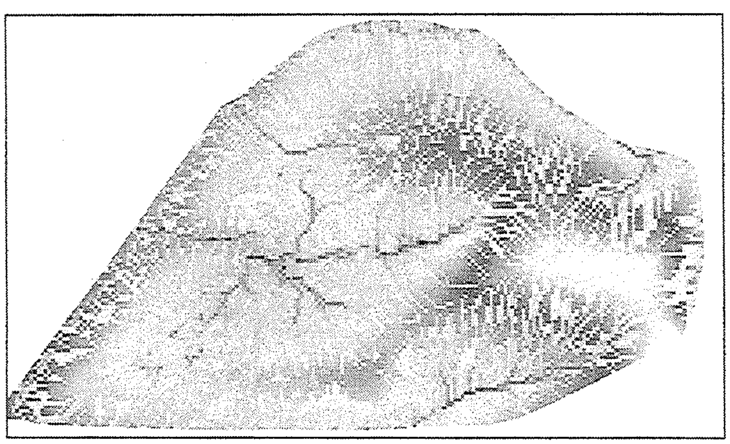

Figure 3 - Wetness Index overlying a 5-meter DEM; Darker cells in the drainage network indicate wetter soils. Areas without a drainage network represent convex knobs and ridges.

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

R. James Cook, Kim Campbell, 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 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 on the Palouse Conservation Field Station. Each site has been under direct seeding for several years and presumably has undergone the so-called "transition" phase.

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. Two different drills have been used, depending on the design of the test and the site. One drill is an 8-row cone seeder equipped with either shanks (for fall seeding) or Yetter coulters (for spring seeding) to place fertilizer below the seed in front of Acra-Plant openers, all on 12-inch spacing (drill similar to the McGregor one-pass drill). This drill is used to plant plots typically 8 rows wide and 24 feet long. The other drill is an air-seeder equipped with Anderson openers for simultaneous placement of seed above the fertilizer band in rows spaced 12 inches apart. This drill is used to test varieties in replicated drills strips 8 feet wide and 100 feet long, or longer. As the WSU Extension variety test program shifts more into direct seeding, our tests under direct seeding are shifting towards more use of drill strips planted with the air seeder but also limited to a more select group of varieties and advanced lines of the three wheat breeding programs.

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, 2 and 3). Furthermore, the highest-yielding varieties under direct seeding tend also to be the highest-yielding varieties under conventional seeding.

Spring wheat yields at the Colfax site were exceptional in 2000 (Table 3), especially considering that the plot site was in a field managed as continuous direct-seeded cereals for the past 9 years (no fallow and no broadleaf break crops; John and Cory Aeschliman farm). The yields on the Pullman site (Palouse Conservation Field Station) for 1998 (winter wheat), 1999, and 2000 (both spring wheat) represent the 17^{th}, 18^{th}, and 19^{th} consecutive years of continuous no-till at this site and the 13^{th}, 14^{th}, and 15^{th} wheat crops in these years. The winter wheat planted in this site in the fall of 1999 was sprayed out in February 2000 because of excessive volunteer spring wheat and then planted to spring wheat (yields shown in Table 3). 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 our small cone seeder to plant through the heavy residue. This has not been a problem for the air seeder and 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 4 gives a summary of the response of Madsen winter wheat to soil fumigation for the past 3 years at Bickleton. The yields of direct seeded winter wheat at Bickleton "dusted in" on recrop, at 35-40 bu/A, are similar to the proven average yields on this farm for winter wheat on fallow but are still only about 70% of the potential yield in this system. With seed treatments such as Dividend XL and Raxil XT, the yields of both spring and winter wheat have been shown to be 75-80% of the potential as revealed in experimental plots with fumigated soil

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

Variety	Palouse Conservation Field Station[a] 1999 (bu/A)	Palouse Conservation Field Station[a] 2000 (bu/A)	Spillman 1999 (bu/A)	Bickleton 1998 (bu/A)	Bickleton 1999 (bu/A)	Bickleton 2000[b] (bu/A)	Colfax 1998 (bu/A)	Colfax 1999 (bu/A)
Penawawa		50.6		18.3			45.8	
Edwall				20.7			46.3	
Pomerelle				14.8			37.4	
Centennial							48.1	
Vanna				18.4			37.9	
Alpowa	63.9	44.8	71.5	20.7	43.2	26.7	47.2	59.9
Wawawai		38.9	72.7	32.1		25.9	46.9	
Whitebird				15.5			47.1	
ID3775				16.9			50.1	
WPB926	67.5		50.4	29.4	35.3		55.4	47.4
Express				18.7			47.2	
Zak	67.2		72.4	32.9		29.7	52.4	58.0
Westbred 936				17.0			46.1	
Butte 86				21.6			45.9	
WA7802				20.8			52.2	
WA7824	66.7	46.9	66.6	29.8	39.2		55.4	56.0
WA7839						24.1		
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	62.3	45.3	65.2	21.8	36.2	26.6	46.7	51.7

[a] The years 1999 and 2000 at this site represent the 18th and 19th consecutive years of no-till and the 14th and 15th wheat crops in the past 19 years.
[b] Seeded as 100-foot-long drill strips, 8 feet wide, replicated four times. All other tests were seeded with small plot drill 8 rows wide and 24 feet long, replicated six times.

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

Variety	Colfax 1997 (bu/A)	Colfax 1998 (bu/A)	Colfax 1999 (bu/A)	Bickleton 1998 (bu/A)	Bickleton 1999 (bu/A)	Bickleton 2000[a] (bu/A)	Pullman 1998 (bu/A)
Madsen	72.5	78.6	50.0	38.3	42.5	34.0	82.2
Stephens		77.4	45.0	38.2	48.0		85.7
Estica						41.1	
Eltan	92.7	71.4	60.3	39.2	47.1	41.3	67.0
Moro				31.6			
Hiller	85.3		43.4	38.6	42.8	41.8	75.7
Coda			52.6		47.9	39.0	
Finley						40.2	
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	44.1	76.8
Rely		71.9	43.0	38.0	42.0	38.2	70.2
Rod		75.4	49.9	38.3	43.3	40.7	76.7
WA7834	73.6	59.0		33.1			62.7
WA7752		76.5		41.0			76.3
WA7871						38.0	
WA7786			45.7				
AWO95352						44.1	
Rohde		74.3		37.2			69.5
OR92054		73.6		37.7			76.6
Lewjain			52.6	36.0	43.5		66.1
Symphony						42.5	
VO95433						36.7	
VO95470						36.2	
Average	81.7	74.0	49.7	37.8	43.0	39.9	74.8

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

Table 3. Yields and grain protein of select varieties and advanced lines of spring wheat seeded directly into standing wheat stubble at the indicated locations for the year 2000. Both sites are long-term no-till.

Variety/ Advanced Line	Class	Palouse Conservation Field Station Yield (bu/A)	Palouse Conservation Field Station Protein (bu/A)	--------Colfax-------- Yield (bu/A)	--------Colfax-------- Protein (bu/A)
Alpowa	SWS	44.8	11.2		
Matt	Durum	42.8	13.7	69.7	12.5
Penewawa	SWS	50.6	11.1		
Wawawai	SWS	38.9	11.5		
Winsome	HWS	53.4	12.7	90.8	10.8
7824	HRS	46.9	13.7	82.7	12.5
7839	HRS	59.1	13.4	87.0	13.0
7850	SWS	47.1	11.8	84.7	11.0
7859	HRS	39.7	14.0	72.9	13.0
7860	HRS	48.9	13.7	75.5	12.8
7864	SWS	46.9	11.9	88.2	11.1
7867	SWS	49.7	11.1	87.5	10.6
7872	HRS	49.9	13.7	80.8	13.3
7874	HRS	56.3	13.3	81.8	13.0
7875	HRS	48.1	14.2	79.9	13.0
7877	SWS	47.5	12.2	89.3	11.2
7879	SWS	44.0	11.1	86.7	10.5
7883	SWS	48.5	11.3	86.6	10.7
7884	SWS	51.7	11.3	90.4	10.5
7885	SWS	50.5	11.5	88.9	10.9
7886	SWS	51.3	11.1	84.5	11.0
7887	SWS	45.4	11.2	84.5	10.8
7888	SWS	48.7	11.1	88.5	10.6
7889	SWS	53.4	11.2	88.3	10.8
7890	SWS	54.2	11.2	88.8	10.5
7891	HRS	47.7	13.4	87.6	12.0
7892	HRS	51.9	13.8	78.4	12.4
7893	HRS	49.8	13.4	78.3	12.5
7894	HRS	51.6	13.4	76.2	12.5
7895	HRS	49.8	14.3	79.9	13.1
7896	HRS	48.6	13.3	89.5	12.2
7897	HRS	63.0	13.4	80.6	13.4
7898	HRS	55.0	14.2	85.1	13.0

Each value is an average based on six replicates (Colfax) or four replicates (PCFS).

Table 4. Average yields of Madsen winter wheat in response to soil fumigation on the Steve Matsen farm near Bickleton, WA, with direct seeding (no-till) into standing wheat stubble (recrop).

Crop Year	Untreated (bu/A)	Fumigated (bu/A)
1997/1998	37.9	58.7
1998/1990	37.2	46.6
1999/2000	34.0	51.1
Average	36.4	52.1

NOTE: Each year, the wheat was dusted in mid October and consequently emerged over winter or in early spring, including under snow.

SPATIAL DISTRIBUTION OF RHIZOCTONIA ROOT ROT AND ITS EFFECT ON YIELD IN DIRECT-SEEDED BARLEY

Timothy Paulitz, Hao Zhang, and R. James Cook

Introduction

Rhizoctonia root rot and bare patch, caused by *R. solani* AG-8 and *R. oryzae*, is a common disease throughout the Pacific Northwest in wheat and barley production. These fungi attack the root system, killing seminal and crown roots, reducing the ability of plants to take up adequate water and nutrients. In the acute phase, bare patches several meters across can be seen in the field, but usually the disease causes a chronic unevenness of the stand and symptoms are only seen on the roots. This research asks two key questions

1) How is the pathogen distributed in chronically infected fields?

2) What is the relationship between the disease, the fungus, and barley yield?

These questions would be impossible to answer with normal field plot experiments. However, with a GPS system, multiple sites can be sampled on a whole farm, spatial maps can be drawn, and yields can be correlated with disease from the same sampled sites.

Methods and Materials

This research was conducted on the WSU Cunningham Farm. This farm is part of a cropping systems project designed for multidisciplinary whole-farm research, with a focus on no-till, direct-seeding. Located 7 miles north of Pullman, the farm has been direct-seeded to wheat and barley for the last three years. One-hundred GPS sites over a 90 acre parcel direct-seeded with spring barley were sampled in summer, 2000. In June, 15 plants were dug from each site, and rated for the percentage of seminal and crown roots showing symptoms of *Rhizoctonia*. In mid July, the same sites were sampled again and roots were placed on selective agar media in the lab to isolate, identify and quantify the *Rhizoctonia* fungi in the roots. At the end of the season, 2 m^2 sections at each site were hand harvested to determine yield. A geostatistical method called kriging was used to interpolate data between the measured GPS sites, and maps were prepared for each data set.

Results

Rhizoctonia disease levels were fairly low and no bare patches were visible on the farm. Averaged over all sites, 48% of the seminal roots showed symptoms (range 14-92%), but only 18% of the crown roots were diseased. At most sites, no *Rhizoctonia* was isolated from the roots, which may reflect the difficulty of isolation later in the season. When *Rhizoctonia* was isolated, only *R. oryzae* was recovered. At the "hottest spots", 5-16% of the roots were infected. *R. oryzae* has a higher temperature requirement than *R. solani* AG-8, and may be more prevalent later in the summer. Barley yields averaged 2500-6200 lbs/acre.

The distribution of diseased seminal roots over the 90-acre site is seen in Fig. 1b. The light areas of the map show the highest levels of disease. High disease levels were seen in the lower left corner of the parcel, which also corresponded to the area with the highest isolation of *Rhizoctonia* from the roots. A horizontal band of higher disease ran through the middle of the parcel (lighter area). This corresponded to areas of lower yield (Fig. 1a, dark areas). Conversely, lower disease (darker color) was seen in the upper right quadrant of Fig. 1b, which corresponded to higher yields in Fig. 1a (lighter color).

Fig. 2a and b show the correlations between yield and root disease or fungal colonization. At sites with low levels of crown root disease (Fig. 2a), there was no relationship between disease and yields. Some sites with low disease had high yields, and some had low yields. In this case, low yield could be due to other soil factors such as nutrients and slope aspect. However, sites with higher crown root disease tended to have lower yields. This same trend was seen with root infection as determined by isolating the fungus from the roots (Fig. 2b). At low levels of root infection, no effect on yield is seen, but as the levels of infection increased, yield decreased. Both regression models were statistically significant.

Take Home Messages...

- Distribution of diseased roots in the field is patchy. Certain areas have higher disease levels than others, even though there are no detectible differences visible above ground.

-the level of fungus in the root systems is even more patchy. We were unable to isolate *Rhizoctonia* from most sites in mid July, and only *R. oryzae* was isolated. *R. solani* AG-8 may be more prevalent or culturable in early spring, when soil temperatures are cooler.

-at low disease levels, *Rhizoctonia* has no effect on yield, but some reduction in yield (roughly 25%) was seen at sites with higher levels. This indicates the potential of this disease to reduce yields **even when above ground symptoms are not apparent in the field.**

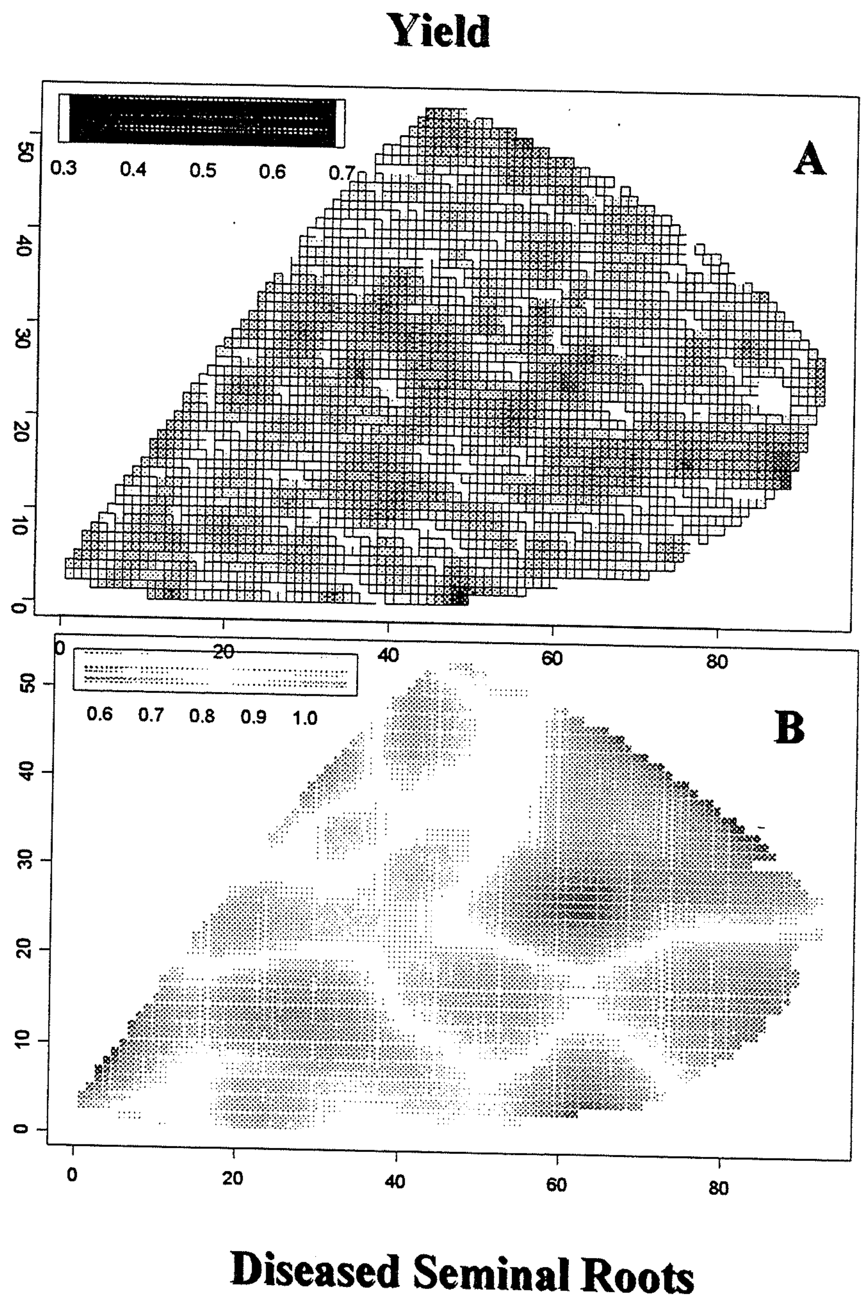

Figure 1. Spatial distribution of yield and Rhizoctonia root rot in a 90-acre parcel of direct-seeded barley, Cunningham Farm, 2000.

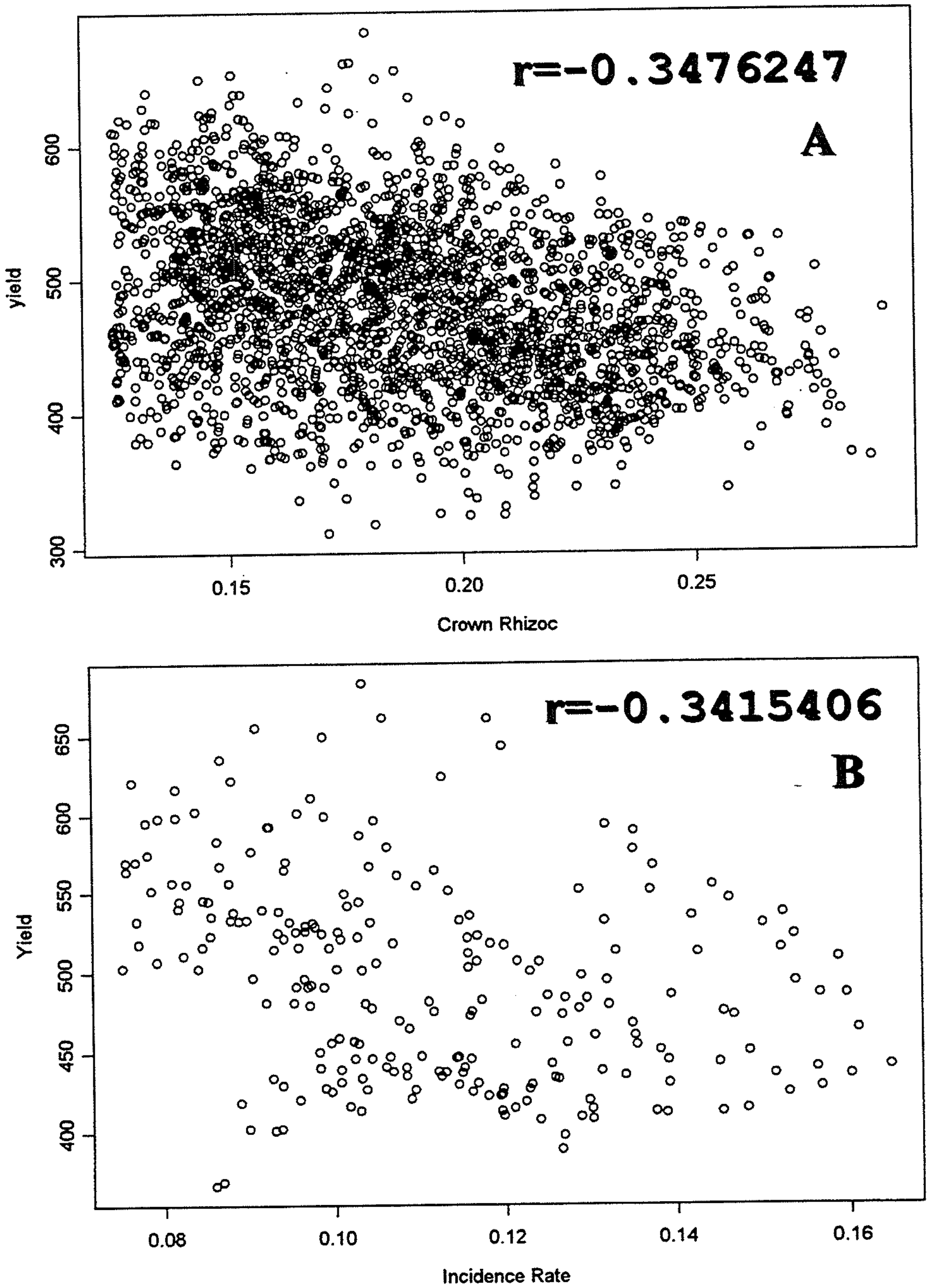

Figure 2. Correlation between yield and diseased crown roots (A) and roots infected by *Rhizoctonia* (B) in a 90-acre parcel of direct-seeded barley, Cunningham Farm, 2000.

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 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 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. In fact, for those growers that are planning to experiment with direct seeding for the first time, planting spring barley directly into standing stubble of any cereal is probably the best way to start into one of these systems. 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 greenhouse 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 seven years ago and now include sites near Ritzville, Colfax, and Pullman, representing the low- intermediate-, and high-precipitation areas, respectively. Prior to 2000, we also had test plots at Bickleton and Dusty, but these were discontinued starting in 2001 as the WSU variety testing program has expanded its work into direct- seed systems in these areas. 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 cereal stubble. 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 reasonably 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 or spring wheat or spring barley.

	-----Pullman[a>]-----		------------------Ritzville[b>] -------------------					-----Dusty[d>]-----		--Bickleton[c>]--		Colfax[e>]
Variety	1999 (lbs/A)	2000 (lbs/A)	1998 (lbs/A)	1999a (lbs/A)	1999b (lbs/A)	2000a (lbs/A)	2000b (lbs/A)	1998 (lbs/A)	1999 (lbs/A)	1998 (lbs/A)	1999 (lbs/A)	2000 (lbs/A)
Crest	3500	5800	2644					3079	1160	1961		
Harrington	3640	5060	2549		1960	2643	2560	2549	1660	1806	2580	5061
Baronesse	4400	6360	2899	2140	2100	2853	3046	3120	1600	2022	2920	6490
Meltan	4620		2571			2524	2657	2993	1500	1550		5515
Mentor		6020				2480	2663					6320
Camelot	3680	6240	2635		2140			3147	1400	1583		
Gallatin	3360	5720	2679	2120	2000	2567	2529	2679	1740	1748	2520	
WA 9792-90	5000											
WA9504-94		6500				2654	2839					
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	6060		2000	2100	2649	2780				2520	
Tena		5680					2516					
Average	4075	5938	2611	2073	2102	2624	2699	2860	1510	1708	2480	5846

[a>] Pullman 1999 □ Spillman Farm, into spring barley stubble; 2000 □ Cunningham Agronomy Farm, into spring wheat stubble
[b>] Ritzville 1999a and 2000a □ Direct-seeded into winter wheat stubble; 1999b and 2000b □ direct-seeded into spring barley stubble; all on Wellsandt Farms
[c>] Bickleton 1998 and 1999 □ Steve Matsen Farm, into winter wheat stubble
[d>] Dusty 1998-99, Bob Wigen Farm, into winter wheat stubble
[e>] Colfax 2000 □ Aeschliman farm, into winter wheat stubble

WHERE ARE DRYLAND CROPS PRODUCED IN THE WESTERN UNITED STATES?

William Schillinger[1], Stephen Guy[2], Robert Papendick[1], Paul Rasmussen[3], and Chris van Kessel[4]
Washington State Univ.[1], Univ. of Idaho[2], USDA-ARS Pendleton, OR[3], and Univ. of California[4]

The major dryland cropping regions in the Western United States are the inland Pacific Northwest situated in eastern and central Washington and the adjacent Idaho panhandle, and in eastern and north-central Oregon, and the intermountain region of southeastern Idaho, northern Utah, and western Montana. Elsewhere, limited dryland crop production is found in the foothills along the Central Valley of California, and except for small scattered areas is almost nil in Nevada and Arizona.

We define dryland cropping as that occurring in areas with 24 inches or less annual precipitation and without irrigation. These areas and their dryland crop acreages are shown in Table 1. Approximate land area devoted to dryland cropping in the Western USA is 10,800,000 acres (Table 1). Of this total area, 8.25 million acres are in the PNW, 2.12 million acres are in the intermountain region and 0.42 million acres are in California. Because of climatic variability, the Pacific Northwest is sub-divided into three average annual precipitation zones: i) low–less than 12 inches, ii) intermediate – 12 to 18 inches, and iii) high – 18 to 24 inches (Table 1).

Table 1. Land area devoted to dryland cropping in three regions of Western United States †

Region	State	Acres
1. Inland Pacific Northwest		
Low (less than 12 inches)	WA	3,021,000
	OR	825,000
Intermediate (12 to 18 inches)	WA	1,512,000
	OR	798,000
	ID	62,000
High (18 to 24 inches)	WA	944,000
	OR	163,000
	ID	924,000
2. Intermountain	ID	1,556,000
	UT	348,000
	MT	220,000
3. California	CA	422,000

Total dryland crop acres by state: Washington 5,477,000; Idaho 2,542,000; Oregon 1,786,000; California 422,000, Utah 348,000; Western Montana 220,000.

† Acreage estimates are those of the authors and should be referenced as such.

ANNUAL NO-TILL CROPPING SYSTEMS RESEARCH AT THE WSU DRYLAND RESEARCH STATION AT LIND

William Schillinger, Harry Schafer, Bruce Sauer, Keith Saxton, Ann Kennedy
Department of Crop and Soil Sciences and USDA-ARS
Washington State University

A 6-year study was initiated in 1998 to evaluate annual no-till cropping at the Washington State University Dryland Research Station at Lind. Annual precipitation averages 9.6 inches and the soil is a deep Shano silt loam. Cropping systems are (i) a 4-year safflower-oats-spring wheat-spring wheat rotation, (ii) a 2-year winter wheat-spring wheat rotation, and (iii) continuous spring wheat. The experimental design is a randomize block with four replications. The spring wheat cultivar is soft white 'Alpowa' and the winter wheat cultivar is soft white 'Eltan'. Individual plots are 500 ft long and all crops are sown with the Cross-slot drill. Measurements obtained each year include soil water use by each crop, weed populations, and grain yield. Safflower has provided stable yields (avg. 890 lbs/a) but depletes soil water to a much greater extent than does spring wheat (data not shown). In 2000, recrop winter wheat yielded 40 bu/a compared to 24 bu/a for recrop spring wheat. We have included the 2-year winter wheat - spring wheat rotation into the Lind study as well as the cropping systems research sites on the Ron Jirava farm in Adams County and the Doug Rowell farm in the Horse Heaven Hills. In addition to higher potential grain yield, recrop winter wheat is much more competitive against Russian thistle compared with recrop spring wheat. Our ability to control downy brome is, of course, a major factor in determining the feasibility of the continuous winter wheat-spring wheat rotation.

Table 1. Grain yield in three rotations at Lind: a 4 year safflower-oats-spring wheat-spring wheat rotation; a 2 year winter wheat-spring wheat rotation and; continuous spring wheat.

	Units	1998	1999	2000
Four year rotation				
Safflower	lb/acre	890	775	1005
Oats	ton/acre	1.23	0.46	0.78
1st year wheat	bu/acre	---	18	21 b‡
2nd year wheat	bu/acre	---	---	22 b
Two year rotation †				
Winter wheat	bu/acre	---	---	40 a
Spring wheat	bu/acre	---	---	24 b
Continuous wheat	bu/acre	28	21	24 b

† The winter wheat - spring wheat rotation was included beginning in the 2000 crop year.
‡ Within column means followed by a different letter show significant wheat grain yield differences at $P < 0.05$.

LONG-TERM ALTERNATIVE CROP ROTATIONS USING NO-TILL: THE FIRST FOUR YEARS IN ADAMS COUNTY

Personnel:

William Schillinger (PI), WSU research agronomist, Lind
Ron Jirava, grower, Adams county
R. James Cook, WSU endowed wheat chair and plant pathologist, Pullman
Doug Young, WSU agricultural economist, Pullman
Harry Schafer, WSU agricultural research technician, Lind
Ann Kennedy, USDA-ARS soil microbiologist, Pullman
Neil Christensen, OSU soil scientist, Corvallis
Ghana Giri, WSU graduate student, Pullman

Summary of Research Findings

We have completed four years of a planned eight-year study to compare annual alternative cropping systems using no-till. Treatments during the first four years were: (*i*) a 4-year safflower/yellow mustard/wheat/wheat rotation; (*ii*) a 2-year wheat/barley rotation, and (*iii*); continuous wheat. The 20-acre experiment site is located on the Ron Jirava farm near Ritzville. Rhizoctonia root rot bare patches in wheat and barley covered 5.4 and 8.4% of total plot area in Adams county in 1999 and 2000, respectively. Rhizoctonia infection was just as severe in safflower and yellow mustard as in cereals. Data from a nutrient study conducted at the Adams county site in 2000 overwhelmingly support the conclusion that micronutrient deficiencies are not a factor contributing to the appearance of rhizoctonia root rot. Russian thistle is the dominant weed. Because no labeled in-crop herbicides are available for safflower and yellow mustard, Russian thistle presents a formidable obstacle to successful production of these crops in low-rainfall dryland regions. Safflower and yellow mustard extract up to two inches more water from the soil profile than spring wheat. The water deficit after growing deep-rooted broadleaf crops may continue for several years after the rotation reverts back to spring wheat. In addition, soil water storage efficiency during the winter after safflower and yellow mustard is generally reduced compared with after wheat or barley. The 4-year grain yield average for annual no-till soft white spring wheat and barley is 43 bu/a and 1.37 t/a, respectively, thus there is wide-spread interest by growers in this study. New treatments have been added to the study beginning with the 2001 crop year.

Methods and Materials. This study was initiated in 1997. Precipitation averages 11.5 inches, elevation is 1850 ft asl, and the soil is a deep Ritzville silt loam. The plot design is a randomized complete block with four replications. During the first four years we tested 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. All phases of all rotations are sown each year. Fertilizer rate (nitrogen, phosphorous, and sulfur) is held constant in all plots and is based on soil test and soil moisture availability. Glyphosate was applied at 16 oz./acre generally three weeks before planting. All crops were planted with either a Flexicoil 6000 or Cross-slot no-till disc drill. 2000. Seeding rates are generally 70, 70, 30 and 8 lb/acre for wheat (Alpowa), barley (Baronesse), safflower, and yellow mustard, respectively.

Crop Yields: Grain yields from all crops during all years are shown in Table 1. Soft white spring wheat grain yield across treatments averaged 41 bu/a in 2000, which was slightly greater than average for the area. Second year wheat after broadleaf crops produced significantly less yield (38.1 bu/a) than wheat after barley. We suspect that these differences are due to less water available to the subsequent crops after growing broadleaf crops. However, there was no significant yield decline in first year wheat after broadleaf crops, indicating that a beneficial rotation affect may be occurring which might offset the greater soil water depletion with broadleaf crops. Spring barley produced 1.3 tons/a in 2000, which was good in comparison to neighboring fields. Safflower and yellow mustard yields in 2000 were below optimum in Adams county due to heavy infestation of Russian thistle. Yellow mustard has been successful in only one year in four (Table 1).

Table 1. Crop yields in three rotations on the Ron Jirava farm in Adams county: a 4-year safflower/yellow mustard/wheat/wheat rotation; a 2-year wheat/barley rotation and; continuous spring wheat.

	Units	1997	1998	1999	2000
Four year rotation	lb/acre				
Safflower	lb/acre	1420	720	1040	600
Yellow mustard	lb/acre	1430	340	110	490
1st year wheat	bu/acre	---	41.1†	26.7	39.7 ab
2nd year wheat	bu/acre	---	---	25.3	38.1 bc
Two year rotation					
Wheat	bu/acre	---	40.3	27.8	44.0 a
Barley	ton/acre	2.30	1.13	0.76	1.30
Continuous wheat	bu/acre	64.3	40.5	26.9	42.5 ab

† Wheat yields among treatments were not significantly different at the 5% probability level in 1998 nor in 1999. Within column wheat yield means in 2000 followed by different letters are significantly different at the 10% probability level.

Rhizoctonia Root Rot: Severe infection of rhizoctonia root rot occurred in wheat and barley at the Adams county site in 1999 and again in 2000. The clearly visible rhizoctonia patches were mapped with a global positioning unit (data not shown). Though cereal grain yields in Adams county were quite satisfactory in 2000, the percent of land area with rhizoctonia patches increased in all cereal treatments from 1999 to 2000 (Table 2).

We have been surprised to find the high incidence of rhizoctonia severity in the four-year rotation where wheat follows two years of broadleaf crops. A survey conducted in May 2000 by Richard Smiley, OSU plant pathologist, showed that root lesion nematodes were not present at the Adams county site and therefore these parasites are not associated with the stunted plant growth within the patches. There were no significant differences in area infected by rhizoctonia in 2000 when all treatments were analyzed together. However, when the wheat treatments were analyzed separately, continuous wheat had significantly ($P = 0.02$) more rhizoctonia than either wheat after barley or first year wheat after broadleaf crops (Table 2).

Table 2. Percent land area in each treatment with rhizoctonia root rot patches at the Adams county site in 1999 and 2000 as measured by a global positioning system.

Crop Rotation	Percent of plot area with Rhizoctonia patches	
	1999	2000
Four year rotation		
Safflower	---†	7.3
Yellow mustard	---	11.1
1st year wheat	3.4	4.5 b‡
2nd year wheat	6.6	9.2 ab
Two year rotation		
Wheat	3.2	5.8 b
Barley	7.3	9.1
Continuous wheat	6.5	11.9 a

† Area infected with rhizoctonia patches was not measured in safflower or yellow mustard in 1999.
‡ Within-column rhizoctonia infection values in wheat followed by a different letter are significantly different at the 5% probability level. There were no significant differences in rhizoctonia when all treatments were analyzed together.

Rhizoctonia-Zinc Association Study: In 2000 we superimposed experiments in the cropping systems plots to study the possible association of zinc with rhizoctonia disease. The objective of this study was to determine whether application of zinc (Zn) fertilizer would reduce the incidence or severity of rhizoctonia root rot bare patch. Laboratory analyses revealed only minor differences between soil samples collected in and out of rhizoctonia root rot bare patches (data not shown). Nutrient concentrations in plants were all within the sufficiency range reported for small grains. Concentrations in healthy plants were not significantly affected by Zn fertilizer application at planting. In contrast, Mn, Zn and B concentrations were significantly higher in stunted plants from bare patch areas as compared to healthy plants. Stunted plants tended to have lower K and higher N concentrations than did healthy plants. Higher concentrations of Mn, Zn, B and N are probably a "concentration effect" related to stunting of plants by rhizoctonia root rot. The tendency for lower K concentration in stunted plants may be a consequence of reduced root growth.

The soil test for Zn indicated that wheat was highly unlikely to respond to Zn fertilizer application. An adequate supply of Zn for wheat was confirmed by Zn concentrations in plant tissue and by the absence of a visual response to Zn fertilizer applied in drill strips through each replicated treatment in all three crop rotations. Besides having no effect on the growth and nutrient concentration of healthy plants, Zn application had no visual impact on the incidence or severity of rhizoctonia root rot bare patches. These data and visual observations overwhelmingly support the conclusion that micronutrient deficiencies are not a factor contributing to the appearance of rhizoctonia root rot in the cropping systems study at the Ron Jirava farm.

New Directions: The long-term study at the Jirava farm has been modified beginning in the fall of 2000 (2001 crop year). The 500 ft x 60 ft plots have been split (now 500 ft x 30 ft) to include a new set of treatments. These are:

1. A four-year winter wheat - winter wheat - spring wheat - spring wheat rotation†.
2. A four-year winter wheat - spring barley - broadleaf - spring wheat rotation.
3. A two-year spring wheat -spring barley rotation.
4. A two-year hard white spring wheat - spring barley rotation.
5. Continuous soft white spring wheat.
6. Continuous hard white spring wheat

† Wheat is soft white unless otherwise indicated. All phases of each rotation appear each year and there are four replications (total of 56 plots).

NO-TILL SEEDING INTO STANDING IRRIGATED STUBBLE INSTEAD OF BURNING

Personnel:
William Schillinger (PI), WSU research agronomist, Lind
Harry Schafer, WSU research technician, Lind
Bruce Sauer, WSU farm manager, Lind
Ann Kennedy, USDA-ARS soil microbiologist, Pullman
Doug Young, WSU agricultural economist, Pullman
Don Wysocki, OSU extension soil scientist, Pendleton
Tim Paulitz, USDA-ARS plant pathologist, Pullman

Grower Advisors: Neil Fink, Clark Kagele, Keith Schafer, Jeff Schibel, and Gary Schell. These growers are deep-well irrigators in east-central Washington.

Abstract of Research Findings

Many deep-well irrigators in east-central Washington practice a continuous winter wheat rotation (i.e., grow winter wheat on the same field every year). Irrigated wheat grain yields range from 100-to 140-bushels per acre with residue production of 10,000 pounds or more per acre. After grain harvest in August, the traditional practice is to burn the stubble and invert the surface soil with moldboard plow tillage in preparation for sowing in September. Generally, growers feel they need to burn their fields because high residue levels hamper sowing. Alternatives to field burning are needed to reduce smoke emissions and maintain air quality. An irrigated cropping systems research project was launched in August 1999 at the Washington State University Dryland Research Station at Lind. A 3-year no-till crop rotation of winter wheat - winter canola - spring barley is grown under three stubble management methods. These stubble management methods are sowing crops: *i*) directly into standing stubble, *ii*) after mechanical removal of stubble (i.e., after swathing and bailing), and *iii*) after burning of stubble. A check treatment of continuous annual winter wheat sown after stubble burning + moldboard plowing is also included.

Research Objectives

The objective of this long-term (6-year) project is to determine the feasibility of direct seeding into high levels of residue as a substitute for burning in irrigated cropping systems. Specific objectives are to:

1. Test a 3-year crop rotation of winter wheat - winter canola - spring barley. All crops will be sown with a Cross-slot no-till drill into standing stubble, after mechanical removal of stubble, and after burning the stubble. An additional treatment of annual winter wheat sown after stubble burning + moldboard plowing will be included as a check.

2. Evaluate and develop effective techniques for sowing crops into heavy surface stubble using no-till methods.

3. Document cumulative effects of a diverse no-till crop rotation under three stubble management practices on soil physical and biological properties, water use efficiency, diseases, weed ecology, and farm economics. Compare these effects to those under the check treatment (i.e., continuous winter wheat after stubble burning + moldboard plowing).

4. Promote and extend research results to growers, agricultural support personnel, and scientists.

Methods and Materials

The experimental design is a split-split plot with four replications. Each portion of the 3-year no-till crop rotation in each stubble management method will be sown each year. Thus there are 40 plots (3 crops x 3 stubble management practices + the check continuous winter wheat x 4 replications). The experiment covers 10 acres.

All plots are sown with an ultra-low disturbance "Cross-slot" drill which delivers seed and liquid fertilizer in one pass through the field. We have achieved excellent stands and grain yields seeding into 6,000 pounds of stubble with the Cross-slot drill and feel irrigated wheat stubble will not present a problem as long as combine cutting height is about 12 inches and the straw and chaff are spread evenly. We expect that the diverse 3-year rotation will allow effective control of downy brome.

In the 3-year rotation, irrigation water will be applied in late August into standing stubble, after burning of stubble, and after mechanical removal of stubble (see calendar of operations). The burn + moldboard plow annual winter wheat check plots will be prepared by first burning all above-ground residue, irrigating, completely inverting the top 5 inches of soil by moldboard plow, packing the soil surface, and sowing with the Cross-slot drill. No-till plots will receive only irrigation prior to sowing. We will use the Cross-slot drill to seed all crops in all treatments (except winter canola which will sometimes be broadcast, see project schedule), which eliminates a source of variability and will allow us to more precisely determine residue effects in this experiment.

Irrigation water is supplied from a deep well at the research station. Hand-line irrigation sprinklers are used. All plots receive 6 inches of water in the fall and an additional 9 inches of water (in 3 sets) during the spring.

The research is envisioned for two cycles of the 3-year crop rotation (i.e., six years total). The general annual calendar of field operations is as follows:

Aug: -Broadcast winter canola seed (8 lbs/a) before winter wheat harvest in standing stubble and mechanical removal from plots.
-Mechanically remove stubble by swathing and bailing in 3-year rotation.
-Burn stubble in 3-year rotation.
-Burn stubble in the annual winter wheat plots.

Sep: -Broadcast winter canola (8 lbs/a) in burned 3-year rotation.
-Broadcast dry fertilizer (N+P+S) in all winter canola plots.
-Irrigate 6 inches all plots (including standing stubble in 3-year rotation).
-Moldboard plow and pack conventional continuous winter wheat plots.
-Apply post-harvest herbicide (glyphosate @ 22 oz./acre) to no-till plots if needed.

Oct: -Seed (100 lbs/a) and apply liquid fertilize (N+P+S) to all winter wheat plots in one pass using the Cross-slot drill.
-Apply grass herbicide (Assure II @ 8 oz/a) to winter canola plots.

Apr: -Sow and fertilize spring barley in 3-year rotation with the Cross-slot drill.
-Top dress winter wheat and winter canola with granular nitrogen.
-Irrigate 6 inches all plots.
-Apply in-crop broadleaf herbicide in winter wheat.

May: -Apply in-crop broadleaf herbicide in spring barley.
-Irrigate 6 inches in winter wheat and spring barley.

Jun: -Irrigate 6 inches in winter wheat and spring barley.

Jul: -Harvest winter canola.

Aug: -Harvest winter wheat and spring barley.
-Cycle begins again.

Results and Discussion

This project is just underway. Comparisons among stubble management systems with the 3-year rotation as well as with the traditionally-grown annual winter wheat will be made. Measurement of soil water relations, weed dynamics, grain yield, as well as management and all field operations, will be handled by Schillinger, Sauer, and Schafer. Soil biological changes which occur over time among treatments will be assessed by Kennedy. Paulitz will monitor and measure plant diseases. An economic analysis of the 3-year rotation vs. annual winter wheat and among residue management treatments will be conducted by Young.

It is envisioned that the project will provide irrigated growers in east-central Washington new information on the feasibility of a diverse 3-year crop rotation with different stubble management practices. Expected outcomes are development of effective new strategies for no-till sowing into heavy surface stubble. This will include documentation of changes across cropping systems and stubble management practices on: 1) soil quality parameters such as organic carbon, microbial biomass, aggregate stability, etc.; 2) an economic analysis of cropping practices; 3) the extent of soil-borne disease pressure and; 4) the long-term agronomic feasibility of intensive irrigated cropping without burning or tillage.

PNW DIRECT SEED CASE STUDY SERIES COMPLETED

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,** USDA-NRCS Resource Conservationist; **Don Wysocki,** OSU Extension Soils Specialist

A series of 16 grower case study publications on direct seeding in the Inland Northwest was completed in January 2001. It is a new series of Pacific Northwest Extension bulletins that is also available on the Internet. These 8-page, full-color case studies were developed through grants from the Western SARE (Sustainable Agriculture, Research and Educations) and PNW STEEP (Solutions To Environmental and Economic Problems) programs.

Why Direct Seeding?

Direct seed farming systems offer unique environmental and economic win-win opportunities for growers and the public. There is a rapidly growing movement towards direct seeding and more intensive cropping systems across North America and around the world. These changes are being driven by a number of factors including: 1) the need to reduce production costs and improve profitability to compete in today's global market; 2) increased awareness of soil quality and productivity benefits of direct seeding and detriments of intensive tillage; 3) increased grower and public concern about soil loss by water and wind erosion, and their environmental impacts; 4) increased yield potential with improved water conservation, 5) advances in direct seed equipment and management technologies.

Many of our global competitors in the crop commodity markets are quickly making the transition to direct seed systems. For example, Western Australia, the Canadian Prairie Provinces, Argentina and Brazil currently have 25% to over 60% of their cropland in direct seeding -- over 60 million acres. Although only about 6% of all PNW cropland (~650,000 acres) is under direct seed systems, it is increasing dramatically in response to this international competition in production efficiency and access to improved management technologies and equipment.

Why a NW Direct Seed Case Study Series?

Many established direct seed growers in the Northwest 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 provides the opportunity for a large number of grower and Ag support personnel -- anyone interested in direct seeding -- to learn from these growers' experiences across 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; 5) Advice for growers new to direct seeding; and 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 also utilize a variety of equipment and cropping systems.

Who is Featured in the Case Studies?
The following is a listing of the PNW Extension Case Study Series on Direct Seeding in the Inland Northwest. They are grouped under low, intermediate and high precipitation zones.

Low Rainfall (7- to 12-inches annual precipitation)
PNW514 John Rea, Touchet, WA
PNW528 Ron Jirava, Ritzville, WA
PNW531 Frank Mader and Tim Rust, Echo, OR
PNW540 Bill Jepsen, Heppner, OR

Intermediate Rainfall (13- to 19-inches annual precipitation)
PNW515 John and Cory Aeschliman, Colfax, WA
PNW524 Jack, Mike and Jeremy Ensley, Colfax, WA
PNW523 Mike Sr. and Mike Jr. Thomas, Prescott, WA
PNW526 Tim, Kevin, and Kurt Melville, Enterprise, OR
PNW521 Paul Williams, Davenport, WA

High Rainfall (20- to 26-inches annual precipitation)
PNW516 Frank Lange, Garfield, WA
PNW527 Pat Barker and Steve Shoun, Dayton, WA
PNW522 Nathan and Steve Riggers, Nezperce, ID
PNW529 Wayne Jensen, Genesee, ID
PNW530 Art Schultheis, Colton, WA
PNW541 David Mosman, Craigmont, ID
PNW542 Russ Zenner, Genesee, ID

Accessing Print and Web Copies
Print copies are available free. They can be ordered through your local Cooperative Extension office or directly from the extension publication offices at the University of Idaho (208) 885-7982, Oregon State University (541) 737-2513 and Washington State University (800) 723-1763.

The publications can also be accessed through the PNW Conservation Tillage Systems Web site (http://pnwsteep.wsu.edu) -- click on Direct Seed Case Studies for viewing, printing or downloading in PDF (Adobe Acrobat) format, just as they appear in printed form. The first item on Case Study Series Web page is a "Series Overview," which briefly describes the format of the publications, and identifies the growers, farm locations, precipitation zones and common crop rotations. A print copy of the Series Overview can be requested from Roger Veseth, WSU/UI Extension Conservation Tillage Specialist, P.S.E.S. Dept., University of Idaho, Moscow, ID 83844-2339, phone 208-885-6386, Fax 885-7760, or e-mail <rveseth@uiaho.edu>.

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NORTHWEST CROPS PROJECT / SPOKANE COUNTY DIRECT SEEDING PROJECT

Dennis Pittmann and Diana Roberts

Farmers across eastern Washington are becoming enthusiastic about the potential of direct seed cropping systems to improve their farm profitability by reducing input costs and by conserving soil and water. WSU is involved in a number of on-farm research and demonstration projects to help growers make successful transitions to direct seeding systems.

Diana Roberts, an agronomist with WSU Cooperative Extension, was the recipient of a grant award from the USDA-SARE program. This grant will help fund the Northwest Crop Project in Whitman County and the Spokane County Direct Seeding Project in that county. After two unsuccessful attempts at grants, it was decided to combine the two projects and seek funding that could help out the projects in both counties.

The final link to the projects was completed in March, when WSU Cooperative Extension hired Dennis Pittmann for the Agricultural Research Technician position that was opened by the grant. Dennis was born and raised in Oakesdale, farming there 33 years, with many years of personal experience with direct seeding. He will be the Coordinator for both projects – laying out plots, collecting data from all sites, and helping the growers involved with seeding and harvesting of plots.

The purpose of the Northwest Crops Project is to expand the knowledge and experience producers need to manage alternative crops in cereal-based rotations under direct seeding. The goals are less erosion, less field burning, and economic stability in an era of volatile markets. 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 or 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 first three years. All seeding is done without tillage and no crop residue is removed.

The participating growers are Tracy Ericksen-St.John, Steve Swannick-Lamont, Dan and Steve Moore-Dusty, Randy Repp-Dusty, John and Cory Aescliman-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.

The Spokane County Direct Seed Project as growers in the annual cropping region (18-22 inches precipitation) have identified residue management as a primary challenge to successfully adopting direct seeding. Seeding through heavy residue can be tough in the fall, and especially in the spring when thick winter wheat straw tends to keep the soil cold and wet.

The Spokane County growers participating in the project decided to identify specific questions they wanted answered, and design their own trials to solve them. Not surprisingly, most of the questions relate to residue management. Growers are:

1. Larry Tee (Latah) is comparing different stubble heights for fall direct seeding, working on the theory that one should not have seeding problems if the standing stubble is shorter than one's drill row width.
2. David Ostheller (Fairfield) has four residue management treatments on winter wheat stubble to prepare for spring direct seeding: 1) mowing, 2) fall harrowing, 3) fall chisel rip plus spring harrowing, and 4) standing stubble.
3. Glenn and Bryan Dobbins (Four Lakes) are testing a commercial residue digester called Biocat. The product is not a microbial solution, but a nutrient mix that stimulates the growth of microbes found naturally in the soil. They apply Biocat to winter wheat residue following harvest, and will look at how it affects stand establishment and yield of direct seeded fall and spring crops.
4. Randy and Jeff Emtman (Rockford) have been successful at taking out bluegrass stands by direct seeding oats into them. However, they haven't always been able to achieve an acceptable test weight on the oats, so they are looking at a fall fertilizer regime that should enable them to do this while allowing them flexibility to keep the grass stand in if it looks good in the spring.
5. Paul and Jake Gross (Deep Creek) want to test a late fall rotary subsoil treatment for its potential to improve water infiltration into the soil and boost crop yields under direct seeding.

Each trial was set up on replicated on-farm testing strips last fall, so 2001 will be the first season of the project. Soil and residue samples have been taken, winter wheat stands have been counted in the appropriate plots. Each grower will repeat his trial for two years so we can develop a good picture of how the treatments work over different seasons.

DO FARMERS WHO ADOPT MULTIPLE WIND EROSION CONTROL PRACTICES DIFFER FROM THEIR NEIGHBORS?

B. M. Upadhyay, D. L. Young, and H.H. Wang
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Wind erosion of soil has been a persistent problem in the 10-15 inch precipitation zone of eastern Washington. The dominant winter wheat/fallow system with conventional tillage leaves the soil vulnerable for substantial portions of the crop cycle. Long-term productivity losses, crop damage and health hazards due to air borne soil particles are important issues. Cleaning costs and traffic accidents due to dust storms have also caused concern to area residents. In response to the wind erosion problem, three key wind erosion control practices--no-till farming, wind strips and continuous spring cropping--are being adopted by some farmers in the 10-15 inch precipitation zone of eastern Washington.

Most prior agricultural technology adoption studies have defined "adopters" as the adopters of a single practice and "non-adopters" as all other farmers. Definition matters because it relates to the degree of innovativeness and ultimately to the amount of soil saved. The objective of this study was to test statistically whether farm and farmer characteristics differ more between adopters and non-adopters of conservation practices when 1) adopters are defined as those who adopt multiple practices as opposed to those who adopt a single conservation practice and 2) non-adopters are defined as adopters of zero conservation practices as opposed to all other farmers.

Data and Estimation

Data were generated through a telephone survey conducted in 1997 of a random sample of 266 dryland farmers from 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).* These farmers represented a 59% response rate. Fig. 1 describes the combination of single and multiple wind erosion control practices used by the sample farmers. Table 1 reports the number of observations, mean and standard deviation of variables in the study.

Methodology

Differences in means and frequencies of farm and farmer characteristics between single practice adopters and multiple practice adopters were statistically tested using T-tests and Chi-square test respectively. Logistic regression, an appropriate analytical tool to deal with a dichotomous choice variable (adopt and not adopt), was used for comparing the association of adoption with farm and farmer characteristics for different adoption definitions.

Six types of binary adoption variables were included in this study: (a) single practice adoption (SINGLE), (b) multiple practice adoption (MULTIPLE), (c) - (f) no-till (NOTILL) and continuous spring cropping (CONTSP) adoption contrasted with zero practice adopters (_ZERO) and the rest of the sample farmers (_REST). Seven farm and farmer characteristics were included in the study. These were the farmer's knowledge of a regional wind erosion educational program (KNOWPM10), index of the farmer's perceived problems with wind erosion (EROSPROB), farm size (SIZE), percentage of rented land (PCTRENTED), age of the farmer (AGE), level of education of the farmer (EDUC) and off-farm income of the farm household (OFF-FARM).

Results

Table 2 evaluates the statistical difference in means of farm and farmer characteristics between adopters and non-adopters when adopters are defined as single practice adopters and multiple practice adopters. There were no statistically significant differences between the characteristics of single practice adopters and zero practice adopters. Only SIZE approached significance with a 0.13 probability. In contrast, both SIZE and EDUC statistically differed at the 0.04 and 0.10 level between multiple practice and zero practice adopters. The significance of SIZE at the 0.04 probability level might indicate greater financial resources among multiple adopters in this arid study region where farm size varied greatly. Greater EDUC might also facilitate information acquisition and use. While the other variables showed no significant differences between the two groups, the probability of type I error is lower for multiple practice adopters for all but EROSPROB.

Table 3 reports results of four Logit regression models. In all four models KNOWPM10, SIZE, OFF-FARM and EDUC were positively related to adoption. The two models defining non-adopters as zero practice adopter displayed superior overall equation significance levels. KNOWPM10 and SIZE showed the most consistent statistical significance at 0.05, 0.10, 0.15 levels. Size of farm is beyond the control of conservation advocates, but it can be used as a targeting criterion for new conservation technologies.

Conclusions

This study suggests defining non-adopters as zero practice adopters to sharpen the distinction between these groups. This study also suggests that early adopters of wind erosion control practices may have larger farms, and that education promotes adoption of these practices. Adopters were also found to be more aware of a local wind erosion control educational program. However, there will be many exceptions to the patterns observed in this study as the level of statistical significance was not particularly strong for many differences.

Knowledge of the attributes associated with innovative multiple practice adopters may permit soil conservation policymakers and field staff to target educational programs more accurately during the early stages of technology dissemination.

Table 1. Variables in Wind Erosion Control Practices Adoption Models

Variable *	Description	N	Mean	S.D.
NOTILL_REST	1=adopt, 0=otherwise	266	0.20	0.40
NOTILL_ZERO	1=adopt, 0=zero practices	215	0.25	0.43
CONTSP_REST	1=adopt, 0=otherwise	266	0.26	0.44
CONTSP_ZERO	1=adopt, 0=zero practices	230	0.3	0.46
SINGLE	1=adopt, 0=zero practices	229	0.3	0.46
MULTIPLE	1=adopt, 0=zero practices	198	0.19	0.39
KNOWPM10	0=not heard of,...,3=very knowledgeable.	266	1.32	0.97
EROSPROB	0=no,...,3=more than 5 problems	266	1.14	0.89
SIZE	Acres	266	3,263	2,593
PCTRENTED	Percentage	266	23.76	30.53
OFF-FARM	1= mostly from farm,...,3=mostly off-farm	266	1.24	0.53
EDUC	0=within secondary,...,2=college Graduate	266	1.04	0.76
AGE	Years	266	53	13

* Suffix REST and ZERO in the variable name denotes adopters are contrasted with rest of the farmer sample and zero practice adopters, respectively.

Table 2. Comparing Single and Multiple Practice Adopters to Zero Practice Adopters on the Basis of Probability of Type I error

Variables	Tests	SINGLE (N=229)		MULTIPLE (N=198)	
		Pr. Error	Direction	Pr. Error	Direction
SIZE	T-test	0.13	+	0.04	+
PCTRENTED	T-test	0.92	+	0.56	+
AGE	T-test	0.74	-	0.54	-
KNOWPM10	chi-sq.test	0.48	+	0.21	+
EROSPROB	chi-sq.test	0.26	+	0.44	+
OFF-FARM	chi-sq.test	0.98	-	0.91	+
EDUC	chi-sq.test	0.45	+	0.10	+

Table 3. Comparison of Regression Coefficient's Significance Levels When Non-adopters is Defined as All Other Farmers versus Zero Practice Adopters.

Variables	NOTILL_REST	NOTILL_ZERO	CONTSP_REST	CONTSP_ZERO
KNOWPM10	(0.058)	(0.069)	(0.136)	(0.137)
EROSPROB	-(0.468)	-(0.345)	-(0.424)	-(0.431)
SIZE	(0.006)	(0.005)	(0.124)	(0.047)
PCTRENTED	-(0.839)	-(0.780)	-(0.653)	-(0.579)
OFF-FARM	(0.712)	(0.566)	(0.353)	(0.428)
EDUC	(0.261)	(0.198)	(0.288)	(0.289)
AGE	(0.584)	(0.689)	-(0.348)	-(0.494)
CONSTANT	-(0.005)	-(0.013)	-(0.148)	-(0.152)
Model Signif.	(0.041)	(0.029)	(0.237)	(0.169)

ECONOMIC RESULTS FOR PHASE I OF RALSTON PROJECT, 1996-2000

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Introduction and Methods

The purpose of this research has been to assess the profitability of three new conservation tillage spring cropping systems and a traditional winter wheat-fallow system which have been tested at Ralston. This report contains the final economic analysis of the five-year Phase One of the Integrated Spring Cropping trials at Ralston in Adams County. All cost and revenue figures are on a per rotational acre basis; for example, for winter wheat-summer fallow, costs and revenues are computed for one half acre of winter wheat and one half acre of fallow. This correctly portrays the average return per acre per year of a grower who has one half of the farm in fallow and one half in winter wheat.

The grain prices used are five-year marketing year averages with long run average adjustments for protein content for hard red spring wheat. Government transition, supplemental, and loan deficiency payments--which were substantial in 1998-2000--are not included in the net revenue results in Table 2. Including government payments would not influence the ranking of the experimental systems as these decoupled payments are not related to cropping system.

Costs are based on the actual sequence of operations conducted on the research plots, but assume typical farm-scale machinery for the region. Fertilizer, herbicide, seed and other input rates are 1996 through 2000 average rates used in the experiment for each crop and rotation. Grain yields from the experiment were averaged over the five years (Table 1).

The experimental trials were initiated in August 1995 on a farm near Ralston in Adams County in a 11.5 inch annual rainfall zone. The main trials at the Ralston site evaluate four crop rotation systems: a) soft white winter wheat alternated with conventional/minimum tillage fallow (SWWW/fallow); b) no-till soft white spring wheat/chemical fallow (SWSW/fallow); c) continuous no-till hard red spring wheat (HRSW); and d) no-till hard red spring wheat/no-till spring barley (HRSW/SB). Above average precipitation patterns during the first three years of this study were relatively favorable to both spring and winter wheat yields.

Ralston Profitability Results

Table 2 reports net returns over total costs and over variable costs for each cropping system. Average net returns over total costs in Table 2 are negative for all four systems, but this profit measure assumes a normal market return for all resources including owned land, equipment investment, and the farmers' unpaid labor. Many farmers may be willing to accept less than market returns for land or labor from crop production because they perceive other returns from farming such as potential long run land value appreciation and possible lifestyle advantages. Grain farmers have also received substantial government payments during 1998-2000 which are not included here. Table

2 also presents net returns over variable costs, which includes the usual cash costs for seed, fuel, fertilizer, chemicals, machinery repair, and also includes a wage for the farmer's labor. It excludes the fixed costs for equipment, land costs, and overhead. Net returns over total costs is a better long run measure of profitability because in the long run equipment must be replaced, whereas net returns over variable costs is often a suitable short run measure.

The traditional SWWW/fallow system dominated in 1996-2000 average profitability at Ralston. Returns over variable costs averaged $43.77 and returns over total costs averaged -$12.71 (Table 2). Winter wheat after fallow has yielded exceptionally well for the region, averaging 69 bu/ac (Table 1). SWWW/fallow enjoyed relatively low production costs (Table 2) which also contributed to its profit advantage. No-till HRSW/SB ranked second in terms of net returns over variable costs at $16.76 and third in net returns over total costs at -$42.73 per acre. Continuous No-till HRSW ranked third at $7.78 in returns over variable costs per acre, but ranked fourth in returns over total costs due to higher fixed costs when compared to the other systems. SWSW with chemical fallow ranked fourth (-$2.13) in terms of net returns over variable costs and was slightly more profitable than no-till HRSW/SB for returns over total costs.

These early results show all spring cropping systems lagging the traditional SWWW/fallow system in profitability. Both prices and yields have hurt HRSW in recent years. Continuous HRSW yields trended down during 1998-2000, while winter wheat after fallow yielded above average levels in both 1998 and 2000. Furthermore, the price premium for HRSW relative to SWWW shrunk from $0.94/bu over the 1993-97 marketing years to $0.74/bu for 1995-99. More yield enhancing research and public support for these soil and soil and air quality conserving spring cropping systems is needed to make them competitive with the relatively profitable, but erosive, winter wheat-fallow system. Other results from farmer surveys and Cooperative Extension farmer panels have indicated that farmers may be able to trim the cost of production for HRSW below the estimates presented here. If possible, this would further improve their competitiveness with winter wheat-fallow.

Other research has shown significant public valuation for higher levels of air quality which are provided by continuous cropping systems. Public cost sharing for soil conserving annual spring cropping would assist innovative growers adopt these systems profitably. Researchers should also make comparisons to other soil conserving systems such as reduced tillage fallow-soft white winter wheat. For example, the "conventional" SWWW-fallow system used as a control in the Ralston experiment employed substantially less tillage during the fallow operation than was typical on most area farms. This "minimum tillage" SWWW-fallow system, and similar systems which have been successfully tested at Lind, might provide a cost effective intermediate step until farmers and researchers perfect continuous spring cropping systems for the region.

Soil Conservation and Dust Abatement Predictions

We applied the NRCS Wind Erosion Equation to the four cropping systems in the Ralston experiment. Surprisingly, the model predicted zero wind erosion for all four systems, including SWWW/F. NRCS review of the WEQ results indicated WEQ had been correctly applied to the Ralston cropping systems, but that known problems with the equation led to underestimating erosion. These problems included a need to increase the published Soil "I" factor for this region. This could increase erosion predictions by 55% or more. The climate "C" factor should also be adjusted for eastern Washington. This factor is based on daily average wind speed, and does not properly account for the intense but short duration wind storms which cause severe dust events.

A dust emission model provided predictions for the Ralston cropping systems which were closer to expectations. Using conventional summer fallow as the base for dust emissions, the emission model estimated that improved (conservation tillage) fallow would reduce emissions by 54% and continuous annual grain cropping would reduce emissions by an impressive 95% (Lee, B.,1999, Civil and Environmental Engineering M.S. Thesis). 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).

Table 1. Average annual crop yields and HRSW protein levels by cropping system, Ralston

Crop: Rotation	1996	1997	1998	1999	2000	Avg.
SWWW (bu/ac): SWWW/ fallow	78	64	73	58	73	69
SWSW (bu/ac): SWSW/chem fallow	51	61	62	38	50	52
HRSW (bu/ac): Cont. HRSW	40	55	39	32	34	40
% protein	13.4	13.0	15.6	15.1	14.0	14.05
HRSW (bu/ac): HRSW/SB	43	56	42	37	39	43
% protein	14.2	13.4	14.4	14.6	14.0	14.1
SB (metric tons/ac): HRSW/SB	0.89	1.52	1.49	0.90	1.02	1.16

Note: All wheat yields reflect 10% moisture and chaff. All barley yields reflect 7.5% moisture and chaff.
The 2000 HRSW protein levels are preliminary.

Table 2. Average revenue, costs, and net returns ($/rot ac)[a] by cropping system for the Ralston Experiment, 1996-2000.

Rotation	Rev/Ac	Cost/Ac		Net Returns Over Cost	
		Variable	Total	Variable	Total
SWWW/ fallow	122.81	79.04	135.52	43.77	-12.71
SWSW/ chem fallow	86.80	88.93	127.79	-2.13	-40.99
Cont. HRSW					
actual protein	165.92	158.14	220.47	7.78	-54.55
HRSW/SB					
actual protein	164.61	147.85	207.34	16.76	-42.73

[a] Example of returns per rotational acre: ½ acre HRSW and ½ acre SB.

HOW COMPETITIVE IS CONTINUOUS NO-TILL SPRING WHEAT IN THE HORSE HEAVEN HILLS?

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This report compares the profitability of a traditional winter wheat (WW)-summer fallow rotation under conventional tillage with a continuous no-till hard red spring wheat (HRSW) rotation. The results are based on a 1997-2000 experiment conducted on the Doug Rowell Farm in the southern section of Horse Heaven Hills (HHH), Benton County, WA. This region averages only 6.5 inches precipitation per year making it one of the driest rainfed grain production areas of the world.

Experiment Description

In collaboration with Doug Rowell and the Benton County Wheat Growers Association, a 6-year experiment was initiated in February 1997 on the driest portion of the Horse Heaven Hills. The experiment compares the traditional winter wheat - summer fallow rotation to continuous no-till hard red spring wheat. Both the crop and fallow phases of the wheat - fallow rotation are present each year. The experimental design is a randomized complete block with six replications (total of 18 plots). The study covers 8 acres with each plot 300 feet long and 60 ft wide. Historic winter wheat yields at the site had ranged from 3-to 30-bushels per acre. The Warden silt loam soil (coarse-silty, mixed, mesic Xerollic Camborthids), is more than six feet deep with a slope of less than two percent.

Equipment and field management for the wheat-fallow system are provided by Rowell. Tillage operations entail primary spring tillage in March with a V-shaped sweep implement or tandem disk, followed by 2 or 3 rodweedings as needed during the late spring and summer to control Russian thistle. Fertilizer is not used during dry years. Winter wheat is sown with a deep furrow drill in August if adequate seed-zone moisture is available, or with 10 inch hoe drills after the onset of rains in October or November. In-crop broadleaf weeds are controlled with 2-4,D herbicide.

In the no-till treatment, hard red spring wheat is sown in February or early March with a low-disturbance Cross-slot drill. The Cross-slot is equipped with notched coulters on 8-inch row spacing that deliver seed and liquid fertilizer in one pass. Soil tests for soil moisture and nutrient availability are taken just prior to sowing each year to determine an optimum fertilizer rate based on 3.5 lbs of nitrogen for each expected bushel of wheat production for 14% grain protein. Two or three herbicide applications are required each year for the no-till continuous spring wheat system: a pre-plant glyphosate application if downy brome is present, an in-crop broadleaf herbicide, and a post-harvest burn-down herbicide for Russian thistle control. All plots are harvested in July with a commercial-size combine equipped with a 30-foot-wide header. Grain yield from each plot is determined by auguring grain into a truck mounted on weigh pads.

Results

Table 1 reports the annual precipitation and crop yields by rotation for the 4-year experiment, the Rowell farm, and a 1993 extension budget for the area. Table 1 shows that continuous no-till HRSW averaged only 10.4 bu/ac from 1997-2000, with protein well below 14 percent in the first two years and just above 14 percent in last two drier years. WW after fallow, on the other hand, averaged 24 bu/ac including a record 41.2 bu/ac in 1998. Average WW after fallow yields on the Rowell Farm

(23.8 bu/ac) and those assumed by the 1993 Extension budget (25 bu/ac) were similar to the Experiment's 24/bu/ac average (Table 1).

Table 1. Crop Yields and Precipitation, Horse Heaven Hills Experiment and Comparison Sites, 1997-2000.

Year Experiment	Precip. (in.) (Aug. - July)	Wheat Yield (Bu/Ac) WW- Fallow	Cont. HRSW
1997	9.44	26.5[a]	13.7 (10.5)[b]
1998	7.87	41.2	18.0 (12.4)
1999	4.25	8.5	3.8 (14.6)
2000	4.76	19.8	5.9 (14.1)
Exp. Av.	6.60	24.0	10.4 (12.9)
Rowell Farm Av.	6.50	23.8	-
EB 1782[c]	8.00	25.0	12

[a] WW not grown in experiment in 1997, which was the first year of the study. Rowell's 1997 winter wheat (WW) yield at the experiment site of 26.5 bushels per acre was substituted for this year.

[b] Parentheses contain % protein for HRSW in the Experiment..

[c] van Doren, G. and G. Willett, *An Economic Analysis of Crop Rotation Alternatives on Dryland Grain Farms*, Horse Heaven Hills Area, Washington, 1993, EB 1782, Cooperative Extension, WSU.

Table 2 reveals comparable average gross returns of about $40 per acre for conventional tillage WW-fallow for the experiment, the host farm, and a 1993 Extension publication. Readers should recall that the WW-fallow gross returns and total costs are per rotational acre which means that the costs and returns are one-half acre fallow and one-half acre WW. The average net returns of -$39.99 per acre for no-till HRSW grown in the experiment suffer due to higher annual production costs, the low average protein level of 12.9 percent and associated annual price discounts, and especially the low 10.4 bushel per-acre average yield. An average protein level of 14 percent was assumed, perhaps generously, for the 1993 publication lacking any empirical source for this panel-constructed budget. The bottom line, however, is that both the four-year experiment and the earlier Extension budget show continuous HRSW wheat substantially lagging in profitability compared with the traditional regional system of winter wheat-summer fallow. These results showing continuous no-till HRSW lagging WW-fallow in profitability parallel those from an experiment at Ralston, WA, which at 11.5 inches per year enjoys five inches more annual precipitation than the Horse Heaven Hills.

In some respects, these results are not unexpected. Winter wheat after fallow has a 100-year research lead over spring grain systems in arid regions of the Pacific Northwest. Additional research is needed in breeding, pest management, nutrient management, and other best management practices to narrow the profitability gap between WW-fallow and soil saving spring cropping systems in arid areas. Other results have indicated that farmers might be able to trim the cost of production for HRSW (Northwest Columbia Plateau Wind Erosion/Air Quality Project 2000 Annual Report, Washington State University, January 2001).

Table 2 includes only market returns. Adding current government payments will not alter rankings by cropping system, but would substantially increase farm-wide net returns. USDA estimated government payments accounted for 42 percent of farm net income nationally in fiscal year 2000, and was likely considerably higher for many grain farms.

Table 2. Average Costs and Market Returns[a] by Rotation and Source, Horse Heaven Hills Region, WA.

Rotation Source	Gross Returns ($/Ac)	Total Costs ($/Ac)	Net Returns ($/Ac)
WW-Fallow:			
Exp. 1997-2000	41.28	41.65	-0.37
Rowell Av.	40.59	37.68	2.91
EB1782[b]	43	61.39 [71.17][c]	-18.39 [-28.17][c]
Contin. HRSW			
Exp. 1997-2000	36.19	76.18	-39.99
EB1782	50.16	75.86 [88.00][c]	-25.70 [-37.84][c]

[a] Returns exclude government payments and any crop insurance claims. The five-year (1995-99 marketing year) average price of $3.44 per bushel was used throughout for WW. Annual HRSW prices were adjusted for annual protein penalties and premiums beginning from the base five-year average price for 14% protein of $4.18 bushels. Long-run average protein adjustment of $0.09 per bushel penalty for each 1/4% below 14% and $0.04 per bushel premium for each 1/4% above 14% to 15.5% was used. A 14% HRSW protein level was assumed for Rowell and EB 1782.

[b] van Doren, G. and G. Willett, *An Economic Analysis of Crop Rotation Alternatives on Dryland Grain Farms,* Horse Heaven Hills Area, Washington, 1993, EB 1782, Cooperative Extension, WSU.

[c] Adjusting costs for inflation from 1993 to 1997-2000.

While no-till HRSW may not match WW-fallow in profitability under current technology in arid farming regions in east-central Washington, there is strong evidence that this cropping system provides substantial soil and air quality benefits. A recent study at Washington State University showed that continuous spring grain reduced airborne dust particulates by 95 percent compared with conventional WW-fallow (Lee, B., *Regional Air Quality Modelling of PM-10 Due to Windblown Dust on the Columbia Plateau.* M.S. Thesis, Washington State University, 1998). Research has shown significant public valuation for air quality improvements which could be provided by continuous spring cropping systems. Public cost sharing for soil conserving annual spring cropping would help innovative growers adopt these systems profitably. Researchers should also devote effort to reducing the erosiveness of WW-fallow systems. Examples are the reduced tillage fallow systems which have been tested at Lind and Ralston, Washington (*Northwest Columbia Plateau Wind Erosion/Air Quality Project 2000 Annual Report*, Washington State University, January 2001). These conservation tillage WW-fallow systems could provide a cost-effective intermediate step until farmers and researchers perfect continuous spring cropping systems for the region.

Readers seeking a more detailed review of the economic analysis of this HRSW no-till experiment are referred to the recent WSU Extension Bulletin 1907, Economics of Winter Wheat-Summer Fallow vs. Continuous No-till Spring Wheat in the Horse Heaven Hills, Washington.

PRELIMINARY FARMER SURVEY RESULTS ON THE ECONOMICS OF THE TRANSITION TO NO-TILL

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Previous research has shown that Pacific Northwest dryland grain farmers who have been using no-till for several years could reduce production costs relative to conventional tillage. However, during periods of low grain prices many growers are legitimately concerned about the economic risk of making the transition to no-till. This concern is rooted in the large up-front financial outlay for a no-till drill and possibly also for a larger tractor to pull the drill. Potential no-till converts are also constrained by the depressed market for conventional tillage machinery. Farmers are unlikely to reap high trade-in or sale values from plows and other conventional machinery. Furthermore, previous surveys indicate that many no-till farmers prefer to keep their conventional machinery as "insurance" in case they need to revert to conventional tillage for some fields.

Survey

The preliminary results presented here are based on personal interviews with 10 no-till dryland wheat and barley growers from Whitman and Adams counties in eastern Washington. Growers were interviewed during the early spring of 2001. The survey sought farmers who considered themselves still in the transition process from conventional farming, but who had accumulated about five years no-till experience. The interviewer sought information on the farm's size, financial position, and crop rotations at the initiation of the transition. The farmer also described his method of no-till drill acquisition (custom, rent, lease, purchase), gradual no-till acreage expansion, and yield experience during the transition period. Only data analysed to date is presented here.

Results

Table 1. The average, lowest response and highest response to selected questions presented to 10 transition no-till farmers in eastern Washington, spring 2001

Question	Low	Mean	High
Year began using no-till	1991	1994	1997
Farm acres currently in no-till	240	1,398	2,500
Percent of farm currently in no-till	7	38	100
At year 1 of Transition, % of land rented	0	46	100
At year 1 of Transition, % of land paid off	5	44	100
At year 1 of Transition, % of land making payments on	0	49	100
If land was purchased during year 1...annual payment ($)	11,200	16,233	25,000
If land was purchased during year 1...Interest rate (%)	7	8	9
If land was purchased during year 1...years to pay off	10	16	32
Percentage crop share to landlord on leased property	30	32	33
Percentage of fertilizer bill paid by landlord	20	26	33

Table 2. Pattern of no-till expansion during transition years for six farmers in east. WA.

Farmer	Year	Crop(s)	Previous Crop	No-Till Acres	% of Farm in No-Till
A	Year 1	WW, SW	SW	250	10
	Year 2	WW, SW	SW	250	10
	Year 3	WW, SW, Seed Peas	WW, SW	385	15
	Year 4	WW, SW, Peas	WW, SW, Peas	450	18
	Year 5	WW, SB, WS, Peas	WW, SW, Peas	1050	42
	Note:	Farmer A completed the transition to 100% no-till in year 6.			
B	Year 1	SW, Peas	WW	400	5
	Year 2	SW, Peas	WW	800	11
	Year 3	SW, SB, Peas	WW	1600	21
	Year 4	SW, SB, WW	Peas	1600	21
	Year 5	SW, SB, Peas	WW	1600	21
C	Year 1	SB	SW	160	5
	Year 2	DNS	SB	160	5
	Year 3	SB	DNS	160	5
	Year 4	SB, DNS	SB	320	9
	Year 5	SB, Yellow Mustard	SB, DNS	492	14
D	Year 1	WW	SB	70	2
	Year 2	WW	SB	90	2
	Year 3	WW	Chem Fallow	245	5
	Year 4	WW	Chem Barley	300	6
	Year 5	WW	Lentils	610	12
E	Year 1	SB, Lentils, WW	WW, SB, Lentils	1800	71
	Year 2	SB, Lentils, WW	WW, SB, Lentils	2400	94
	Year 3	SB, Lentils, WW	WW, SB, Lentils	2400	94
	Year 4	SB, Lentils, WW	WW, SB, Lentils	2400	94
	Year 5	SB, Lentils, WW	WW, SB, Lentils	2500	98
F	Year 1	SB	WW	80	4
	Year 2	SB, SW, Mustard	WW, SB, WW	365	16
	Year 3	SW, Mustard, SB	SB, WW, WW	585	26
	Year 4	SW,Must,Safflower,SB,Oats	SB, WW, WW,	845	38
	Year 5	Safflower, SB, SW	WW, Mustard, SB	2250	100

Table 3: Percent of nine farmers acquiring no-till drills by different means during the 5-year transition period

Year	Custom	Rent	Purchase
1	33	44	22
2	22	56	22
3	0	67	33
4	11	33	56
5	11	22	67

Discussion

The ten farmers whose responses are summarized in Table 1 show great disparity in land tenure structure at year 1 of their no-till transition. The group includes farmers who rented all their land, who owned all their land but were still paying for it, and who owned all their land and had fully paid for it. This suggests that the no-till transition may not require one particular land tenure situation.

These preliminary survey results also suggest that most eastern Washington farmers make the transition to no-till gradually. Although the speed of conversion to no-till varied greatly among the six farmers listed in Table 2, it is interesting that none of the six "backtracked" in no-till acreage over the five years. Each year the same or an increasing percent of acreage was no-tilled. The results in Table 3 indicate that most farmers began by custom hiring or renting a drill in years 1-3 of the transition. But over half of this group of eastern Washington growers had purchased a drill by years 4 and 5. Some 89% of the drill purchasers in this group reported having paid cash for their no-till drills which ranged in cost from $13,618 to $65,000. The types of drills purchased included: McGregor, Yielder, Great Plains, Cross Slot, Palouse Zero Till, and Flexicoil Air Seeder. These growers usually kept their conventional tillage equipment.

Selected Farmer Comments

This section presents selected farmer responses to the general question: "Would you have done anything different to maintain a secure cash flow after switching to no-till?"

A. The biggest problem with no-tillers is that there is always the fear of the unknown. Most guys personally know four or five farmers that went bankrupt trying to make it work. This is quite discouraging, and you feel like at times you are alone in a new "frontier."

B. I do wish that the cost of those drills would come down a bit.

C. You need to find an inexpensive drill to get started with and try not to [rely on] custom hire. It is sad when you see others go bankrupt, but you just got to keep on trying.

D. I'd try to find a less expensive high horsepower tractor, and I'd sell all of my conventional tillage equipment. It's tough to try to find the right drill that will work for you, and to absorb the initial cost. Since we don't like to burn, we want a drill that is big enough to finish seeding on schedule, and can punch through all of the extra residue.

HOW DOWNSIZING A CROP MANAGEMENT FIELD EXPERIMENT AFFECTS ECONOMIC RESULTS

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Overview

In recent years, there has been increased interest in long-term, field-scale cropping systems research to improve pest management, to protect air and soil quality, and to increase or maintain growers' profits. However, these studies require large tracts of land, sizeable labor forces, and substantial inventories of equipment, which make them very expensive to conduct. Because of recent concerns about reducing field research costs this study compares economic and biological results from an original complete 6-yr Integrated Cropping Management (ICM) Systems field study to results from several downsized experiments which were components of the complete study. Compared to the original ICM study, the downsized experiments reduced the number of treatment replications from four to three, reduced the number of crop rotation cycles from two to one (from 6 to 3 yrs), or only grew one crop per rotation each year. The effect of downsizing on the profitability analysis and the statistical (biological) analysis were similar. Reducing replications altered both profitability and biological conclusions less than reducing the number of rotation cycles. Reducing crop rotation cycles markedly altered treatment profitability rankings compared to the complete study. Growing only one crop in a rotation per year was the most detrimental to biological results and entirely precluded computing mean annual cropping system profitability. This empirical study supports the importance of replicating treatments fully over time, over space, and over crop rotational positions.

Profitability Results

This following discussion highlights the effects of downsizing on only the profitability results. The two data sets from the short duration experiment (yr 1,2,3 and yr 4,5,6) produced very different inferences about mean profitability of different cropping systems compared to the complete 6-yr study. All cropping systems but one averaged a positive profit in yrs 4 to 6 compared to yrs 1 to 3 when no cropping system was profitable. In the complete study two systems averaged a positive return over total costs. Average profit of all 12 systems in yrs 4 to 6 was overestimated by \$98.42 ha^{-1} (58.61 minus –39.81) relative to the complete study. Years 1 to 3 underestimated mean profit by a similar amount compared to the complete study. A \$100 difference in per ha profit would misportray annual profit on the typical 565-ha farm in the study region by \$56,500. The complete study experienced a representative range of precipitation, whereas the first three years experienced drier weather and the last three years wetter weather.

More importantly, from the standpoint of making technology recommendations, the reduced duration experiments produced different profitability rankings of the 12 cropping systems compared to the complete study. The average of the absolute value changes in economic ranks from the reduced duration experiments versus the complete study is 1.67 integer ranks. The Spearman correlation coefficient relating profitability rankings for the complete study to the reduced duration experiments ranged from 0.76 to 0.83, which was significantly ($p < 0.05$) less than 1.0, the correlation coefficient for identical rankings. The two top ranked cropping systems, conservation tillage with ww-sb-sp rotation and moderate or maximum weed management, have strong economic robustness because they were ranked first or second in profitability by all three experiment durations. However, cropping systems with small profit differences can exhibit different profitability rankings over various experiment durations.

Reducing replications, from four in the complete study to three in the downsized experiments, also altered profitability rankings, but by much less than reducing the duration of the experiment. Estimates of average profitability over treatments for reduced replications ranged from -\$6.01 ha^{-1} below to \$3.81 ha^{-1} above that for the complete study. The average absolute value of changes in preference ranks of downsized compared to the complete study ranged from only 0 to 0.67 integer ranks. The Spearman correlation coefficient for rankings ranged from 0.96 to 1.00 which indicates very good agreement between the downsized replication experiments and the full study. No test of significance was conducted because the correlation coefficients were too large for valid application of the test. As in the experiment duration comparisons, the top two economic cropping systems retained their top rankings in the three-replication experiments as in the complete study.

Based on this study, the reduced replication experiments are recommended over the other downsized experiments. Of course, the amount of replication required in future experiments would depend on the size of treatment differences to be detected and the inherent variation in the data. Also, researchers may wish to preserve four replications in the field as insurance against a lost replication. Based on data analyzed, conclusions from long-term agricultural cropping system studies may be in error if only one cycle of crop rotation is observed or if all crops are not grown every year. It was not possible to analyze one reduced data series in the economic preference comparisons in this study because it did not provide for growing every crop in the system every year. For balancing seasonal labor and machinery use, for smoothing cash flows, and for capturing the risk management advantages of a diversified crop mixture, farmers generally allocate close to 1 n^{-1} of their acreage to each crop in an n-crop rotation each year. Consequently it is important to have economic data on each crop every year to estimate a farmer's annual income level and risk.

Short duration and weakly replicated experiments are vulnerable to confounding by weather cycles and topographic or soil differences. Unfortunately, financial constraints and agency and university publication incentives increase pressures to downsize and reduce experiments. This empirical analysis supports the importance of replicating treatments fully over time, over space, and over crop rotational positions.

For more detail on complete agronomic, statistical, and economic results of this study, see "Downsizing an Integrated Crop Management Field Study Affects Economic and Biological Results" in *Agronomy Journal*, vol. 93, March-April, 2001, pages 412-417.