COOPERATIVE EXTENSION

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Department of Crop and Soil Sciences

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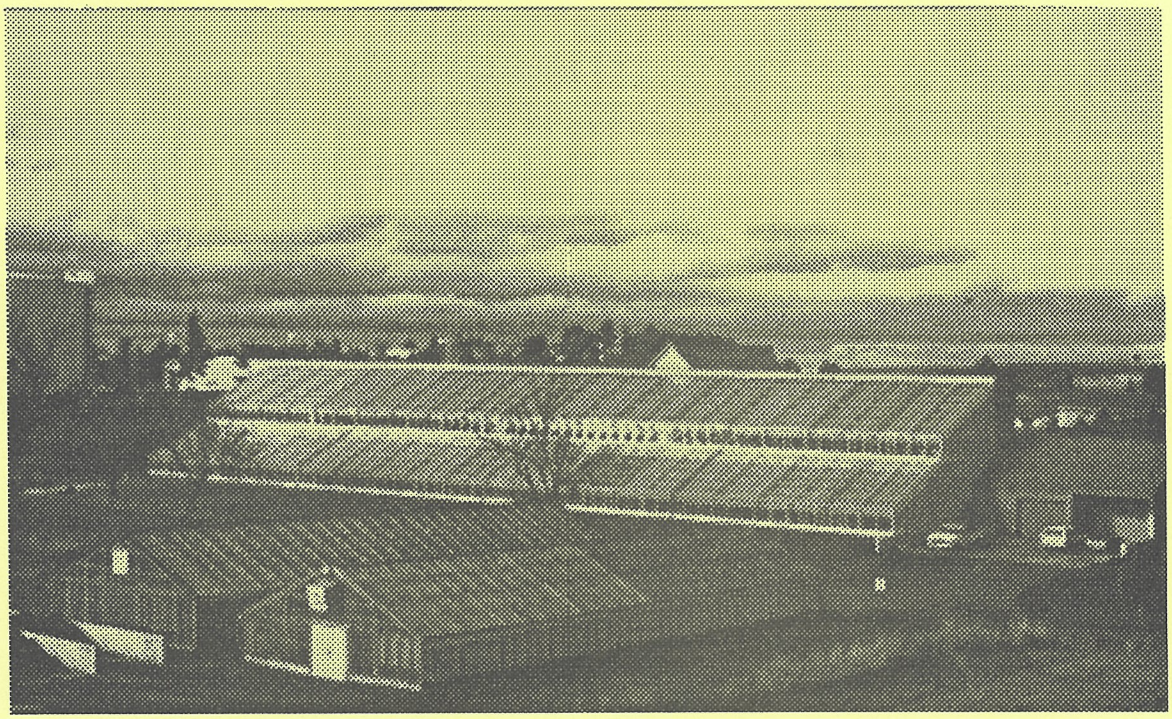

1998 Field Day Proceedings: Highlights of Research Progress

Dryland Research Unit, Lind
June 11, 1998

WSU/USDA, Pullman
July 9, 1998

Edwin Donaldson, Editor

Contributing agencies; Washington State University, U.S. Department of Agriculture and Department of Crop and Soil Sciences
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BARLEY IMPROVEMENT RESEARCH

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D. von Wettstein, F. Han, E. Donaldson,
P.E. Reisenauer, J.A. Froseth, R.J. Cook , and R.L. Line

Cultivar Development/Variety Testing

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

The latest releases from the Barley Improvement Program were two new spring barley cultivars in 1997; 'Bear', a two-row hulless type and 'Washford,' a six-row hooded (beardless) hay type.

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

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

For spring barley in 1997, 130 crosses were made. In 1998, plants will be selected from 53 segregating F_3 populations (50-100/population). In addition, there are101 F_2 single seed descent populations in the greenhouse. Lines will be selected from approximately 4,500 head and rows. There are 1255 single replication evaluation plots planted at Spillman Farm and Ritzville or Royal Slope this year; the entries of which mostly came from 1997 head/plant rows. The more advanced lines are tested in 18 30- to 60-entry major yield trials at Spillman Farm and throughout eastern Washington including a 45 entry preliminary state yield trial at three locations – Pullman, Fairfield, and Ritzville – and the state uniform trial of 39 entries planted at 13 locations (7 extension/Donaldson, and Reisenauer). There are approximately 12 grower-conducted on-farm tests with seven entries in seven counties in 1998 coordinated by Kevin Anderson of Great Western Malting Company and area/county extension agents in eastern Washington.

Barley performance in 1997 was presented in the Novermer7, 1997 *Green Sheet* and in the January 1998 *Wheat Life*.

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

Pest 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 and soil borne pathogen resistance is underway. The Russia wheat aphid is a relatively new pest in the Pacific Northwest (PNW) and has the potential to inflict serious damage to the barley crop. Reaction screening is carried out at the USDA-ARS Insect Laboratory at Stillwater, Oklahoma. RWA resistant lines are in field tests in 1998.Barley stripe rust (BSR) is a new disease to the PNW and little resistance exists in currently grown barley cultivars. Rollie Line is collaborating on monitoring and testing for this disease. We have had germplasm screened for barley strip rust reaction the past several years in Bolivia, Texas, Colorado, and Washington. Expanded field testing of BSR resistant lives began in 1997. There appears to be good resistance in a number of WSU breeding lines. Soil borne pathogens probably affect barley production more than we realize. A new effort was initiation in 1994 through Vadim Jitkov's M.S. research project in collaboration with Jim Cook to screen for reaction to soil borne pathogens in the field and growth chamber. Barley cultivars and breeding lines have been identified with resistance to *Rhizoctonia solani* for the first time. Relatively simple inheritance of resistance is indicated which should facilitate breeding for resistance to this soil borne pathogen. Field testing for soil borne pathogen reaction has been expanding over the past few years with nurseries planted at Spillman Farm, Dusty, Ritzville, and Bickelton in 1998.

Application of Biotechnology

Collaboration in the North American Barley Genome Mapping Project involves work on several fronts with Andy Kleinhofs, Janet Clancy, Feng Han, and Wenxiang Gao. The first comprehensive map developed from Steptoe/Morex is being applied to quantitative trait locus (QTL) analysis and molecular marker assisted selection relevant to cultivar development. We are verifying QTL identified and developing molecular marker assisted selection strategies for use in the breeding program. Initially, we are concentrating on the dormancy trait and yield from Steptoe, several malting quality traits from Morex, and *Rhizoctonia* resistance from identified germplasm sources. Mapping populations from the Harrington/TR306 and Harrington/Morex crosses are also being evaluated. The incorporation of yield QTL from Baronesse and barley stripe rust QTL from Orca into Harrington and the incorporation of Steptoe yield QTL into Morex are collaborative projects with Andy Kleinhofs, Dave Kudrna, and Nejdet Kandemir. The availability of a detailed genome map allows us for the first time to begin to understand the genetics of complex economically important agronomic (yield, lodging, maturity) and quality (feed, kernel, malting) traits through QTL analysis. With the identification and location of specific genes, marker-assisted selection strategies can be developed to allow more directed breeding of these important economic traits.

Collaboration in breeding proanthocyanidin-free barley and transformation of barley with a heat-stable beta-glucanase (brewing and feed quality traits) is underway with Diter von Wettstein and Judy Cochran. The transformation project will see transformed plants in the field for the third year in 1998. 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) in the breeding program. Newer breeding lines of 6- and 2-row pant types have a much better combination of quality and agronomic traits than previously.

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Fertilizer, Seed and Amendments

Blue Mountain Seed
Whitman County Growers
Latah County Growers
Wilbur-Ellis
Ritzville Chemical

Herbicides

AgrEvo USA Company
Monsanto Co.
American Cyanamid
Rhone-Poulenc, Inc.
McGregor Company
Wilbur-Ellis

Cash/Equipment Contributors

AgrEvo Company
E.I. DuPont de Nemours & Co.
Monsanto Co.
USA Dry Pea & Lentil Council
WA State Comm. on Pesticide Registration
American Cyanamid
Flexicoil Co., Minot ND
Novartis Crop Protection Inc.
Walter Implement, Odessa
WA Wheat Commission
Zeneca Ag. Products
BASF Corp.
McGregor Company
Tri-River/UAP
WA Barley Commission
Wilbur-Ellis

Field Day Contributors for Lind Dryland Research Station, Spillman Farm and Palouse Conservation Field Station

Adams County Wheat Growers
McGregor Company
American Malting Barley Assn
Whitman County Wheat Growers

Farmer Cooperators

Gene Aunne	Lacrosse
Dale Bauermeister	Connell
Broughton Land Co.	Dayton
Dan/Doug Bruce	Farmington
Larry Cochran	Colfax
Dave Cornwall	Fairfield
Evelyn Crowe	Spokane
John DeWald	Ritzville
Rob DeWald	Ritzville
Jay DeWitt	Walla Walla
Roy Druffel	Colton
Mike Druffel	Colton
Richard Druffel	Pullman
Roger/Mary Dye	Pomeroy
Tracy Ericksen	St. John
Karl Felgenhauer	Fairfield
Ferrel Bros.	Walla Walla
Bob Garrett	Endicott
Eric Hasselstrom	Winchester ID
Curtis Hennings	Ritzville
Mark/Mary Hoffman	Pullman
Clarence Hughes	Endicott
Ron Jirava	Ritzville
Frank/Jeff Johnson	Clarkston
Hal Johnson	Davenport
Ron Juris	Bickleton
Randy/Larry Keatts	Lewiston ID
Roger Koller	Mayview
Bob/Mark Kramer	Harrington
Jerry Krause	Creston
Randy Kulm	Lind
Karl Kupers	Harrington
Liberty High School FFA	Spangle
Jay Lyman	Dayton
Bill Mains	Bickleton
Steve Matsen	Bickleton
Mac Mills	St. John
Steve Moore	Lacrosse
Ray Myklebust	Hay
Bruce Nelson	Farmington
Randy Repps	Dusty
Nathan/Steve Riggers	Nezperce ID
Dave Roseberry	Prosser
David/Paul Ruark	Garfield
Mike Schmitt	Prosser

Farmer Cooperators

Howard Smith Jr. and Sr.	Walla Walla
Steve Swannack	Lacrosse
Larry Tannenberg	Coulee City
Reggie Waldher	Pomeroy
Jim Walesby	Almira
Don Wellsandt	Ritzville
Doug Wellsandt	Ritzville
Curt/David/Gill White	Lamont
Bob Wigen	Colfax
Kevin Wigen	Rockford

HISTORY OF THE DRYLAND RESEARCH STATION

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

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

Dr. M. A. McCall was the first superintendent at Lind. McCall was a gifted researcher given somewhat to philosophy in his early reports. In a 1920 report he outlined the fundamental reasons for an outlying experiment station. He stated: "A branch station, from the standpoint of efficiency of administration and use of equipment, is justified only by existence of a central station". For 81 years, the Lind station has followed the policy of studying the problems associated with the 8-to 12-inch rainfall area.

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

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

Since 1916 an annual field day has been held to show growers and other interested people the research on the station. This year marks the 82nd field day. Visitors are welcome at any time, and your suggestions are appreciated.

HISTORY OF SPILLMAN FARM

In the fall of 1955, 222 acres of land were acquired from Mr. and Mrs. Bill Mennet at the arbitrated price of $420 per acre. The money for the original purchase came as the result of a fund drive which raised $85,000 from industry and wheat growers. In addition, $35,000 came from the Washington State University building fund, $11,000 from the State Department of Agriculture, and another $10,000 from the 1955-57 operating budget. The dedication of the new facility took place at the Cereal Field Day July 10, 1957. In 1961 the Agronomy Farm was named Spillman Farm after the distinguished geneticist and plant breeder at Washington State University in the late 1880s.

Through the dedicated efforts of many local people and the initiative of Dr. Orville Vogel, arrangements were made to acquire an additional 160 acres north of the headquarters building in the fall of 1961. This purchase was financed jointly by the Wheat Commission and Washington State University. The newly acquired 160 acres were fenced and the wetland drained; it became an integral part of the Agronomy Farm, now consisting of 382 acres.

The headquarters building, which is 140 feet long and 40 feet wide, was completed in 1956. A 100 by 40 feet addition was built in 1981. In 1957 a well that produced 340 gallons per minute was developed. In 1968 the Washington Wheat Commission provided funds for a sheaf storage facility that was necessitated by the increased research program on the farm. At the same time the Washington Dry Pea and Lentil Commission provided $25,000 to build a similar facility for the pea and lentil materials. The facilities of the Spillman Agronomy Farm now range in value well over a half million dollars.

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

Dick Hoffman was appointed farm manager in 1994.

PALOUSE CONSERVATION FIELD STATION

The Palouse Conservation Field Station was established as one of 10 original erosion experiment stations throughout the United States during the period 1929 to 1933. The station consists of a number of buildings including offices, laboratories, machine shop, a greenhouse, and equipment buildings, as well as a 60 acre research farm. Scientists and engineers from the USDA/ARS and Washington State University utilize the Station to conduct research projects ranging from soil erosion by wind and water to field-scale cropping and tillage practices in the steep slopes common on the Palouse. Several persons are employed at the Station by both the federal and state cooperators. The Station has a full time manager who lives on site and maintains the busy flow of activities which characterize the farm. This includes the day-to-day routine items, farm upkeep, maintaining the complex planting and harvest schedule to meet the requirements of the various cropping research, and operating the machine shop which fabricates a majority of the equipment used in the research projects. There are also a number of part time employees, many of whom are graduate students, working on individual projects. Along with the many research projects, a no-till project at the Palouse Conservation Farm was initiated on bulk ground in the fall of 1996. The objective of this project is to determine if it is technologically possible and economically feasible to grow crops in the eastern Palouse under no-till. The ARS Units at Pullman are focusing on technologies and research needed to make no-till farming possible in this region.

Table 1. Temperature and precipitation at Palouse Conservation Field Station, Pullman, 1997-98

Month	Monthly Avg. Temperature(F) Max.	Min.	Precipitation (in) 30-Yr Avg.*	Monthly	Total Accum.	Deviation from Avg. Monthly	Accum.
1997							
January	35.7	24.5	2.89	2.66	2.66	-.23	-.23
February	39.1	28.1	2.09	1.79	4.45	-.30	-.53
March	46.3	32.5	1.96	1.85	6.30	-.11	-.64
April	51.9	33.8	1.58	2.61	8.91	1.03	.39
May	66.8	44.8	1.52	1.07	9.98	-.45	-.06
June	67.7	46.0	1.49	.84	10.82	-.65	-.71
July	80.2	51.0	.53	1.63	12.45	1.10	.39
August	86.6	52.8	.95	.16	12.61	-.79	-.40
September	74.9	48.3	.99	1.05	13.66	.06	-.34
October	58.9	37.9	1.61	3.32	16.98	1.71	1.37
November	47.3	34.3	2.64	2.54	19.52	-.10	1.27
December	35.2	25.1	3.07	1.41	20.93	-1.66	-.39
TOTAL			21.32		20.93		-.39
1998							
January	37.5	26.5	2.89	2.05	2.05	-.84	-.84
February	44.6	31.8	2.09	.99	3.04	-1.10	-1.94
March	48.7	32.9	1.96	1.09	4.13	-.87	-2.81
April	56.5	35.9	1.58	.85	4.98	-.73	-3.54
TOTAL			8.52		4.98		-3.54
1997 CROP YEAR Sept. 1996 thru June 30, 1997			19.84		23.75		3.91

*Thirty year average for precipitation, 1951-1980

1997 VARIETY TESTING PROGRAM WINTER WHEAT

T. A. Lumpkin, E. Donaldson, S. S. Jones and P. E. Reisenauer

The 1997 soft white winter wheat variety evaluation trials were established at eighteen locations in eleven counties. Five of the sites were conducted in cooperation by the winter wheat breeding programs. An additional six sites included the hard red winter wheat varieties which were incorporated into the breeder nurseries. Thirty soft white varieties were evaluated. An additional 15 seed mixture were evaluated at fourteen locations. This concluded a three year study on the possible advantages of using seed mixtures in certain locales and cultural practices. Varieties in the trials included all significant publicly released varieties from the Pacific Northwest, public varieties from the tri-state nurseries being considered for release and private varieties entered on a 'fee for entry' basis.

Fall planting conditions were excellent at the later planted locations. Some of the earlier planted locations were planted into a fairly deep dust mulch in order to reach moisture. Acceptable stands at these sites were established and the nurseries filled in well during the spring and summer portion of the year. Most all nurseries survived the winter in good shape and spring growth was excellent. The nursery at Anatone did not establish well and spring growth was poor. The winter nursery at Bickleton was lost to goatgrass. Although there was an extremely heavy infestation of cheat grass at Lamont, the nursery was treated with M37500 and excellent control was obtained. The nursery at Farmington was lost to flooding and root diseases. Yields were excellent and grain quality was outstanding. Harvest was accomplished in a timely fashion and harvest rains were nonexistent.

The results from the trials and the WSU breeder's trials were summarized and reported in a winter Washington State Crop Improvement Seed Buying Guide. The variety performance results were also reported in the Washington Association of Wheat Growers Green Sheet, Wheat Life, each of the county agent's newsletters and placed on the Internet for electronic access.

1997 WSU WINTER WHEAT VARIETY TRIAL SUMMARY
YIELD (BU/A)

VARIETY NAME	ASOTIN	LIND DRY	RITZVILLE	PULLMAN LATE	FAIRFIELD	CRESTON	DAYTON	REARDAN	LAMONT	POMEROY	MAYVIEW	MOSES LAKE	WALLA WALLA	DUSTY	ST. JOHN	VARIETY AVERAGE
Soft White Common																
123-M	61.7	72.0	82.4	97.2	111.6	100.9	109.4	115.3	114.5	118.8	125.3	126.8	129.3	130.6	145.0	109.3
BASIN	53.5	51.4	75.0	99.0	113.3	93.3	107.6	98.6	105.1	105.1	120.7	117.0	114.1	122.7	137.2	100.8
CASHUP	65.9	56.0	80.2	102.4	114.8	105.4	108.9	111.2	124.4	108.6	130.7	127.9	115.7	131.4	150.0	108.6
DAWS	40.1	61.4	69.0	90.1	104.5	102.3	103.4	112.4	88.8	118.8	109.8	117.6	114.6	125.6	133.4	99.6
ELTAN	56.6	64.1	74.6	85.0	94.7	73.2	107.5	120.1	113.5	123.4	126.2	117.0	130.2	118.3	123.9	101.7
HILL 81	57.1	56.7	72.8	95.6	102.2	101.6	95.0	103.6	104.5	111.2	111.7	119.4	139.6	126.3	135.9	102.2
HILLER	65.9	71.9	75.2	96.8	99.1	111.7	110.8	121.5	117.9	123.9	130.6	117.6	117.2	132.1	139.7	108.7
ID10420A	66.7	60.1	80.8	97.4	102.8	98.7	98.7	104.5	94.6	117.5	118.5	123.0	145.9	128.8	139.8	105.4
ID14502B-BRUNDAGE	53.9	57.6	65.6	89.6	98.7	118.4	117.9	106.4	117.0	116.4	113.2	109.3	111.4	135.0	163.5	104.7
LAMBERT	58.8	59.9	79.1	95.5	99.6	103.0	105.7	100.7	124.1	126.0	117.3	127.5	139.8	143.9	157.9	109.0
LEWJAIN	49.4	59.3	74.4	70.9	97.5	108.4	89.3	121.4	123.7	111.7	115.7	106.0	119.8	121.9	134.7	99.9
MACVICAR	57.3	60.6	64.2	94.7	97.9	100.1	101.2	98.5	130.0	116.0	115.4	120.8	133.4	135.6	135.1	103.6
MADSEN	62.3	56.3	69.4	94.3	97.9	113.7	100.9	96.9	101.9	105.1	111.5	116.5	126.8	121.7	135.8	100.7
NUGAINES	45.4	53.2	63.3	95.4	100.9	93.6	98.2	84.4	95.3	114.1	121.2	120.0	98.7	123.6	118.8	95.1
OR870082	57.0	49.9	50.5	93.6	94.5	65.8	94.7	24.6	96.3	97.8	111.3	129.0	120.8	108.6	132.5	90.6
OR898120	63.9	53.7	61.0	92.6	89.0	98.2	83.0	91.3	87.3	97.5	101.8	108.0	112.7	109.2	127.0	91.8
QUANTUM HYBRID 1019	56.7	71.2	83.1	102.5	97.5	105.6	120.9	89.4	123.8	129.4	121.1	139.9	133.3	141.3	148.9	110.8
ROD	72.5	69.9	88.5	103.0	106.1	107.3	109.7	123.4	122.8	126.1	127.5	124.4	143.8	126.0	151.7	113.4
STEPHENS	63.7	69.1	67.6	102.4	86.7	106.9	105.0	103.3	121.1	118.5	116.3	123.8	130.3	124.5	146.4	105.4
WA7794	58.4	73.2	84.4	90.3	103.1	118.0	110.6	110.3	127.2	114.0	123.3	122.3	126.4	130.2	146.5	108.9
WESTBRED 470	55.6	64.3	70.3	102.6	91.9	102.3	127.7	74.3	124.3	127.3	126.5	130.0	126.7	141.1	149.4	107.3
WESTBRED 481	69.5	78.2	69.1	114.0	98.9	105.1	106.3	91.8	129.8	121.3	119.1	136.4	138.2	131.1	137.5	109.4
Soft White Club																
HYAK	46.8	60.0	63.8	86.3	103.4	119.5	99.2	105.1	110.8	111.2	100.9	97.8	104.5	124.3	128.0	97.2
OR920049	58.5	59.3	67.2	83.8	84.6	103.7	101.4	92.7	108.1	112.1	102.2	107.4	98.4	135.6	135.6	96.5
OR920054	63.4	73.6	65.8	90.4	101.0	108.0	102.5	102.4	114.2	119.8	113.8	102.3	112.4	129.5	152.2	103.2
RELY	54.8	69.0	75.8	86.2	96.8	101.9	108.7	103.7	112.5	117.5	126.5	120.4	128.0	119.3	133.1	103.5
ROHDE	55.0	61.3	73.8	86.0	110.3	98.8	107.3	107.0	118.0	122.2	111.7	119.8	131.3	123.5	142.6	104.3
TRES	46.6	64.3	63.6	73.2	108.0	100.5	92.6	116.8	118.4	116.5	107.9	112.1	124.3	130.7	140.2	100.8
WA7752	58.6	65.6	85.6	98.1	104.3	110.4	109.0	104.8	96.2	117.7	115.6	129.0	123.7	123.0	130.6	105.0
WA7793	68.2	63.7	79.1	84.6	105.3	103.9	114.2	74.1	107.6	105.8	107.7	115.9	123.2	137.8	150.0	102.7
Hard Red Common																
ESTICA	70.7	76.9	84.9	104.7	99.9	126.8	113.9	107.5	119.4	121.8	125.2	133.0	135.2	135.8	163.2	114.5
NURSERY MEAN	60.0	63.3	72.9	94.8	101.0	103.3	105.3	106.0	113.8	115.9	116.7	119.9	124.2	127.2	138.8	105.0
CV (%)	15.1	11.3	10.1	9.6	13.8	8.1	5.9	11.1	19.1	11.0	9.4	8.4	6.1	7.6	7.8	10.3
LSD @ .10	10.5	8.3	8.7	10.7	16.4	9.8	7.2	13.8	29.5	15.0	12.8	11.8	9.0	11.3	12.7	6.2

Analysis Method - General Linear Models Proceedure

1997 WSU WINTER WHEAT VARIETY TRIAL SUMMARY
TEST WEIGHT (LBS/BU)

VARIETY NAME	ASOTIN	LIND DRY	RITZVILLE	PULLMAN LATE	FAIRFIELD	CRESTON	DAYTON	REARDAN	LAMONT	POMEROY	MAYVIEW	MOSES LAKE	WALLA WALLA	DUSTY	ST. JOHN	VARIETY AVERAGE
Soft White Common																
123-M	60.4	61.7	60.6	59.6	59.8	60.0	60.2	57.7	59.4	61.1	60.9	58.1	59.1	59.7	59.9	59.9
BASIN	61.3	63.6	61.7	61.5	60.7	60.8	60.9	58.1	61.3	62.1	62.0	57.8	58.7	60.7	61.0	60.8
CASHUP	59.9	61.6	62.5	60.2	59.5	60.0	61.4	58.3	60.4	61.6	61.8	60.5	61.0	60.6	61.5	60.7
DAWS	59.8	62.8	63.0	59.8	59.3	59.8	60.7	60.0	61.4	62.5	62.0	58.5	60.3	61.2	61.2	60.8
ELTAN	59.1	62.9	62.2	56.5	59.1	56.5	60.0	57.3	59.7	58.4	60.5	56.8	59.9	59.7	58.4	59.1
HILL 81	59.2	62.5	62.4	59.4	59.3	58.8	61.2	58.0	60.7	61.5	60.9	58.2	60.8	61.0	61.3	60.4
HILLER	57.6	58.8	59.7	55.8	58.2	57.3	57.0	57.4	57.6	58.7	59.2	54.8	57.2	57.9	58.5	57.7
ID10420A	60.1	62.6	61.8	59.7	60.4	58.9	61.6	57.5	60.1	61.9	61.2	59.9	61.0	60.6	60.9	60.6
ID14502B-BRUNDAGE	62.0	63.4	63.0	61.5	61.3	61.6	61.7	57.9	61.1	62.3	62.4	57.7	61.1	61.4	62.9	61.4
LAMBERT	60.4	62.1	60.3	59.8	59.7	59.4	60.1	56.2	59.3	60.8	60.6	60.0	60.7	59.2	60.4	60.0
LEWJAIN	60.1	63.5	62.9	55.5	58.6	59.7	60.7	59.0	61.5	61.5	61.5	56.5	60.1	60.5	60.7	60.1
MACVICAR	59.6	62.7	61.6	58.4	60.5	59.8	60.8	58.0	60.5	62.5	60.7	55.6	60.5	60.8	60.2	60.2
MADSEN	59.8	62.2	61.2	59.8	59.3	59.9	60.6	58.4	59.7	61.2	60.8	58.2	60.2	60.1	61.2	60.2
NUGAINES	62.9	63.1	63.2	61.2	62.0	60.6	61.7	58.1	61.5	63.3	62.3	57.9	60.7	61.3	60.5	61.4
OR870082	59.3	62.4	61.0	59.2	59.0	59.9	60.1	57.6	60.9	60.6	60.4	59.9	60.1	59.9	60.8	60.2
OR898120	59.2	61.7	61.1	59.5	59.4	59.9	59.7	57.2	59.5	61.4	60.2	57.8	59.2	59.9	60.6	59.8
QUANTUM HYBRID 1019	61.9	63.8	62.5	62.8	60.6	61.9	62.0	59.6	61.8	62.9	62.0	62.4	61.7	61.8	62.1	62.0
ROD	58.7	61.7	61.2	58.3	58.3	58.2	58.3	57.8	59.5	60.3	60.5	56.6	58.8	59.1	60.4	59.2
STEPHENS	59.8	60.5	59.7	59.3	57.9	59.5	59.3	57.4	59.5	60.9	60.4	58.2	59.8	58.5	60.0	59.4
WA7794	59.8	63.1	62.5	57.9	60.2	60.7	61.2	59.2	61.8	61.8	61.6	57.8	59.3	61.7	61.6	60.7
WESTBRED 470	62.7	64.7	63.5	63.0	61.2	62.9	63.3	60.6	62.9	64.3	63.0	60.6	62.3	62.9	62.8	62.7
WESTBRED 481	60.1	62.2	61.6	60.9	59.5	59.7	60.5	58.8	60.8	62.2	61.3	58.6	61.0	60.6	60.5	60.6
Soft White Club																
HYAK	57.4	61.7	61.2	57.1	59.3	58.8	60.2	58.3	58.8	61.4	60.3	52.7	59.4	58.8	59.0	59.0
OR920049	57.4	60.1	59.9	54.9	57.0	57.5	57.5	57.3	59.2	60.3	58.0	53.0	57.9	59.1	59.0	57.9
OR920054	60.3	62.2	62.2	59.2	60.0	59.9	59.9	59.1	60.0	60.0	61.8	57.4	60.5	60.3	61.5	60.3
RELY	59.6	60.9	62.0	58.2	59.3	58.3	59.7	58.4	59.5	60.6	60.4	57.5	60.3	58.7	59.2	59.5
ROHDE	61.2	63.5	62.9	59.7	61.1	59.8	61.4	59.5	60.8	63.0	61.7	60.1	61.0	60.4	61.5	61.2
TRES	59.8	61.6	62.3	56.9	60.8	59.7	60.9	59.7	60.9	61.5	61.4	58.0	60.7	60.2	61.1	60.4
WA7752	61.4	62.1	62.9	60.0	61.5	60.9	60.2	59.7	61.0	63.1	62.0	60.4	60.8	60.2	61.4	61.2
WA7793	57.5	58.4	60.2	56.9	58.7	57.6	57.5	56.9	58.3	58.9	58.4	55.4	58.1	58.8	59.7	58.1
Hard Red Common																
ESTICA	55.7	59.4	58.7	56.2	57.5	57.8	58.6	55.8	58.3	59.1	58.4	56.9	58.4	58.5	60.7	58.0
NURSERY MEAN	59.7	62.1	61.7	58.8	59.5	59.4	60.3	58.1	60.2	61.4	60.9	57.9	60.0	60.0	60.4	59.9
CV (%)	1.5	1.0	0.7	1.4	1.9	1.0	1.4	1.0	1.9	1.2	0.7	3.2	0.9	1.3	1.4	1.6
LSD @ .10	1.1	0.7	0.5	1.0	1.3	0.7	1.0	0.7	1.6	0.8	0.5	2.1	0.6	0.9	1.0	0.5

Analysis Method - General Linear Models Proceedure

1997 WINTER WHEAT

Stephen S. Jones

Growers planted over 2.25 million acres of winter wheat for the 1997 crop year. Madsen, Eltan and Stephens were the three most popular common white varieties, accounting for almost 83% of the total winter wheat acreage in Washington State. Hard red replaced white club as the second most popular class of winter wheat at 9% and 8% respectively.

Accomplishments

Yield and disease trials are now being conducted at 23 locations statewide. Seven are in the low rainfall zone (<12"), 8 in the intermediate zone (12-18"), and 8 in the high rainfall zone (>18").

A Cephalosporium nursery was established at Pullman in the fall of 1996. There is currently no chemical control or resistant wheat varieties to combat this disease. From crosses made to wild wheat grasses, approximately 1000 new lines were field-tested and almost 600 exhibited Cephalosporium resistance. The resistant lines are continuing to be tested under severe Cephalosporium infestation and the best selections will be entered into preliminary yield trials this fall.

1997 was the second continuous year for severe snowmold in the northern counties of the State. Snowmold is a fungal disease that attacks wheat plants under conditions of long-term, constant snow cover and unfrozen soil. In Douglas County the snow cover typically lasts for one to two months. The threshold for disease development is about 100 days of constant snow cover. This past crop year (1996-97) there were more than 150 days of snow cover in some areas. As can be seen in the following table, none of the available wheats are truly resistant. The rating scale used is 0 = no regrowth to 8 = 100% regrowth, so higher numbers indicate a higher tolerance to the disease.

Snowmold (Mansfield, WA 1996 & 1997)

	Snowmold Rating		Yield (bu/a)		Test Wt. (lbs/bu)	
	97	96	97	96	97	96
WA7833	**5.0**	**5.7**	**68**	**88**	**58.1**	**57.9**
Sprague	5.8	5.0	53	77	61.7	60.6
Eltan	4.8	3.5	63	73	55.7	57.8
Edwin	**4.5**	**3.3**	**61**	**63**	**61.0**	**61.3**
Moro	4.3	3.2	53	55	60.0	58.3
Tres	2.7	2.4	35	48	60.7	59.8
Rely	2.8	2.2	26	56	57.0	60.4
Rohde	1.5	2.0	28	31	58.3	61.2
Madsen	2.7	1.5	34	11	59.5	54.5
Stephens	2.0	0.0	17	6	58.5	49.0

Results

WA7833, a soft white common, was approved for Preliminary Breeder's Seed Increase (the last step before full release approval). It is potentially an Eltan replacement for the northern areas of the State, as this wheat will give those growers an earlier maturing, stronger snowmold resistant variety. WA7833 has been in 14 field trials the past 2 years and its average yields have exceeded those of Madsen and Eltan across the State. In the snowmold areas it generally outyields Eltan and Sprague while maintaining a similar test weight.

1997 Statewide averages (8 locations)				
	WA7833	Madsen	Eltan	Sprague
Yield	77.5	61.6	73.9	66.0
Test wt.	**58.6**	59.9	58.9	60.1
Eyespot*	**1.52**	1.00	1.64	-
Coleoptile	**67**	62	65	-
Plant ht.	**34.0**	34.4	35.4	34.6
Heading date	**153**	163	167	160

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Edwin (WA7834) was approved for Cultivar Release this spring. Edwin, a tall soft white winter club, is a Moro replacement. Moro was released in 1965 and is the predominant SWW club variety grown in the low rainfall areas of the State. Moro is highly susceptible to stripe rust. It has excellent emergence ability, but exhibits weak straw strength and is extremely susceptible to lodging. Edwin has superior straw strength, adult plant stripe rust resistance and emergence that is equal to Moro. Its average plant height is three inches shorter than Moro, has excellent winterhardiness and good snowmold resistance. In the Moro production area 24 site-year mean, Edwin out yielded Moro by 8 bu/a and had a 2 lbs/bu heavier test weight. Foundation seed should be available in the fall of 1999.

Mean values for 1997 Moro production area						
Test*	# sites	**Edwin**	Moro	Rely	Tres	Rohde
Yield	12	**68.0**	64.1	68.1	69.3	64.0
Test wt.	12	**60.6**	59.0	61.0	60.2	60.1
Protein	12	**9.2**	9.6	9.8	**	**
Flour yield	12	**69.1**	69.5	67.0		
Milling	12	**88.6**	87.4	84.7		
Cookie	12	**9.5**	9.7	9.3		

*Higher values better, except for Protein, **data unavailable

WA7835 was approved for Preliminary Breeder's Seed Increase in 1997. This is a hard white winter wheat that outyields Eltan and Madsen in the high rainfall areas. The Wheat Marketing Center in Portland and the Western Wheat Quality Lab have both confirmed good noodle quality. However, final release is being delayed until further input from Asian buyers is obtained on its end-use quality.

1997 Statewide averages	WA7835	Madsen	Eltan	Rod
Yield	**73.8**	73.9	74.7	85.3
Test wt.	**60.6**	59.5	59.5	58.9

1997 mean quality values			
Test*	WA7835	Eltan	Arlin**
Test wt.	**60.6**	59.5	61.4
Protein	**10.0**	10.0	11.0
Mix time	**4.3**	4.1	3.4
Color	**83.3**	84.4	79.0

*Higher values better for all tests
**Kansas hard white winter

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1997 Hard Red Yield Trial Summary

Variety	St. And.	Connell	Finley	Horse Heaven	Average
Estica (European hard red)	55.7	81.2	79.8	55.0	68.7
WSUN9408908	74.4	67.0	59.5	58.4	64.9
WSUN9408903	74.3	66.1	64.4	54.9	64.9
Eltan	80.3	70.6	52.7	50.7	63.6
Finley	64.0	66.3	63.6	55.5	62.4
WSUN9100902	76.7	69.3	53.3	49.0	62.1
WSUN9205002	64.0	61.6	63.8	56.2	61.4
WSUN9410001	63.2	60.0	54.4	61.9	59.9
Buchanan	72.4	53.5	61.5	50.6	59.5
Symphony	63.2	71.0	47.9	49.3	57.9
QH 542	51.6	68.3	64.3	44.2	57.1
Weston	60.4	63.4	45.7	46.2	53.9
Hatton	56.9	56.0	53.4	47.9	53.6
Wanser	51.4	57.4	48.9	40.2	49.5

W S U
WinterWheat

1997 Soft White Yields (bu/a)

Low Rainfall

Variety	St. Andrews	Connell	Finley	Horse Heaven	Average
VH94755	76.5	83.3	73.3	66.5	74.9
Hiller	80.6	73.9	72.5	59.5	71.6
Rod	63.9	82.1	66.8	66.7	69.9
Lewjain	69.1	73.5	62.5	66.2	67.8
WA7768	69.2	63.3	65.9	66.8	66.3
Eltan	81.7	60.3	56.4	53.9	63.1
WA7813	65.5	64.2	58.2	62.7	62.7
Daws	59.1	73.9	67.5	49.8	62.6
Madsen	60.6	72.3	64.7	52.1	62.4
Sprague	78.7	64.2	57.9	46.1	61.7
WA7835	67.0	64.5	61.6	50.8	61.0
Stephens	46.9	70.3	52.0	57.0	56.6
Arlin	57.0	44.4	43.9	38.3	45.9

Intermediate Rainfall

Variety	Hartline	Ritzville	Average
WA7768	97.2	90.0	93.6
Rod	97.1	89.4	93.3
VH94755	93.5	85.5	89.5
Hiller	91.8	84.4	88.1
Lewjain	82.3	82.2	82.3
Eltan	86.1	77.5	81.8
WA7813	71.8	90.9	81.4
WA7835	82.5	75.2	78.9
Stephens	77.4	74.0	75.7
Daws	73.4	76.6	75.0
Arlin	71.0	75.8	73.4
Madsen	72.9	67.6	70.3
Sprague	68.8	70.7	69.6

High Rainfall

Variety	Walla Walla	Colton	Pullman	Average
Rod	134.3	105.7	75.5	105.2
WA7813	129.4	91.5	84.3	101.7
VH94755	131.4	89.4	79.4	100.1
Madsen	127.9	88.1	78.0	98.0
Stephens	118.8	91.3	70.2	93.4
Hiller	107.9	98.3	72.4	92.9
WA7768	128.3	71.3	75.1	91.6
WA7835	121.6	88.1	62.7	90.8
Sprague	115.7	81.8	72.8	90.1
Daws	119.1	87.8	63.3	90.1
Eltan	116.0	69.9	84.0	90.0
Arlin	130.6	68.8	65.8	88.4
Lewjain	120.2	68.3	69.7	86.1

****

Winter Wheat Breeding Personnel

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The Washington State University Winter Wheat Breeding Program would like to thank the WWC, WAWG, WSU Extension Agents and University colleagues, Grower Cooperators, and other concerned parties for their assistance in the continuing improvement of Washington wheat varieties.

USDA–ARS WHEAT BREEDING & GENETICS

J.A. Anderson, J.A. Pritchett, L.M. Little, R.E. Allan (Collaborator)

Soft White Winter Wheat Variety Development.
Three hundred seventy four crosses were made in 1997. Parents included elite breeding materials and germplasm for genetic studies. Approximately 17,000 F3-F5 headrows were evaluated based on agronomic phenotype and disease reaction. Two hundred and sixteen of 1115 F_4 lines were selected based on agronomic phenotype, micro-sedimentation test, grain protein, and kernel hardness. Two hundred forty four lines were evaluated in yield tests grown at 2 to 9 locations. Two club lines [WA7854 (ARS9615) and WA7855 (ARS9623)] were advanced to the Western Regional Performance Nursery, and one soft white common (WA 7853, a reselection of WA7794) was advanced to the Washington Extension trials. WA7855 has outyielded Coda, Rely, Rohde, and Hiller in 1996 and 1997. The club variety Coda (WA7752) was officially released and foundation seed is being produced. Coda combines high end-use quality and yield potential, with footrot resistance. A total of 389 experimental lines in yield trials and more than 10,000 early generation lines have been added to our project from the former Oregon club breeding program based in Pendleton. Germplasm originating from Pendleton and Pullman are being grown at locations in both Oregon and Washington for 1998 harvest.

Tall Clubs.
The goal of this project is to breed club wheat varieties that will perform well in the low rainfall areas. The approach emphasizes selecting lines that equal Moro for emergence characteristics while exceeding it for disease resistance, yield potential and club wheat quality. The 1997 ARS tall nursery consisted of 41 experimental lines and 5 check varieties. Two of these lines, ARS96329 and ARS96342 are believed to contain the semidwarfing gene *Rht8* that does not reduce coleoptile length as do the semidwarfing genes that are present in most PNW varieties. Despite having small seeds, ARS96329 emerges as well as Moro and has outyielded Moro by an average of 10% at low rainfall sites in 1996 and 1997. Lodging resistance of ARS96329 is better than Moro, but not as good as other semidwarf clubs. Quality has been acceptable. This line is currently being reselected to remove plants containing undesirable glutenin patterns and is a candidate for pre-release in 1999.

ARS96343, Stephens with its semi-dwarfing gene removed by backcrossing, emerged significantly better than Moro in field tests in 1996 and 1997. Unfortunately, it has low yield potential, averaging 5% less than Moro at low rainfall sites in 1996 and 1997. Additional study is needed to determine if the superior emergence of this line is related to its relatively large seed size. This line is being used in crosses to improve emergence of new germplasm.

High quality advanced club selections were identified that express outstanding resistance to strawbreaker foot rot. These lines definitely have the gene (*Pch1*) for resistance that occurs in Hyak. Results from Tim Murray's lab indicate that these lines do not have a second gene (*Pch2*) for footrot resistance. One experimental line, ARS9557, was confirmed by Murray's lab to contain both footrot resistance genes *Pch1* and *Pch2*. This line did not show increased resistance compared to Hyak and Coda, which contain only *Pch1*. Other experimental lines will be tested for the presence of both genes to verify this result in other genetic backgrounds.

Grain Quality Evaluations.

More emphasis is being placed on selecting for grain quality prior to preliminary yield testing. During the winter of 1996/97, test weight, grain protein, kernel hardness, and micro-sedimentation (correlates with gluten strength) were run on 1115 lines prior to entry in 1998 yield trials. Almost 40% of these lines were eliminated from the breeding program due to quality alone. This should result in fewer lines having to be discarded due to poor grain quality during the expensive and time-consuming yield testing stages. The microsedimentation test is being thoroughly investigated for use in screening early generation club lines for end-use quality. Genetic studies are in progress to map genes influencing grain quality parameters, including preharvest sprouting resistance.

SPRING WHEAT BREEDING AND GENETICS: 1997 PROGRESS REPORT

K. Kidwell, B. Barrett, V. DeMacon and G. Shelton

Overview: The primary goals of the spring wheat breeding and genetics program are to 1) release profitable cultivars for production in each climatic zone in WA State; and 2) develop molecular and genetic technologies to improve the effectiveness and efficiency of the breeding program. Specific objectives are to 1) increase grain yields of spring wheat varieties to improve economic viability; 2) improve end-use quality of spring wheat grain to increase the market demand for WA wheat; and 3) incorporate genetic resistances to primary disease and insect pests into spring wheat varieties to reduce input costs and diminish the risk of environmental contamination through inorganic chemical use.

1. Field Breeding Program:

Over 400 crosses were made in 1997, and novel genes conferring resistance to the Hessian fly and the Russian wheat aphid were incorporated into adapted soft white, hard red, hard white and spring club germplasm (Table 1). More than 16,000 lines were advanced or evaluated in the field in 1997 (Table 2).

Table 1: Number of soft white (SW), hard red (HR), hard white (HW), spring club, winter/spring (WS), and Russian wheat aphid (RWA) crosses made on the spring breeding program in 1997.

	Number of Crosses					
Location	SW	HR	HW	Club	WS	Total
Field	0	0	0	0	0	0
Greenhouse	106	121[1]	138[2]	37	20	422

[1] Includes 70 backcrosses to incorporate RWA resistance genes into elite lines.
[2] Includes 41 backcrosses to incorporate RWA resistance genes into elite lines.

Table 2: Number of breeding lines and/or named varieties evaluated or advanced per generation in spring wheat breeding or variety evaluation field plots in 1997.

	Market Class[1]				
Generation	SWS	HRS	HWS	Club	Total
F_1	126	121	138	37	422
F_2	449	384	344	240	1417
F_3	291	187	96	92	666
F_4	322	327	44	4	693
F_5	3840	6240	1920	140	12140
F_6	460	379	2	4	845
F_7	102	63	13	0	178
F_8	46	48	0	0	94
$\geq F_9$	45	60	20	1	125
Total:	5681	7809	2577	518	16585

[1] SWS: soft white spring; HRS: hard red spring; HWS: hard white spring; Club: spring club

Seventh generation lines (178) were evaluated for agronomic performance in replicated field trials, and 219 advanced lines (F_8+) were evaluated at 3 to 12 locations under annual crop, crop/fallow and irrigated conditions (see Spring Wheat Variety Testing Results for 1997). Grain samples from 350 advanced lines with superior agronomic performance were sent to the Western Wheat Quality Laboratory for quality assessment.

3. Early generation selection for end-use quality: High molecular weight glutenin (HMWG) proteins are routinely used in a marker-assisted selection strategy to identify individuals with superior end-use quality potential from segregating progenies for advancement in the breeding program. Seed storage proteins, extracted from half kernels of wheat, are separated in polyacrylamide gels to fractionate the HMWG subunits. Variation for HMWGs has been associated with end-use quality characteristics in wheat. Plants with desirable HMWG patterns for each market class are selected for advancement in the greenhouse and for subsequent field evaluation. More than 2000 spring wheat crossing parents and breeding lines were evaluated for HMWG during 1997 (Table 3).

Table 3: Number of early generation lines, advanced breeding lines and named varieties assayed for high molecular weight glutenin banding profiles in 1997.

	Market Class[1]						
Generation	SWS	HRS	HWS	SC	WXS	Winter	Total
F_1	30	22	77	9	0	0	138
F_2	0	30	246	347[2]	189	0	812
F_3	0	0	0	0	0	0	0
F_4	0	0	0	0	0	0	0
F_5	0	0	126[3]	25	0	0	151
F_6	546[4]	197	2	5	0	0	750
F_7	65	28	11	0	0	0	104
F_8	32	23	0	0	0	0	55
$\geq F_9$	34	41	16	1	0	50	142
Total:	707	341	478	387	189	50	2152

[1]SWS: soft white spring; HRS: hard red spring; HWS: hard white spring;
SC: spring club; WXS: progeny from winter by spring crosses; Winter: winter types
[2]212 were selected for advancement
[3]These HWS were identified among SWS and HRS head row selections.
[4]Includes 147 single plot samples from 1996.

4. Additional Research Efforts:

A. Insect Resistances: Hessian fly (HF) is one of the most destructive pests of wheat, and this insect is most efficiently controlled through the use of resistant cultivars and/or by planting spring varieties early enough to avoid infestation. Currently, only a few HF resistant spring wheat varieties are available, and all of these carry the same resistance gene even though 23 other resistance genes have been identified. The probability of the fly overcoming this resistance would be reduced if cultivars carrying different resistance genes were available for production. The Russian wheat aphid (RWA) also can be problematic in Washington, particularly in dryland areas and in spring wheat fields that were planted late. Several resistance genes to RWA have been identified; however, no RWA resistant spring wheat varieties have been release in the PNW.

Progress: Six new HF and 5 novel RWA resistance genes were incorporated into PNW spring wheat varieties through 3 generations of backcross breeding in the greenhouse. Seed of segregating progenies was sent to Kansas State and Oklahoma State for insect screenings. Resistant lines were returned to Pullman for seed increase, and advanced material from these lines will be evaluated in the field in 1998.

B. Characterizing Spring Growth Habit Genes in PNW Wheat Varieties: Several spring growth habit (SGH) genes have been identified in wheat and at least three are known to be controlled by single, dominant genes (*Vrn*1, *Vrn*2 and *Vrn*3). Results from other studies indicated that cultivars carrying two SGH genes (*Vrn1* and *Vrn3*; *Vrn2* and *Vrn3*) mature earlier and have higher grain yield potential than lines with only one SGH gene; therefore, it may be possible to improve grain yields of spring wheat varieties by manipulating alleles at *Vrn* loci. The objective of this study was to determine which *Vrn* gene(s) is(are) carried by elite, spring wheat germplasm adapted to the Pacific Northwest.

Progress: Identified *Vrn* genes present in 39 spring wheat cultivars from the PNW, and discovered a majority of germplasm in the WSU program carries *Vrn*1. Incorporated parents carrying *Vrn* 2 and *Vrn*3 into the crossing program to create multiple *Vrn* gene combinations in resulting progenies. Developed segregating progenies for genetic linkage map construction to identify DNA tags for each *Vrn* gene. These tags will be used in marker-assisted selection strategies to pyramid superior *Vrn* gene combinations into a single cultivar.

C. Enhancing Hybrid Wheat Performance Via Inter-Growth Habit Crosses: Even though producing winter wheat on the rolling hills of the Palouse and in the light soils of the semi-arid production region has resulted in enormous soil losses due to water and wind erosion, winter wheat production predominates since it is more profitable than producing spring wheat. Since 1995, inter-growth habit (spring by winter) crosses have been made to convert adapted winter wheat varieties to spring types for reseeding purposes. The following observations were made: 1) hybrids created through inter-growth habit crosses are spring type; and 2) hybrids generated via spring by winter crosses are much more vigorous than traditional (intra-growth habit) spring wheat hybrids. Therefore, it may be feasible to increase the grain yield potential of spring wheat by developing hybrids through inter-growth crosses. The objective of this study is to compare the agronomic performance of adapted hybrid wheat varieties generated through intra- and inter-growth habit crosses with the field performance of their inbred parents.

Progress: Established a collaborative effort with HybriTech Seed International to develop and evaluate adapted spring and winter inter- and intra-growth habit hybrids using their chemical sterilization agent, Genesis™.

D. Genetic Diversity: Selection of parents for use in variety development programs is one of the most important decisions made by wheat breeders. Genetic variability permits continual progress in developing high yielding, high end-use quality wheat cultivars; therefore, genetic diversity among parents is essential to deriving superior offspring from crossing and selection programs. Many wheat cultivars of several market classes have been developed that are adapted for production in the PNW; however, little is known about the level of genetic diversity among these varieties. Pedigree information can be used to examine relationships among varieties; however, these data do not account for the effects of selection, mutation or mistaken pollination during cultivar development. The advent of molecular markers has made it possible to estimate genetic diversity among varieties at the DNA level for a large number of genetic markers distributed throughout the genome. The objectives of this study were to *i*) use amplified fragment length polymorphisms (AFLPs) to assess genetic diversity among wheat cultivars adapted to the PNW; and *ii*) compare AFLP and pedigree-based genetic diversity data.

Progress: Results indicated: 1) highest levels of diversity existed between winter and spring germplasm which supports the hypothesis of the hybrid wheat project (Section C); and 2) pedigree records do not accurately reflect differences among cultivars at the DNA level. These data were used to select parents for the hybrid wheat project (Section C).

E. Developing a Non-Destructive, PCR-Based Marker-Assisted Selection Procedure for Strawbreaker Foot Rot Resistance in Winter Wheat: Strawbreaker foot rot is a devastating disease of winter wheat grown in the Pacific Northwest. At least two genes (*Pch*1 and *Pch*2) have been identified that confer resistance to this disease, and two resistant winter wheat varieties, 'Hyak' and 'Madsen', are available for commercial production. During the genetic diversity assessment (Section D), an AFLP fragment was identified that was only present in these two varieties. This fragment is a putative DNA-tag for Strawbreaker foot rot resistance. The objective of this study is to develop a non-destructive, PCR-based DNA marker for Strawbreaker foot rot resistance. This marker will be useful for identifying resistant seedlings among segregating progeny for winter wheat variety development.

F. Monitoring Genetic Responses of Diverse Wheat Populations to Selection in Direct Seeded vs. Conventional Tillage Systems: Direct seeding is an effective method for controlling soil erosion resulting from intensive crop production. However, eliminating tillage passes increases soil moisture levels, reduces soil temperatures and alters fungal pathogen activities compared to conventionally tilled fields. Little information concerning the feasibility of improving the adaptation of wheat varieties to direct seeding systems is available. The objective of this study is to monitor allele frequency changes in progenies of identical parentage that were simultaneously selected in no-till and conventional tillage systems using AFLP analyses. Results will be used to determine whether: a) unique genotypes are advanced through generations of selection in each tillage system; and b) no-till breeding nurseries are essential for developing varieties tailored to production in direct seeded systems.

SPRING WHEAT VARIETY TESTING RESULTS FOR 1997

K. Kidwell, E. Donaldson, V. DeMacon, G. Shelton and P. Reisenauer

Thirty-nine spring wheat entries were evaluated for agronomic performance at thirteen sites in eastern Washington during the 1997 growing season. Planting condition, fertilizer rate, precipitation level and harvest date for each location are listed in Table 1. Grain yields, test weights and protein contents of all entries in each nursery are listed tables 2, 3, and 4, respectively. Precipitation levels were higher than average in 1997 and favorable weather conditions allowed for timely planting at all locations. As a result, grain yields of entries in most nurseries were higher than average. However, during the first week of June, the Ritzville nursery was heavily damaged by hail. The 1997 nursery average of 31 bu/A was 37% lower than the average of the nursery at this location in 1996 (49 bu/A; data not shown). Agronomic data from Ritzville in 1997 reflects the ability of these varieties to recover from hail damage (Table 2), and may not reflect variety performance potential under normal growing conditions. Additional performance information for certified spring wheat varieties can be found in the "1998 Certified Seed Buying Guide for Barley and Wheat, Spring Varieties," published by WSU and the Washington State Crop Improvement Association.

Variety Releases and Promising Experimental Lines

WA7802, named 'Scarlet', is targeted to the semi-arid, hard red spring wheat production region of eastern Washington as a replacement for 'Butte 86'. Based on two year averages for locations with less than 16 inches of average annual rainfall, the grain yield of Scarlet was 4 and 6 bu/A higher than Westbred 926 and Butte 86, respectively (data not shown). Scarlet typically is 1-2 inches shorter than Butte 86, and is 2-4 inches taller than Westbred 926. Scarlet has a slightly lower test weight than Butte 86; however, their grain protein contents are similar in the targeted production region. Scarlet has superior bread baking quality compared to Butte 86, and is moderately resistance to leaf rust. Breeders seed of Scarlet was produced in 1997, and Foundation seed of this variety will be produced in 1998. The PVP status of Scarlet is pending.

The semi-dwarf soft white spring line, WA7850, is targeted as a replacement for Penawawa in the higher rainfall zones of eastern Washington. In 1997, WA7850 had a 2 bu/A higher grain yield average across locations than Penawawa (Table 2). The test weight of this line is similar to that of Penawawa; however, WA7850 has a lower grain protein content. WA7850 heads two days later and is 3 inches taller than Penawawa. Based on preliminary data, WA7850 may be resistant to stripe and leaf rust. The end-use quality of this line is outstanding compared to other soft white spring wheat varieties currently in commercial production in the PNW.

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Table 1. Cultural data for the 1997 WSU spring wheat variety testing trials.

Annual Rainfall (in)	Nursery Location	Previous Crop	lb Base Fertilizer			Planting: Date	Planting: Seeding Rate (lb/A)	Planting: lb Starter Fertilizer			Planting: Planter Type*	Planting: Row Space (in)	Planting: Soil Moisture** (in)	Precip. after planting (in)	Harvest Date	Soil Type
			N	P	S			N	P	S						
< 16	Lind Annual	Spring Wheat	30	0	10	11-Mar	60	4	14	0	HDD	8	6.95	5.06	4-Aug	Ritzville Silt Loam
	Lind Fallow	Fallow	30	0	10	11-Mar	60	4	14	0	HDD	8	8.08	5.06	4-Aug	Ritzville Silt Loam
	Bickleton	Spring Wheat	45	0	0	9-May	60	7	21	0	DD	7	7.54	2.30	10-Sep	Broadax Silt Loam
	Horse Heaven	Winter Wheat	45	20	8	13-Mar	60	7	21	0	DD	7	6.08	1.07	16-Jul	Warden Silt Loam
	Lamont	Winter Wheat	70	0	12	4-Apr	70	7	21	0	DD	7	8.72	2.56	22-Aug	Athena Silt Loam
	Dusty	Winter Wheat	80	0	14	1-Apr	70	7	21	0	DD	7	9.90	2.71	6-Aug	Onyx Silt Loam
	Ritzville	Spring Barley	70	0	5	7-Apr	60	4	14	0	H	8	7.27	3.27	18-Aug	Walla Walla Silt Loam
16-20	Pomeroy	Winter Wheat	75	0	12	2-Apr	70	4	14	0	H	8	7.48	6.52	28-Aug	Athena Silt Loam
	Dayton	Winter Wheat	95	0	0	18-Apr	80	7	21	0	DD	7	8.32	4.8	15-Aug	Athena Silt Loam
	Reardan	Winter Wheat	65	0	4	6-May	80	7	21	0	DD	7	10.90	2.81	9-Sep	Hanning Silt Loam
	St. John	Winter Wheat	70	0	12	16-Apr	80	7	21	0	DD	7	11.73	3.39	14-Aug	Athena Silt Loam
> 20	Pullman	Peas	67	0	25	17-Apr	80	4	14	0	DD	6	10.06	6.89	28-Aug	Palouse Silt Loam
Irrigated	Royal Slope	Corn	150	0	0	24-Mar	90	0	0	0	DD	4	pre-irrigated	na***	11-Aug	Neppel Sandy Loam

* DD = double disc drill; H= Hoe openers, HDD= Heavy double disc

** Inches of moistue in the top 4 ft for all locations except Bickleton where a 3 ft profile was evaluated.

***not available

Table 2. Summary of grain yields of spring wheat varieties grown in the 1997 variety testing trials.

Variety	Seed Status*	Lind Annual Crop	Lind Fallow	Horse Heaven	Bickleton	Dusty	Ritzville	Lamont	Pomeroy	Dayton	Reardan	St. John	Pullman	Royal Slope	Average Across Locations
		-----------Yield (bu/A)-----------													
Soft White															
Alpowa	A	55	63	34	46	71	39	64	77	69	75	78	78	125	67
Centennial	A	51	60	33	45	74	34	63	81	65	69	78	76	114	65
Edwall	A	56	66	36	52	73	33	72	81	70	76	76	77	115	68
Fielder	A	50	60	37	52	69	33	67	78	63	68	71	72	117	64
ID488	E	59	68	35	46	73	34	70	83	69	77	80	81	117	68
Penawawa	A	51	61	34	46	71	35	65	80	60	75	68	72	123	65
Pomerelle	A	64	69	35	52	73	39	66	79	64	71	70	78	133	69
Westbred Sprite	A	50	62	32	40	67	34	61	81	61	70	65	70	118	62
Westbred Vanna	A	61	70	37	53	76	37	69	84	71	74	80	82	138	72
WA7805	E	51	68	34	47	77	37	67	78	68	70	79	63	132	67
WA7831	E	47	66	37	49	77	32	63	89	70	72	77	74	128	68
WA7848	E	50	58	35	44	77	27	64	83	68	67	79	74	118	65
WA7849	E	48	65	34	51	71	30	66	85	63	70	78	74	112	65
WA7850	E	56	71	34	43	73	38	61	78	68	76	80	71	130	67
Wakanz	A	55	67	35	47	68	42	61	80	70	74	71	77	127	67
Wawawai	A	52	65	33	44	73	36	63	82	64	67	74	79	119	65
Whitebird	A	50	67	32	45	68	39	62	80	60	72	76	75	114	65
	Average	53	65	34	47	72	35	65	81	66	72	75	75	122	66
White Club															
Calorwa	R	46	57	31	42	64	26	65	79	65	69	76	72	104	61
Hard Red															
Butte 86	A	40	48	28	39	57	22	56	66	51	59	65	54	95	52
Express	A	49	52	31	38	57	26	57	69	59	62	59	64	110	56
ID462	E	49	60	29	44	59	32	55	74	63	66	66	70	125	61
ID492	E	44	55	30	45	63	27	62	73	62	64	61	69	110	59
Kulm	A	36	42	26	40	50	22	52	58	50	52	58	48	89	48
Spillman	A	53	64	31	42	61	29	62	75	58	66	67	66	113	60
WA7800	E	47	65	30	39	60	31	53	77	66	58	68	69	120	60
WA7802	B	50	63	32	40	62	28	53	75	64	67	66	66	121	60
WA7822	E	45	57	31	50	58	26	64	76	66	68	69	71	108	61
WA7823	E	47	58	32	41	64	26	60	75	65	69	69	62	108	60
WA7824	E	43	53	32	41	61	27	56	77	67	62	69	62	102	58
WA7838	E	42	50	28	40	55	23	48	66	56	56	70	54	105	53
WA7839	E	41	59	30	40	59	28	52	72	60	62	69	64	106	57
WA7845	E	49	55	33	41	63	28	54	73	66	64	62	63	115	59
Westbred 926	A	40	50	29	40	59	29	54	72	62	58	73	63	105	57
Westbred 936	A	45	58	30	42	60	28	57	74	55	66	71	66	100	58
Westbred 331	E	44	52	32	44	61	25	57	76	69	66	82	71	115	61
	Average	45	55	30	42	59	27	56	72	61	63	67	63	108	58
Hard White															
ID377S	C	54	68	33	43	72	31	68	85	68	70	77	78	124	67
Klasic	A	38	41	27	47	56	24	57	67	52	59	68	58	96	53
OR870453	E	54	63	30	40	65	30	65	77	56	73	70	71	129	63
OR895181	E	56	57	31	42	63	29	63	74	58	69	73	67	120	62
	Average	50	57	30	43	64	29	63	76	58	68	72	68	117	61
Average per location		49	60	32	44	66	31	61	77	63	67	71	69	116	63
LSD (10%)		6.3	7.1	3.8	9.5	7.9	3.2	8.8	4.2	5.9	3.9	9.3	6.8	8.9	3.1

*A = Available; B = Breeder Seed; F = Foundation Seed; R = Registered Seed; C = Certified Seed; E = Experimental Seed

Table 3. Summary of test weights of grain from the 1997 spring wheat variety testing trials.

Variety	Seed Status*	Lind Annual Crop	Lind Fallow	Horse Heaven	Bickleton	Dusty	Ritzville	Lamont	Pomeroy	Dayton	Reardan	St. John	Pullman	Royal Slope	Average Across Locations
		---Test Weight (lb/bu)---													
Soft White															
Alpowa	A	63.0	63.0	60.8	57.8	62.0	61.7	61.5	62.7	61.2	60.2	62.0	62.0	63.7	61.7
Centennial	A	62.9	62.6	60.9	58.6	61.9	60.8	60.6	62.3	61.6	59.6	61.5	61.4	63.1	61.4
Edwall	A	60.5	60.3	58.8	54.1	59.6	58.2	59.7	60.2	57.5	58.3	58.4	58.6	61.1	58.9
Fielder	A	62.0	61.9	60.0	57.8	61.0	59.8	60.8	61.2	58.9	59.7	59.4	59.6	62.3	60.3
ID488	E	62.8	62.6	60.9	58.7	61.6	60.6	60.7	62.5	61.7	60.3	61.6	61.3	63.3	61.4
Penawawa	A	62.4	62.4	59.9	58.1	61.9	61.3	61.8	62.7	61.6	59.0	61.5	61.0	62.8	61.3
Pomerelle	A	61.8	61.5	60.5	56.9	60.5	59.9	59.7	61.2	60.3	58.7	59.9	59.8	61.3	60.2
Westbred Sprite	A	63.0	62.5	60.3	55.3	61.2	60.3	60.9	61.4	59.3	59.3	59.9	60.1	63.6	60.5
Westbred Vanna	A	62.1	62.0	59.2	55.2	61.2	60.1	60.9	61.9	60.1	59.0	60.8	60.8	62.6	60.5
WA7805	E	62.2	62.2	60.3	58.6	61.8	61.5	61.5	62.7	60.9	59.3	61.6	61.3	62.9	61.3
WA7831	E	62.2	62.8	60.1	57.5	61.3	60.4	60.3	61.7	59.7	59.7	60.6	60.9	63.1	60.8
WA7848	E	62.4	62.9	61.0	58.5	61.4	60.8	60.8	61.8	60.6	59.0	61.0	60.8	63.1	61.1
WA7849	E	62.6	62.6	60.8	59.1	61.1	60.6	60.4	61.5	61.2	58.8	60.6	61.0	63.5	61.1
WA7850	E	62.1	62.0	60.5	57.1	60.8	61.0	60.3	61.9	60.4	59.1	61.0	61.0	62.6	60.8
Wakanz	A	61.5	61.7	59.3	55.7	60.7	60.5	60.1	61.7	60.8	58.7	60.5	60.3	62.2	60.3
Wawawai	A	62.8	62.7	61.3	59.4	62.7	62.2	62.2	63.1	61.1	61.7	62.4	62.4	63.4	62.1
Whitebird	A	62.3	63.0	60.9	57.2	61.3	60.9	60.3	62.0	59.7	59.6	60.4	60.4	62.7	60.8
	Average	62.3	62.3	60.3	57.4	61.3	60.6	60.7	61.9	60.4	59.4	60.8	60.7	62.8	60.8
White Club															
Calorwa	R	61.8	62.2	59.2	57.3	61.8	59.8	60.8	62.0	60.2	58.1	61.1	59.9	61.0	60.4
Hard Red															
Butte 86	A	62.2	62.1	61.7	59.0	61.6	61.1	61.0	62.0	60.8	60.4	61.7	60.9	62.3	61.3
Express	A	61.9	61.8	61.1	56.9	62.0	60.8	62.2	62.6	60.8	60.8	61.3	61.0	62.5	61.2
ID462	E	62.8	62.6	61.2	59.8	61.9	61.1	60.9	61.7	60.5	61.1	60.1	60.6	63.1	61.3
ID492	E	63.2	63.1	61.7	59.5	62.8	61.7	62.7	62.9	60.6	62.0	61.5	61.4	64.1	62.1
Kulm	A	63.0	62.3	61.9	61.0	62.6	62.6	62.8	62.7	62.1	61.6	63.0	61.5	62.6	62.3
Spillman	A	61.6	61.7	60.2	57.3	60.5	60.3	61.4	60.9	58.3	59.9	60.1	59.2	61.7	60.2
WA7800	E	62.9	62.6	60.9	59.8	62.8	62.5	62.9	63.3	61.4	61.1	62.2	61.6	62.9	62.1
WA7802	B	61.7	61.9	60.5	57.6	61.7	60.9	61.6	61.5	59.3	60.6	60.1	60.3	62.3	60.8
WA7822	E	62.8	63.1	61.8	60.0	63.2	62.0	62.4	63.2	61.9	61.2	61.9	61.3	63.2	62.2
WA7823	E	63.1	63.2	62.1	59.2	62.8	61.1	61.6	62.9	61.1	60.7	61.4	61.1	63.5	61.8
WA7824	E	62.5	62.1	61.3	60.1	62.6	61.5	61.9	62.4	60.6	61.5	61.1	61.3	62.6	61.7
WA7838	E	62.8	62.7	61.8	59.7	61.9	62.0	61.7	62.4	60.4	61.5	61.9	61.5	63.1	61.8
WA7839	E	62.7	62.7	61.8	59.1	62.2	61.2	61.7	62.2	60.2	61.1	60.7	60.5	62.9	61.5
WA7845	E	62.5	62.7	61.5	59.0	62.3	61.5	61.9	62.6	60.9	60.8	60.8	61.6	63.1	61.6
Westbred 926	A	62.0	62.1	61.2	58.5	61.1	60.4	61.0	61.5	59.1	60.0	59.9	59.3	62.1	60.6
Westbred 936	A	62.1	61.9	61.1	58.1	61.1	60.7	61.0	61.0	59.7	61.0	60.0	59.8	62.7	60.8
Westbred 331	E	61.5	61.0	59.6	58.5	61.3	59.6	61.3	61.8	60.1	60.3	61.4	61.0	61.9	60.7
	Average	62.4	62.3	61.3	59.0	62.0	61.2	61.8	62.2	60.5	60.9	61.1	60.8	62.7	61.4
Hard White															
ID377S	C	63.6	63.3	61.8	59.7	63.2	62.8	63.0	63.2	61.4	62.2	62.1	62.0	64.3	62.5
Klasic	A	63.3	62.9	61.3	60.8	62.2	61.1	62.4	62.5	61.2	61.1	61.2	59.5	63.8	61.8
OR870453	E	62.5	62.4	61.4	54.7	61.4	60.5	61.2	61.6	60.6	59.7	60.6	60.6	62.6	60.8
OR895181	E	61.2	61.1	59.2	55.7	59.8	58.7	59.6	61.2	58.7	58.8	59.4	59.7	62.0	59.6
	Average	62.7	62.4	60.9	57.7	61.7	60.8	61.6	62.1	60.5	60.5	60.8	60.5	63.2	61.2
Average per location		62.4	62.3	60.8	58.1	61.7	60.9	61.3	62.1	60.4	60.1	61.0	60.7	62.7	61.1
LSD (10%)		0.4	0.5	0.6	1.4	0.4	0.4	0.5	0.4	0.8	0.4	0.7	0.4	0.4	0.3

*A = Available; B = Breeder Seed; F = Foundation Seed; R = Registered Seed; C = Certified Seed; E = Experimental Seed

Table 4. Summary of grain protein contents of spring wheat varieties grown in the 1997 variety testing trials

Variety	Seed Status*	Lind Annual Crop	Lind Fallow	Horse Heaven	Bickleton	Dusty	Ritzville	Lamont	Pomeroy	Dayton	Reardan	St. John	Pullman	Royal Slope	Average Across Locations
		-------------Protein Content (%)-----------													
Soft White															
Alpowa	A	11.6	11.3	9.8	8.9	8.4	8.1	7.2	10.1	10.9	8.4	9.3	8.6	12.2	9.6
Centennial	A	11.6	10.9	9.6	8.5	8.9	8.6	7.4	10.6	11.8	8.8	9.4	9.1	11.5	9.7
Edwall	A	11.2	11.2	9.7	8.9	8.9	8.5	8.0	10.4	12.0	9.1	9.8	9.5	11.7	9.9
Fielder	A	11.4	11.6	9.7	7.9	9.3	8.6	8.2	10.5	12.1	8.7	10.1	9.2	12.5	10.0
ID488	E	11.0	11.5	9.7	8.5	8.7	7.9	7.0	9.8	11.7	8.6	9.6	9.1	11.4	9.6
Penawawa	A	10.7	11.1	9.5	8.6	9.3	8.6	7.6	10.6	12.0	8.4	9.5	8.8	12.2	9.8
Pomerelle	A	11.2	10.7	9.3	8.4	8.4	8.4	7.3	9.5	11.2	8.5	9.1	8.9	10.5	9.3
Westbred Sprite	A	11.9	12.2	10.1	8.6	9.5	8.9	8.0	10.5	12.5	8.9	9.4	9.7	12.2	10.2
Westbred Vanna	A	11.7	11.3	9.8	8.2	8.5	7.7	7.5	9.8	11.6	8.3	8.9	8.7	11.8	9.5
WA7805	E	10.3	11.2	9.9	8.3	8.9	8.5	8.3	10.2	12.2	8.7	8.8	8.8	11.4	9.7
WA7831	E	11.4	11.6	10.2	9.1	9.4	9.0	8.0	10.3	11.8	9.4	9.8	9.3	12.3	10.1
WA7848	E	11.1	12.0	10.4	8.5	9.5	9.5	8.2	10.3	11.9	9.4	9.2	9.6	12.2	10.1
WA7849	E	11.8	11.7	9.9	8.5	9.0	9.0	7.8	10.2	11.7	9.0	9.5	9.6	12.3	10.0
WA7850	E	11.5	10.8	9.8	9.0	9.2	8.6	7.5	10.1	11.8	8.9	9.6	9.0	11.2	9.8
Wakanz	A	11.9	11.7	10.3	9.2	9.0	8.9	8.1	10.0	11.7	9.0	10.6	9.2	11.7	10.1
Wawawai	A	12.2	12.5	10.3	9.2	9.7	9.0	8.3	10.2	12.4	9.9	9.7	9.9	12.5	10.4
Whitebird	A	10.6	11.9	9.5	8.5	9.4	8.4	8.1	10.4	12.4	8.6	9.6	9.9	11.6	9.9
	Average	11.4	11.5	9.9	8.6	9.1	8.6	7.8	10.2	11.9	8.9	9.5	9.2	11.8	9.9
White Club															
Calorwa	R	11.4	12.0	10.1	9.2	9.0	9.9	8.3	10.7	11.9	9.4	9.6	9.3	11.5	10.2
Hard Red															
Butte 86	A	13.3	14.3	11.5	9.6	10.8	11.6	9.4	13.1	13.9	10.9	11.4	12.2	16.1	12.2
Express	A	14.8	13.9	12.0	10.4	10.3	10.8	9.7	11.7	13.6	11.2	11.3	11.3	14.1	11.9
ID462	E	13.6	12.6	11.7	9.6	10.3	9.8	8.6	12.4	13.1	10.7	11.3	11.4	14.0	11.5
ID492	E	14.9	14.8	11.8	9.0	9.6	9.8	8.7	12.1	13.7	10.5	10.9	11.1	15.0	11.7
Kulm	A	14.2	16.1	11.9	10.2	11.8	12.1	10.9	14.2	14.9	11.7	12.8	12.8	17.3	13.1
Spillman	A	14.3	14.1	11.9	9.6	10.3	10.2	10.4	12.4	13.8	10.3	11.0	11.7	13.8	11.8
WA7800	E	12.3	12.4	11.7	9.4	9.4	9.3	9.0	11.5	13.2	10.1	10.4	10.3	14.4	11.0
WA7802	B	13.3	13.1	12.0	9.9	9.5	10.2	9.6	11.6	13.8	10.5	11.2	11.2	14.2	11.5
WA7822	E	13.5	14.2	11.3	8.9	9.7	9.9	8.2	11.5	12.7	10.3	10.4	11.2	14.0	11.2
WA7823	E	12.5	13.6	11.2	9.8	9.1	9.2	7.4	10.7	12.9	10.4	10.0	10.4	13.5	10.8
WA7824	E	13.4	13.4	12.4	9.8	10.3	10.0	9.2	11.7	13.0	10.3	10.3	10.9	14.3	11.5
WA7838	E	15.0	14.8	12.1	9.1	11.0	10.0	9.5	12.9	14.3	10.8	11.9	11.6	15.1	12.2
WA7839	E	14.5	14.8	12.0	10.1	10.6	10.6	9.2	11.8	13.5	11.9	11.2	11.5	14.4	12.0
WA7845	E	13.4	13.1	11.5	9.9	10.0	9.8	9.4	12.8	13.9	11.6	11.8	11.7	13.9	11.8
Westbred 926	A	14.7	14.3	13.0	10.9	11.1	10.7	9.4	12.4	13.4	12.2	11.3	11.7	14.1	12.2
Westbred 936	A	14.4	14.7	11.3	10.5	10.2	10.0	8.6	12.3	13.6	11.2	11.1	11.3	14.3	11.8
Westbred 331	E	12.7	13.5	11.6	9.7	10.4	10.4	8.9	11.0	13.3	10.4	10.4	10.6	15.3	11.4
	Average	13.8	14.0	11.8	9.8	10.3	10.3	9.2	12.1	13.6	10.9	11.1	11.3	14.6	11.7
Hard White															
ID377S	C	12.0	11.5	11.0	9.0	8.7	9.1	8.0	10.7	12.4	9.1	10.5	9.9	12.8	10.4
Klasic	A	12.9	15.0	10.5	9.8	10.9	10.4	8.3	11.0	13.0	11.0	10.2	9.9	13.6	11.3
OR870453	E	11.3	11.7	10.7	10.4	9.0	9.1	8.0	10.6	11.6	9.4	10.3	9.6	12.1	10.3
OR895181	E	12.5	12.4	11.0	9.5	9.6	9.9	8.3	10.8	11.5	9.5	9.8	9.8	13.3	10.6
	Average	12.2	12.7	10.8	9.7	9.6	9.6	8.2	10.8	12.1	9.8	10.2	9.8	13.0	10.6
Average per location		12.5	12.7	10.8	9.3	9.6	9.5	8.5	11.1	12.7	9.9	10.3	10.2	13.2	10.8
LSD (10%)		1.2	0.8	0.5	0.8	0.8	0.4	0.8	0.7	0.8	0.6	2.1	0.6	0.7	0.1

*A = Available; B = Breeder Seed; F = Foundation Seed; R = Registered Seed; C = Certified Seed; E = Experimental Seed

TRANSGENIC BARLEY IN FIELD TRIALS

Diter von Wettstein, Jintai Huang, Steve Ullrich, Judy Cochran, Henny Horvath, Oi Wong

In a recent survey of the current status of the commercialization of transgenic crops it is shown that this biotechnology has been adopted faster than any other technology in agriculture. Thus in 1996 7 million acres of commercialized transgenic crops were grown, while the global area of transgenics increased to 31.5 million acres in 1997. With 44% corn is the most frequent planted transgenic crop in the US , followed by tomato (12%), soybean (11%), potato (11%), cotton (8%), tobacco (4%), melon/squash (4%), canola (2%), and sugar beet (1%). As to the improved traits of these transgenic crops 30% concern herbicide-tolerance, 24% insect resistance, and 21% product quality, whereas viral and fungal resistance are also prominently represented. In corn transgenic resistance to the cornborer is a major success, as is bollworm control in cotton. Among the quality traits a changed fatty acid composition and a novel hybrid seed technology ranks high on the agenda in canola. In corn and potatoes higher starch storage content and different chemical composition of starch has been achieved.

In the last few years it has become possible also to genetically transform wheat and barley. In wheat transgenic lines are under development in which a gene for a special high molecular weight glutenin (1Ax1) has been inserted in additional copies and provides a 71% increase of this glutenin in the grain resulting in drastically improved dough elasticity and bread making quality. Another example is provided by the transgenic barley plants which synthesize a protein-engineered, thermostable (1,3-1,4)-beta-glucanase during germination and as we know from experiments of the last few months during malting. It is this transgenic barley that we work on at Pullman and which is in field trials at the Spillman farm for the third year and this year also at the Royal Slope station. It may be pointed out that genetic transformation is an additional tool for the plant breeder complementing breeding by selection, hybridization, mutation, polyploidy and chromosome engineering but not substituting for these techniques.

Advantages of providing added value to crops by transformation with single genes.
In the use of genetic transformation for breeding the first step is to isolate and improve a useful gene from a plant, an animal, a microorganism or the human being. The gene is cloned and propagated in a bacterium or a yeast species and then inserted into the chromosomes of a new host plant. The advantage is that one adds a single known gene to the genome of the plant instead of adding a whole chromosome with many known and unknown genes as it happens in the traditional breeding by crossing. The new gene to be added is well characterized: one knows the region that codes for the protein or enzyme and the different signal and regulatory sequences in the DNA of the gene.

There are two technologies available to transform barley and wheat. In the ballistic method one shoots the DNA on small gold mikroprojectiles with a diameter of 0.001 mm into the scutellum part of the 1-2 mm large immature zygotic embryos of the developing grain. The holes made by these small bullets in the cell walls and plasma membrane of the embryo cells are so small that they can be repaired by the living cell. Individual cells of the scutellum pieces are regenerated by tissue culture into somatic embryos and these into transformed barley plants. The progenies of such transformed or transgenic plants are growing in the field nursery at the Spillman farm.

Over the last year we have adapted a transformation method that in our hands is more efficient than the ballistic method. It is the method employing the disarmed soil bacterium, *Agrobacterium tumefaciens* that is generally used to transfer genes into dicotyledonous crop plants such as soybeans, peas, squashes, cotton or tomatoes. The *Agrobacterium* causes crown galls, that is tumors, on wounded plant parts by transferring a piece of T-DNA from its Ti-plasmid into the plant cell through the thick cellulose wall that surrounds the cell. The T-DNA is directed to the chromosomes in the cell nucleus and the two DNA borders, the left and the right border, effect the insertion of the T-DNA into the chromosomes. The T-DNA contains three tumor inducing genes. These are transcribed and translated into enzymes, that together with the plant's enzymes produce extra amounts of 2 hormones. The transformed cells no longer differentiate into roots and shoots but grow as unorganized lumps of tumor cells and produce special amino acids that are used by the *Agrobacterium* as food. After basic research had clarified these aspects of tumor formation, the tumor inducing genes were removed from the T-DNA in the Ti plasmid and the disarmed bacterium is used to transfer novel and useful genes into our crop plants. The desired gene is inserted between the two DNA border elements of the disarmed plasmid , the *Agrobacterium* transformed with the plasmid and co-cultivated - in our case- with the scutellum of immature barley embryos. The DNA with the inserted gene or genes moves from the bacterium into plant cells and from these we regenerate transgenic plants as with the ballistic method. To obtain first generation transgenic grains takes about a year.

Tailoring a new malt enzyme

Malt production and brewing of beer or alcohol free beer is based on the prominent heat stability of alpha-amylases. The number of barley varieties which can be used for malting and brewing though is limited by the low heat stability of another important malt enzyme, (1,3-1,4)-beta-glucanase. During malting the aleurone and scutellum cells synthesize the enzyme (1,3-1,4)-beta-glucanase and deliver it to the endosperm for liquification of the cell walls which enclose the starch grains deposited in the course of grain maturation in the field. As the cell walls are removed , the alpha-amylases - also synthesized by the aleurone cells and secreted into the endosperm - can reach the starch grains and begin to hydrolyse these into sugar. During steeping and germination of the many tons of barley, the malster wishes to get rid of the endosperm cell walls and distribute the alpha-amylases uniformly throughout the endosperm. However he wishes at the same time to hydrolyse as little starch as possible, since the production of fermentable sugars for the wort is to take place only later in the mashtun. Therefore the germination of the grain is discontinued at the end of the malting by drying the grain on a kiln at temperatures of 76 to 85 ^{0}C. Alpha-amylases survive this heat treatment and can work in the mashtun. Here the starch of the milled malt is converted at temperatures up to 70^{0}C into sugars to serve as nutrients for the beer-producing yeast.

The beta-glucanase does not survive kiln drying and can therefore not act in the mashtun. This causes a dilemma for the malster and brewer. The low heat stability of the beta-glucanase forces him to get rid of the beta-glucans of the endosperm walls as completely as possible before kiln drying. Otherwise partially degraded polymers will dissolve during mashing and make the wort to viscous for straining and filtration. If the malster germinates the grain to long to avoid this problem, he risks to loose so much starch that the yield of sugars in the brew-house, becomes unacceptably low. Synthesis in the barley grain during germination of a beta-glucanase that matches the heat stability of the alpha amylases would avoid these problems and, more important, allow a better utilization of the grains carbohydrate stores: During mashing a larger portion of starch and a considerable amount of beta-glucans could then be utilized for sugar production. To achieve this goal a heat-stable betaglucanase has been tailored and the gene has been inserted into barley plants of the malting cultivar *Golden Promise*, the only variety that can be transformed with a reasonable efficiency. The senior author brought these transgenic plants to Pullman, when he transferred from the Carlsberg Laboratory at Copenhagen to WSU.

Bacillus species synthesize and secrete (1,3-1,4)-beta-glucaneses with the same specificity for converting the cell wall beta-glucans into sugars as the barley enzymes. Their heat stability is slightly better but not good enough for the purpose. When hybrid genes were constructed with the polymerase chain reaction (PCR) and these expressed in the bacterium *E.coli,* it was discovered that hybrid enzymes combining portions of the polypeptide from *Bacillus amyloliquefaciens* with portions of the polypeptide from *Bacillus macerans* were more heat stable than enzymes of both parents. In a hybrid enzyme containing 12 N-terminal amino acids from the *amyloliquefaciens* enzyme and the rest from the *macerans* betaglucanase residue 13 was deleted. This yielded so far the best hybrid enzyme and increased its half-life at 70^0C from 6 minutes to more than 4 hours. Pilot mashing experiments with hybrid enzyme demonstrated the power of the enzyme in degrading large amounts of beta-glucans at high temperature in the mashtun. The gene encoding the enzyme was provided with the barley alpha-amylase gene promoter and the code for the alpha-amylase signal peptide, which is required for the transport from the site of synthesis to the outside of the aleurone cell. Surprisingly, transfection of aleurone cells yielded no enzyme.

It was earlier found that beta-glucanase and alpha-amylase genes of barley use a special set of nucleotide triplets ending with a G or a C to determine the amino acids which have to be added to the growing polypeptide chain. Out of 215 codons specifying the amino acid sequence of the mature enzyme, 141 were changed to fit the aleurone specific code. This led to excellent synthesis of the enzyme in transfected aleurone cells and the gene could now be expected to function according to intention in transgenic barley plants.

The transgenic barley plants produce the tailored novel enzyme during malting
Green-house analyses and field trials at Pullman in 1996 and 1997 provided the following results: The gene for the heat-stable (1,3-1,4)-beta-glucanase has been inherited faithful over four consecutive generations. Homozygous plants contain twice as many gene copies as heterozygous plants. The expression of the gene and the synthesis of the transgene product has been determined by immunofluorescence microscopy to follow the same time course as the endogenous barley high pI alpha-amylases. The protein is synthesized in the scutellum and aleurone tissue and secreted and distributed across the endosperm during germination. The heat stable (1,3-1,4)- beta-glucanase was purified by immunoaffinity chromatography from transgenic grains and shown to be fully active. Based on measurements of the activity it is estimated that at least 20mg of active enzyme can be produced per kg of grain during malting. Western blot analyses show that the amount of recombinant protein synthesized in the different transgenic lines corresponds to the

different levels of enzyme activity determined. 27 homozygous lines comprising 9800 plants have been harvested from the 1997 field trial and between 0.5 and 4.5 kg of transgenic grain has been obtained from some of the lines. A first series of micromaltings with the equipment available at the Department of Crop and Soil Sciences has been completed successfully. Four lines contained 0.87, 0.84, 0.19 and 0.09 μg of heat-stable (1,3-1,4)-betaglucanase per mg of protein in green malt after a standard steeping and germination program . Excellent survival of the activity of the enzyme during kilning up to 80°C was observed, while no activity of the barley endogenous enzyme survived. Production of the endogenous barley (1,3-1,4)-betaglucanase during malting corresponded to a level of 0.05 to 0.1 μg per mg protein.

Prospects

We expect to harvest from the propagations at Royal Slope some 30 kg of our best transgenic lines. This grain is to be used in micromalting trials to assess its malt quality by analyzing congress worts for extract yields, total nitrogen, free amino nitrogen, diastatic power, total protein and beta-glucans according to the methods of analysis of the American Society of Brewing Chemists. This will tell if the expected benefits of the heat-stable enzyme are realized. These are the possibility to shorten the malting time by one or two days because of the opportunity to carry out the depolymerization of the beta-glucan walls to a large extent in the mashtun rather than in the Saladin boxes of the malting plant. This in turn should increase extract yield (i.e.fermentable sugars) in the wort used in the production of beer and non-alcoholic beverages. It should increase the amount of high molecular weight proteins required for foam stability and cling. It should change the soluble nitrogen profile in various ways allowing the production of beverages with specialized tastes (providing defined brewers yeast strains are used).The malt containing the heat-stable enzyme will consistently result in worts of low viscosity.

It is necessary to move the transgene from *Golden Promise* into varieties adapted to the Pacific Northwest such as the high yielding cultivar Baronesse. It will be a challenge to see if the transfer of the gene expressing the heat-stable (1,3-1,4)-beta-glucanase can convert Baronesse from a feed barley into a malting barley. The F_3 generation of appropriate crosses are to be analyzed for segregation in this year's nursery.

Efforts are under way to obtain transformants expressing the gene for the heat-stable beta-glucanase in developing grain, so that the enzyme is present in the mature grain. According to a large number of investigations the digestion of barley endosperm walls in monogastric animals is limited by their inability to synthesize (1,3-1,4)-beta-glucanase. This reduces the feeding value of barley for chicken and piglets. Presence of the protein engineered heat-stable betaglucanase enzyme in the mature grain will improve the feeding value of barley, because the enzyme will survive the heat developed during feed pellet pressing and pasteurization to kill *Salmonella* infections. It can then act in the small intestine of the animals.

The extensive expression of the heat stable (1,3-1,4)-beta-glucanase in the aleurone and the large amount secreted into the endosperm has elicited the interest to use the germinating barley grain as a bioreactor to produce proteins of pharmaceutical or nutriceutical importance in the malting plant. We will report on these endeavors next year.

1997 VARIETY TESTING PROGRAM SPRING BARLEY

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V. A. Jitkov and J. S. Cochran

The 1997 spring barley variety trials were conducted at seven locations in four Eastern Washington counties. Complimentary nurseries in six additional locations were grown in cooperation by the breeding program. Forty-six varieties were tested. These included seventeen 6-row and twenty-nine 2-row entries. Four additional lines were grown in the irrigated nursery at Lind. Varieties in the trials included all significant publicly released varieties from the Pacific Northwest, public varieties from the tri-state nurseries being considered for release and private varieties entered on a 'fee for entry' basis.

Spring planting weather was excellent. All nurseries were planted on a timely basis and established well. The growing season provided ample moisture with a cool period for early plant growth. The Farmington nursery data was not included due severe variation and the Fairfield nursery was lost to an infestation of wild oats. Harvest was completed during the normal period. Grain yields and quality were both excellent. Overall, Baronesse was the top yielding variety, averaging 2.5 tons per acre. A Western Plant Breeders selection, BZ 549-19 was second, yielding 2.25 tons per acre. Steptoe remained the top yielding 6-row barley at 2.2 tons per acre. Test weights for all the 2-row entries were at least 50 pounds per bushel, with the 6-row entries weighing in the 48 to 50 pounds per bushel range.

The results from the trials and the WSU breeder's trials were summarized and reported in the spring Washington State Crop Improvement Seed Buying Guide. The variety performance results were also reported in the Washington Association of Wheat Growers Green Sheet, Wheat Life, each of the county agent's newsletters and placed on the Internet for electronic access.

1997 SPRING BARLEY VARIETY TRIAL SUMMARY
YIELD (LBS/A)

VARIETY NAME	RITZVILLE	LIND DRYLAND	BICKLETON	PULLMAN	DUSTY	LAMONT	REARDAN	LIND IRRIGATED	DAYTON	ST. JOHN	POMEROY	VARIETY MEAN
6-Row												
MOREX	1589	2439	2948	2343	3229	3079	3199	3652	3952	4374	3145	3086
STANDER	1159	2381	3125	2900	3544	3255	3797	4065	4146	4533	4207	3374
STEPTOE	2213	2779	3471	3528	4403	4730	4310	5115	5143	5714	6775	4380
WA 10142-93	1878	3740	3170	3891	3979	3788	4459	4229	5062	5025	5364	4053
WA 10178-93	2011	3219	3299	2862	3972	3957	4277	4088	5156	5232	5391	3951
WA 10494-93	2149	3301	3132	3524	3867	3813	4299	4265	4983	5327	5198	3987
WA 17866-94	1986	2620	3118	2747	3869	3484	4040	3801	5012	5296	3733	3610
WA 18009-94	1576	2906	3670	4046	4100	4055	4438	4196	5327	5451	6157	4174
WA 18060-94	1695	2840	3005	3558	4144	3575	4098	3833	5473	5313	5830	3942
WA 8069-93	1801	2546	3206	3565	3508	4018	3758	4055	5406	4891	6110	3897
WA 8201-93	1934	2769	3221	3390	3802	3860	3938	3562	5170	5199	5071	3810
WA 8217-93	1944	3383	3170	3612	4011	4142	4020	4018	4997	5188	5093	3962
WA 9307-93	1819	3353	3439	4193	4634	4234	4656	4643	5154	6273	4587	4271
WA 9339-91	1943	3135	3346	3239	4254	4314	4377	5023	5278	5321	4556	4071
WA 9792-90	2192	3112	3317	3951	3835	4830	4778	4069	5485	5090	5813	4225
WA 9812-93	1563	2859	3119	3778	4337	4711	4405	4803	5115	5194	6313	4200
2-Row												
2B91-4947	.	.	.	4606	.	.	.	4910	.	.	.	.
2B92-5550	.	.	.	3980	.	.	.	3935	.	.	.	.
2B94-6337	.	.	.	4163	.	.	.	4895	.	.	.	.
ALEXIS	2693	3656	3237	4175	4107	4841	4465	5036	5246	5108	5926	4408
ANT-2110	2717	3371	3601	4482	4264	4244	4879	4606	5247	6103	6459	4543
B1202	.	.	.	3729	.	.	.	4496	.	.	.	.
BANCROFT	2394	3658	3201	3803	3972	4797	4337	4297	4577	5027	5231	4117
BARONESSE	2973	3630	4062	5056	4515	5624	5266	5663	5358	6806	6228	5016
BZ 594-19	2329	3772	3482	4625	4277	4970	4498	5170	5291	5891	5840	4559
CA 808505	2482	3340	3210	3846	4160	3985	4612	4636	4830	5679	5466	4204
CAMELOT	2438	2941	3444	4100	4093	4278	4091	3762	4937	5259	5398	4067
CAMINANT	2833	3638	3567	4596	4189	3946	4717	4328	5264	6029	6618	4520
CHINOOK	2407	3575	3540	4190	4167	3903	4146	4043	5134	5182	5243	4139
CREST	2321	3215	3081	3947	3851	4320	3944	4442	4464	4530	5090	3928
GALLATIN	2395	3463	3503	3846	3963	4318	4375	4549	4996	5009	5030	4131
GARNET	2397	3447	3516	3435	3780	4358	4227	4019	4850	4735	4854	3965
HARRINGTON	2291	3667	3206	3940	4104	4294	3929	4572	4853	4965	5375	4109
MELTAN	2770	2960	3820	4313	4260	5110	4409	4452	5244	5418	6426	4471
ORCA	2204	2726	3153	3898	3210	4255	3454	4208	5085	4806	5000	3818
RIVIERA	2474	3303	3650	4406	4345	4762	4390	4427	5128	5566	6141	4417
TR-133	2039	2862	3048	3661	3953	3698	3847	4321	4507	5041	3234	3655
WA 7114-93	2750	3619	3578	4339	4183	3950	5014	5127	5182	5370	5775	4444
WA 7642-92	3121	3522	3732	4470	4177	4459	5040	4443	5298	5788	5942	4544
WA 7758-89	2637	3010	3690	3871	4356	4126	4508	4841	5475	5333	5884	4339
WA 8394-93	2969	3354	3513	4443	4367	3937	4514	4544	5396	5682	5926	4422
WA 8529-93	2613	2982	3401	3885	4054	3817	4302	4249	5255	5374	5420	4123
WA 8611-90	2498	3397	3405	4482	3924	3897	4606	4521	4844	5296	5805	4243
WA 8625-90	2636	3075	2995	3569	4200	3846	3864	3999	4958	5114	5557	3983
WA 8770-93	2747	3493	3301	3999	4109	3895	4484	4119	5178	5989	5725	4276
WA 8772-93	2988	3175	3779	4091	4045	4197	5119	4592	5249	5895	5752	4444
WA 9088-94	2614	3510	2874	4167	4194	4301	4521	4562	4933	5501	5384	4233
WA 9504-94	2817	3537	3637	4158	4249	4234	4587	4719	5306	5878	5681	4436
Hulless												
BEAR	2284	2281	2220	3176	3352	3400	3277	3684	3524	3745	3705	3150
CONDOR	2183	2888	3026	3313	3307	3887	3931	3988	4125	4707	4686	3640
NURSERY MEAN	2315	3184	3331	3878	4026	4163	4308	4391	5013	5309	5394	4119
CV %	11.5	14.0	17.0	6.1	12.8	18.2	10.5	15.1	6.4	9.3	6.6	11.8
LSD @ .10	362	603	768	323	698	1025	614	901	436	670	485	230

Analysis Method - General Linear Models Proceedure

1997 SPRING BARLEY VARIETY TRIAL SUMMARY
TEST WEIGHT (LBS/BU)

VARIETY NAME	RITZVILLE	LIND DRYLAND	BICKLETON	PULLMAN	DUSTY	LAMONT	REARDAN	LIND IRRIGATED	DAYTON	ST. JOHN	POMEROY	VARIETY MEAN
6-Row												
MOREX	47.3	51.3	50.2	50.9	51.7	50.9	49.8	51.6	49.8	51.4	51.9	50.6
STANDER	48.7	49.9	50.5	51.2	51.3	51.1	49.5	51.8	51.2	53.0	53.6	51.1
STEPTOE	45.6	50.3	47.2	48.0	48.7	49.1	49.0	48.6	45.9	49.8	50.2	48.4
WA 10142-93	45.5	50.6	46.5	50.1	49.5	48.4	48.1	49.6	48.8	51.5	52.2	49.2
WA 10178-93	45.1	49.7	46.8	49.3	49.0	48.6	48.1	50.6	47.2	50.6	51.1	48.7
WA 10494-93	48.3	52.5	49.8	51.8	51.8	51.4	50.8	52.9	50.7	53.0	53.7	51.5
WA 17866-94	48.7	51.8	48.1	51.4	51.6	50.6	50.5	51.8	49.6	51.3	53.1	50.8
WA 18009-94	43.9	48.4	45.3	48.1	48.7	48.2	48.7	49.5	45.8	49.1	50.7	47.8
WA 18060-94	43.6	49.1	46.2	48.4	47.5	48.1	47.2	48.5	47.5	49.3	50.5	47.8
WA 8069-93	44.1	47.6	46.0	48.4	48.8	46.6	47.0	48.7	47.1	48.7	50.2	47.6
WA 8201-93	47.1	50.8	49.5	50.9	50.4	49.3	48.5	50.3	49.9	52.1	52.8	50.1
WA 8217-93	47.5	51.1	48.5	50.9	50.1	49.2	48.6	49.7	49.1	51.5	51.5	49.8
WA 9307-93	45.4	47.5	46.4	48.8	49.8	48.7	47.6	49.2	46.6	49.7	50.4	48.2
WA 9339-91	48.5	51.0	48.1	50.6	50.4	49.7	49.1	51.0	49.6	52.2	52.5	50.2
WA 9792-90	48.4	51.7	47.9	51.2	50.6	50.1	49.5	49.7	49.8	51.4	52.8	50.3
WA 9812-93	43.8	48.9	44.1	49.0	48.7	47.7	48.6	50.5	45.9	49.8	51.2	48.0
2-Row												
2B91-4947	.	.	.	51.5	.	.	.	52.0	.	.	.	.
2B92-5550	.	.	.	53.1	.	.	.	52.5	.	.	.	.
2B94-5337	.	.	.	52.9	.	.	.	53.4	.	.	.	.
ALEXIS	50.0	52.5	50.1	51.5	51.9	51.0	51.0	52.3	51.5	53.3	54.7	51.8
ANT-2110	49.2	51.6	48.5	52.1	50.8	51.1	49.7	51.3	50.2	53.2	54.2	51.1
B1202	.	.	.	52.2	.	.	.	52.5	.	.	.	.
BANCROFT	49.2	53.0	50.4	51.8	51.7	52.3	50.9	52.6	50.3	51.8	53.7	51.6
BARONESSE	49.8	52.9	50.4	53.3	53.1	53.0	51.4	53.7	51.0	53.0	55.8	52.5
BZ 594-19	50.6	52.7	50.8	53.8	52.9	53.0	51.3	53.7	51.3	54.3	55.2	52.7
CA 808505	48.9	51.8	48.8	51.8	51.3	50.7	50.5	52.3	51.0	53.7	54.7	51.4
CAMELOT	51.0	53.7	51.2	54.5	53.5	53.4	52.4	53.9	53.6	54.4	56.0	53.4
CAMINANT	50.6	51.8	48.6	51.7	51.4	51.2	49.6	53.0	50.3	53.1	53.7	51.4
CHINOOK	50.6	53.3	51.2	53.6	53.0	53.4	52.1	53.7	51.2	53.4	55.3	52.8
CREST	50.7	53.1	51.8	53.9	52.9	52.8	52.0	53.7	53.3	54.6	55.9	53.1
GALLATIN	50.4	52.3	52.1	53.6	53.4	53.2	51.8	54.3	53.2	54.6	56.0	53.2
GARNET	48.6	52.2	50.3	51.8	51.0	50.9	50.5	51.2	51.6	51.8	53.9	51.3
HARRINGTON	48.3	53.4	51.4	52.6	51.9	51.5	50.3	53.1	50.3	51.7	53.8	51.7
MELTAN	51.4	53.7	51.5	52.8	53.2	53.0	52.0	53.6	52.0	53.6	54.6	52.9
ORCA	51.0	52.1	51.4	53.1	52.2	51.0	49.7	52.8	50.9	53.3	53.3	51.9
RIVIERA	48.3	52.0	49.3	51.4	51.7	51.4	50.3	52.3	51.3	52.9	54.9	51.4
TR-133	48.3	52.7	50.7	52.4	52.0	51.5	50.9	52.6	51.9	53.4	55.0	51.9
WA 7114-93	48.0	52.4	49.6	51.9	49.7	50.4	49.2	50.9	48.2	50.3	53.6	50.4
WA 7642-92	51.4	52.5	51.4	52.9	52.8	52.4	51.5	53.1	51.2	54.2	56.1	52.7
WA 7758-89	49.8	51.8	50.9	52.1	51.9	51.4	50.5	52.4	52.6	53.5	54.6	52.0
WA 8394-93	48.6	51.7	49.1	51.0	51.0	51.5	50.1	52.3	50.4	52.3	54.6	51.1
WA 8529-93	49.2	53.3	51.6	52.8	52.3	52.0	51.1	53.0	51.4	52.6	54.6	52.2
WA 8611-90	48.8	51.0	49.1	52.1	50.8	50.9	49.8	51.3	49.6	50.5	54.2	50.7
WA 8625-90	49.6	53.1	51.5	53.1	52.4	52.0	51.3	53.7	51.8	53.0	55.2	52.4
WA 8770-93	51.0	53.3	51.4	53.2	52.8	53.1	51.3	53.9	52.6	54.4	54.9	52.9
WA 8772-93	50.6	53.1	50.8	53.5	53.0	52.6	51.8	54.5	53.1	54.3	55.5	53.0
WA 9088-94	48.4	52.3	48.1	52.4	51.4	52.4	50.7	52.9	50.4	53.1	55.1	51.6
WA 9504-94	50.3	52.9	49.4	52.5	51.3	52.1	50.1	53.2	51.1	53.9	54.5	51.9
Hulless												
BEAR	57.3	58.3	56.8	60.0	59.8	58.6	57.9	60.9	59.4	59.5	61.3	59.1
CONDOR	56.6	59.0	60.8	61.9	62.3	59.9	59.5	61.1	60.1	58.5	62.1	60.2
NURSERY MEAN	48.9	52.0	49.8	52.1	51.7	51.3	50.5	52.4	50.7	52.6	54.0	51.5
CV %	1.5	1.3	1.8	0.7	0.8	1.4	1.0	1.9	1.8	2.3	1.0	1.5
LSD @ .10	1.0	0.9	1.2	0.5	0.5	0.9	0.7	1.4	1.3	1.6	0.8	0.4

Analysis Method - General Linear Models Proceedure

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

R. James Cook, Steve Jones, Kim Kidwell, and Jim Anderson

Direct seeding is attracting considerable interest in the Inland Northwest as a means to both reduce soil erosion and improve the profitability of wheat and crops grown in rotation with wheat. One part of the total research and education effort on direct seeding is focused on development and implementation of more diverse cropping systems so as to simultaneously increase the cropping intensity and lengthen the crop rotation. Another aspect of this effort is focused on reducing the risks and increasing the profits for wheat planted directly into cereal stubble. Even with 3- and 4-year crop rotations, because of the lack of alternate crops and ideal conditions for production of cereal grains in the Inland Northwest, winter and spring wheat and spring barley will make up 50-75% of the rotations. Thus, in virtually any direct-seeded cropping system used in the Inland Northwest, half or more of the wheat could be planted into cereal stubble.

Efforts are underway to evaluate the performance of a limited number of advanced lines and standard varieties under direct-seed conditions in the field. The project was begun in 1995/1996 crop year with a spring-wheat test on winter wheat stubble near Dusty and a winter-wheat on spring wheat stubble near Pullman (in the 15th year of continuous direct-seeding). The project was expanded in the 1996/1997 crop year to include two spring-wheat tests near Colfax and Pullman (the site now in the 16th year of direct seeding), respectively, and one winter-wheat test near Colfax. The project was expanded further in the 1997/1998 crop year to include two spring wheat tests near Colfax and Bickleton, respectively, and three winter wheat tests near Colfax, Bickleton, and Pullman (the site now in the 17th year of continuous direct seeding), respectively.

Among the winter wheats, Madsen has not performed as well as Eltan (Table 1). The potential yield for Madsen is high with direct seeding, based on its average yield in 1997 of 106/bu in fumigated plots compared with 72 bu/A in nonfumigated plots. These results point clearly to a role of root diseases in the relatively poor performance of this variety when direct seeded. The yield of Eltan (93 bu/A) in the 1997 test near Colfax was obtained without soil fumigation. Yields of the spring wheats have been good but below their potential, also owing to pressure from root diseases (Table 2). Rhizoctonia root rot and take-all both were important constraints to yield of spring wheat in 1996 at the Dusty site. Yields in the continuous direct-seeded plot at Pullman were exceptionally good for both the winter wheats in 1996 and the spring wheats in 1997 (Tables 1 and 2). Take-all has all but disappeared from this site, owing to the natural conversion of the soil from take-all conducive to take-all suppressive, Rhizoctonia and Pythium root rots both still occur at this site.

These results are still too preliminary to serve as a basis for differentiating varieties for direct-seed systems. Many other factors must also be considered when choosing a variety for direct seeding, including the amount and nature of the straw produced and potential for establishment or persistence as volunteer in the "greenbridge" effect. Nevertheless, the work points positively towards the potential for high yields of wheat seeded directly into cereal stubble.

Table 1. Grain yields (bu/A) of advanced lines and varieties of winter wheat planted directly into spring wheat stubble.

Pullman - 1996		Colfax - 1997	
Variety	Yield	Variety	Yield
Madsen-check	87	Madsen-check	72 c
Eltan	105	Eltan	92 ab
Hiller	102	Hiller	85 bc
VH 094755	105	VH 094755-AW 25	85 bc
VH 091505	111	VH 091505-AW 36	82 bc
VH 091239	106	VH 091739	72 c
VH 092245	100	VHO 94522	84 bc
VH 094753	113	Wa-7835	86 bc
Moro	68	Wa-7832	74 c
VH 094757	114	Wa-7836	76 c
DH 930263	83	Wa-7833	80 bc
DH 940037	91	Wa-7834	73 c
		Wa-7813	76 c
		Wa-7811	75 c
		Madsen-fumigated	106 a

1) This site was in the 16th consecutive year of direct seeding and the 13th wheat crop (14th cereal crop, including one year of spring barley).

Table 2. Grain yields of advanced lines and varieties of spring wheats planted directly into winter wheat stubble.

	Dusty - 1996	Pullman - 1997[1)]
Alpowa	42	66
Edwall	38	72
Centennial	46	64
Penewawa	43	71
Pomerelle	45	57
Vanna	40	67
Wakanz	40	
Wawawai	40	69
Whitebird	47	67
Sprite	39	
ID488		77
ID3775		71
Express		71

1) This site was in the 17th consecutive year of direct seeding and the 14th wheat crop (15th cereal crop, including one year of spring barley).

WHEAT AND BARLEY ROOT DISEASE RESEARCH

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Our research is focused on three major root diseases of wheat and barley. These are: Take-all caused by *Gaeumannomyces graminis*, var. *tritici*; Pythium root rot, caused by several *Pythium* species; and Rhizoctonia root rot, caused by *R. solani* AG8, *R. oryzae*, and *R. cerealis*. These root diseases occur in various mixtures in wheat and barley fields of the Inland Northwest and collectively cause major damage to these crops, especially when these crops are direct-seeded into cereal stubble. Best control is achieved with 3- and 4-year crop rotations that include broadleaf crops alternated with wheat and barley. The practices are also now becoming available to manage these root diseases on wheat and barley seeded directly into wheat or barley stubble. These practices are:

- Eliminate volunteer and grass weeds (the green bridge) in the stubble early, especially for spring cereals seeded directly into cereal stubble, since theses plants can serve as hosts for wheat and barley root pathogens;
- Use "new" seed, preferably current year seed, but no older than 1 to 2 years old, since older seed is more vulnerable to damage caused by *Pythium*;
- Treat the seed with a combination of products active against all three root diseases, including, as options, Dividend/Apron or Raxil/thiram, remembering that seed treatments provide protection mostly against seed and very early root infections;
- At the time of planting, place fertilizer and especially the phosphorus where these nutrients will be readily accessible to the seedling roots, even if the roots are damaged by root diseases;
- Plant the new rows at an angle--any angle up to 90 degrees--to the direction of the previous year's rows, to maximize the amount of seed placed between rather than directly within the rows of old stubble where inoculum of root pathogens is most concentrated;
- Provide for soil disturbance below the seed and not just to the depth of the seed, which helps reduce the amount of infection by *Rhizoctonia*; and
- Clear trash from within the seed row, which also helps reduce infection by *Rhizoctonia*, possibly by exposing the soil surface in the row to slightly greater warming and drying.

While mixtures of root diseases are the rule and not the exception, the importance of any one component in the mixture can vary with soil conditions and cropping practices. For example, the more acidic clay type soils typical of the very southeastern edge of Washington and adjacent northern Idaho favors Pythium, whereas the neutral-alkaline, lighter-textured soils favor *R. solani* AG8. Barley in the rotation favors *R. solani* AG8, wheat favors take-all, and peas favor *Pythium ultimum*. We have only recently begun to examine wheat after bluegrass where we find heavy pressure from both *Pythium* and *Rhizoctonia*. A treatment designed to control just one component can sometimes favor another component in the mixture. Our research program is continuing to a) identify and learn more about the species and subspecies of wheat and barley root pathogens; b) find out more about how soil conditions and practices favor different mixtures of these pathogens; and c) develop the means to control the entire mixture.

Seed treatment chemicals are available to control components but not all of the pathogen-mixture responsible for seed infections and seed rot, and they do little to protect against any of the pathogens responsible for root rots. For example, Apron controls *Pythium* attack of seeds, but can leave the germinating seed vulnerable to attack by *Rhizoctonia*. A combination of Dividend + Apron or Raxil + Thiram controls both pathogens on seeds and very young seedlings, but the plants are still vulnerable to take-all as well as root infections by *Rhizoctonia* and *Pythium* species. Thiram and Captan control seed-infecting pathogens only, although neither of these fungicides is as effective as Apron against *Pythium*. Dividend on seed controls seed infection and possibly some root infection by *Rhizoctonia* and take-all but has no affect on *Pythium*. We are continuing to test existing new seed treatment fungicides for activity against one or more of the wheat and barley root pathogens.

The good news is that one of the three root diseases, namely take-all, subsides and eventually all but disappears from fields cropped continuously to wheat. This remarkable phenomenon, known as "take-all decline," has been observed wherever wheat is grown throughout the temperate world. The bad news is that, in eastern Washington, take-all decline requires 12-15 years of wheat monoculture. Nevertheless, we have documented take-all decline in many fields in the Inland Northwest, including with long-term direct-seeding (no-till).

Unraveling the mechanisms responsible for take-all decline has revealed one of the most fascinating soil microbiological processes ever discovered. Our research traces back to experiments started in eastern Washington more than 30 years ago, and it has continued to develop. To encapsulate: after one or more outbreaks of take-all, and with continued cropping to wheat, the make-up of soil bacteria in the rhizosphere (rhizobacteria) shifts towards types that produce antibiotics inhibitory to the wheat take-all fungus. This is a natural defense system provided by rhizobacteria that forms a kind of symbiosis with the roots of wheat. The work shows further that the strains responsible for this defense are both highly adapted as wheat root colonists and they produce the antibiotic 2,4-diacetylphloroglucinol. We now have a gene test that allows us to identify where the populations of this particular antibiotic-producing rhizobacteria are sufficient to control take-all.

The obvious practical direction to go with our research is to develop the technology for introduction of these bacteria into the rhizosphere of wheat. We began to investigate this approach in the early 1980s, including field tests in cooperation with growers. All of our tests starting about 10 years ago have been on winter and spring wheat seeded directly (no-till) into cereal stubble--conditions under which root disease control is most needed. Our biggest challenge has been to find the right strains. Our program has moved progressively though a succession of strains always selecting for better strains. The process is similar to breeding and selecting new varieties of crops. Table 1 gives yield data for Madsen winter wheat treated with two of our most promising strains and seeded directly into stubble of spring wheat southwest of Colfax. Note that these bacteria are not only compatible with the currently-available seed-treatment chemicals, they enhance the yield beyond what can be achieved with these chemicals.

One problem with the naturally occurring bacteria responsible for take-all decline is their antibiotic control take-all but not Rhizoctonia or Pythium root rots. Other antibiotics are needed to protect wheat from these root diseases. During the past year, one of our best phloroglucinol-producing strains was transformed to express genes from another rhizobacterium for production of an antibiotic more inhibitory to Rhizoctonia and Pythium. This transformed strain with ability to produce TWO antibiotics was shown in greenhouse tests during the past winter to be active against all three root diseases. Both the U.S. EPA and the WSU BioSafety Committee have approved our proposed field test with this engineered strain, which was planted on the WSU Plant Pathology Farm in late April. It is still too early to report on the results.

The next step towards delivery of this technology into use by growers is to license the strains and their use to a company. We are currently into discussions with several companies.

Future efforts will continue to concentrate on combining our best strains of biocontrol bacteria with the seed-treatment chemicals with best cultural practices for root disease control in no-till systems. Ultimately, we expect to have varieties of wheat and barley with resistance to at least some of the root pathogens to complete the package.

Our research has been supported by the Washington and Idaho Wheat Commissions, the Washington Barley Commission, the O.A. Vogel Wheat Research Fund, the USDA's National Research Initiative Competitive Grants Program, and many growers and agribusiness cooperators.

Table 1. Yields of Direct-Seeded Madsen Winter Wheat in 1997 in Response to Treatment with Strain Q8R1.

Seed Treatment	Yield (bu/A)
Check	72
Q8R1 (biological)	81
Dividend + Apron	79
Dividend + Q8R1	79
Raxil - Thiram	84
Raxil - Thiram + Q8R1	84

CEPHALOSPORIUM STRIPE AND STRAWBREAKER FOOT ROT

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Strawbreaker foot rot 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 precip.) of Washington State, but also cause significant losses in the lower rainfall areas. Both diseases are most severe on early-seeded winter wheat, especially when planted following summer fallow, and for both diseases, the yield in fields where disease is severe may be only half of that where disease is not a problem. The snow mold diseases are limited to the northernmost wheat-producing areas of Lincoln and Douglas Counties and southern Okanogan County where snow cover frequently persists for 100 days or more.

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.

Growing disease resistant varieties is the most reliable method of controlling Cephalosporium stripe; however, true resistance to this disease does not exist in cultivated wheat. Several winter wheat varieties adapted to the Inland Pacific Northwest have been identified that are tolerant of the disease (Table 1). Over the past three years, Eltan has consistently had the greatest yield and has been among the commercial varieties with the least Cephalosporium stripe of those tested. Two adapted breeding lines, WA7437 and REA9232, have also proven to be very tolerant of Cephalosporium stripe. A better source of resistance to Cephalosporium stripe has been found in the wheat x wheatgrass hybrid AT3425. Studies are in progress to determine the number and location of genes in AT3425 conferring resistance to Cephalosporium stripe so they can be transferred 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.

A foliar fungicide applied in the spring before jointing and the use of the foot rot resistant variety Madsen are the two most common tools used for control of strawbreaker foot rot. Although the level of resistance in Madsen is very effective for control of strawbreaker, additional resistant varieties adapted to intermediate- and low-rainfall areas are needed. We developed the GUS seedling test to screen wheat for resistance to Strawbreaker foot rot in the greenhouse. This test, which can be completed in two months, is being used to identify and transfer new sources of resistance in wild relatives of wheat to cultivated wheat. To date we have identified and named two new genes for resistance to strawbreaker. In conjunction with Dr. Stephen Jones, the winter wheat breeder, we are in the process of transferring these genes to adapted winter wheat varieties. Our first goal is the development of an Eltan-like wheat with resistance to strawbreaker foot rot.

Table 1. Cephalosporium Stripe Variety Trial, WSU Agronomy Farm 1997.

Variety	Market class	Disease index[a]	Yield, bu/A	Test wt., lbs/bu
AT 3425[b]	perennial	8.9	66.9	55.5
WA 7437[c]	club	23.0	81.2	57.3
Lewjain	SWW	31.5	55.4	56.5
Madsen	SWW	35.9	45.5	53.4
CI 13113[c]	HRW	40.2	44.7	60.2
Nugaines	SWW	43.2	45.3	54.5
REA9232[c]	club	46.4	69.3	55.1
Rod	SWW	48.1	58.3	54.0
Eltan	SWW	48.2	71.6	55.3
Kmor	SWW	51.8	63.3	55.7
Cashup	SWW	53.5	47.2	55.7
GWB80-112[c]	SWW	54.6	53.2	56.2
Stephens	SWW	55.3	16.1	48.4
Hill 81	SWW	55.3	40.6	54.1
Winridge	HRW	57.1	44.8	57.8
REA9257[c]	club	58.0	56.4	51.6
Daws	SWW	58.4	39.2	55.0
Sprague	SWW	60.8	40.3	54.9
Lambert	SWW	65.3	42.6	51.8
Gene	SWW	74.7	15.4	50.5
LSD[d] 5%		17.3	13.1	1.8

[a]- Disease index ranges from 0 to 100 and is a combination of the percent infected stems and disease severity on those stems. A 0 represents no disease and 100 is uniformly severe disease. Larger numbers are associated with greater yield loss.
[b]- AT 3425 is a wheat-wheatgrass hybrid that is perennial.
[c]- Experimental lines used as controls or sources of resistance to Cephalosporium stripe.
[d] - Least significant difference: Two figures in the same column must differ by this amount to be considered statistically different.

Fungicides will continue to be an important tool for strawbreaker control until resistant varieties adapted to all production areas of Washington State are available. Last year about 200,000 acres in Washington were treated with a fungicide for strawbreaker. We tested several fungicides in a field plot near Ralston, WA on Eltan winter wheat. Disease incidence was greater than 80% infected stems at the time of fungicide application on April 2, 1997. There were small but significant differences among treatments for disease control (Table 2) however there were no significant differences in yield or test weight. The lack of yield differences are attributed to the relatively cool, wet spring, which delayed and/or reduced water stress that normally occurs and which allowed infected plants to compensate for the disease. Based on this study, the experimental treatments tested were no more effective than currently available commercial products. This work is continuing with several new materials that are being examined for their effectiveness in controlling strawbreaker in a plot near Ritzville.

Table 2. Disease index, yield and test weight of Eltan winter wheat treated with foliar fungicides for the control of strawbreaker foot rot on the Knodel farm, Ralston, WA 1997.

Treatment	Rate, ai/A	Disease index	Yield, bu / A	Test Wt., lbs / bu
Untreated Control	-	64.0	74.7	61.3
RH7592 +	0.094 lbs	60.8	74.7	61.0
Latron CS7	0.125 %			
RH7592 +	0.094 lbs	56.5	74.2	61.6
Latron CS7 +	0.125 %			
Mertect 340F	0.360 lbs			
Mertect 340F	0.360 lbs	52.6	80.8	61.4
Tilt +	1.70 oz	56.1	83.5	61.7
Topsin-M4.5F	0.35 lbs			
LSD 5%		3.4	0.2	5.0

[1]- Disease index is a product of the percent infected stems and disease severity and ranges from 0 to 100, where 0 is no disease and 100 is uniform severe disease. Larger numbers are associated with greater yield loss.

[2]- Fungicides were applied in 20 gal water per acre on 2 April 1997. Disease evaluations were made 30 June when plants were in the milky ripe stage of kernel development. Harvest occurred on 29 July 1997. Eltan soft white winter wheat.

SOIL WATER USE AND GROWTH OF RUSSIAN THISTLE AFTER WHEAT HARVEST

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Russian thistle (*Salsola iberica*) is a major broadleaf weed in the low-precipitation dryland wheat production region of the inland Pacific Northwest. Russian thistle infestation is frequently acute when wheat stand establishment is poor and during drought years. The weed produces substantial dry matter after wheat harvest, extracting soil water below the available range for wheat.

Study Methods

In a 2-year study at the WSU Dryland Research Station at Lind, WA (9.5 inch average annual rainfall), selected Russian thistle plants were allowed to grow without competition from neighboring thistles in a field of spring wheat. After grain harvest, neutron probe access tubes were installed at distances of 1, 2, 3, 5, and 10 feet from each selected thistle. The measurement taken 10 feet from the thistle was our check treatment, where we assumed no water extraction by the thistle would occur. Beginning in early August and continuing until killing frost in October, we measured soil water use by six different Russian thistle plants to a depth of six feet every 10-to 14-days. In addition, we measured dry matter and seed production from thistles of similar size to our target plants on each of the sampling dates.

Results

At time of harvest of spring wheat in early August of 1996 and 1997, individual Russian thistle plants had already used about 20 gallons of water (Fig. 1) and produced about 150 grams of dry matter (Fig. 2). By October of both years, each thistle had consumed about 40 gallons of water and produced 1300 grams of dry matter, i.e., about a nine-fold increase in dry matter.

Soil water extraction by depth and time in relation to distance from the Russian thistle plant for 1996 and 1997 is shown in Fig. 3 and Fig. 4. In both years, most of the soil water was extracted within a 3-foot radius of the thistle. There was little difference in soil water extraction between measurements obtained at 5 versus 10 feet from the thistle until late September, at which time significant quantities of water were extracted at the 3-to 6-foot soil depth 5 feet away from the plant. These data agree with root scans obtained by Bill Pan of WSU showing prolific rooting by Russian thistles at soil depths below 3 feet.

Russian thistle plants did not start to produce seeds until late September either year (Fig. 5) when they began to become water stressed. At time of killing frost in October, thistles had produced about 70,000 and 20,000 seeds in 1996 and 1997, respectively.

Results from this study show the value of controlling Russian thistle after wheat harvest in marginal production years to conserve soil water and minimize weed seed production. We plan to write a complete report on this study after data have been fully analyzed.

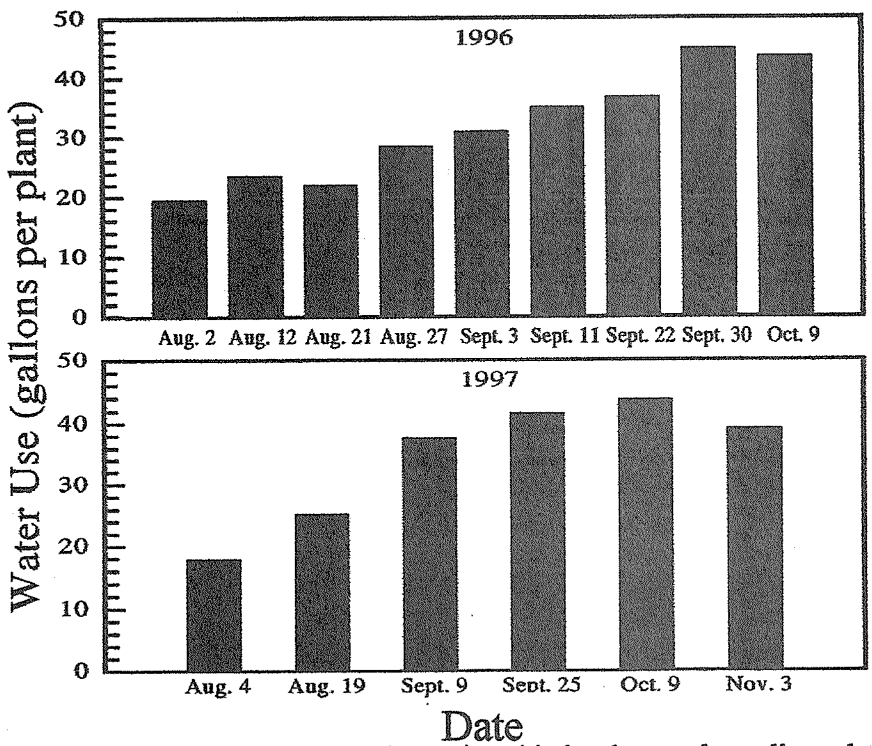

Fig 1. Average soil water use by individual Russian thistle plants when allowed to grow undisturbed in spring wheat stubble from early August until killing frost in October in 1996 and 1997.

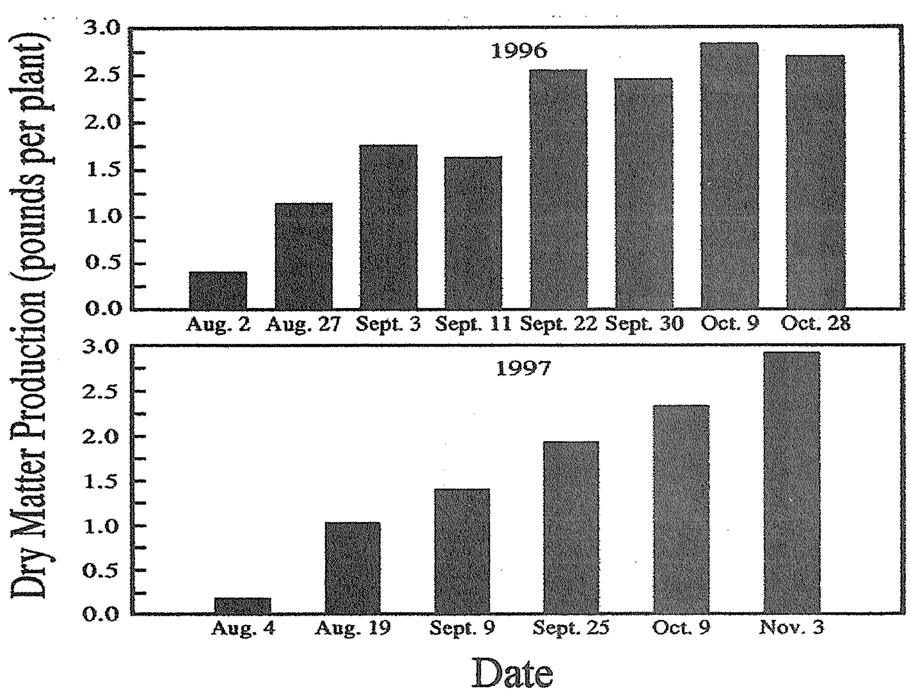

Fig. 2. Dry matter production of Russian thistle plants allowed to grow undisturbed in spring wheat stubble from early August until October in 1996 and November in 1997.

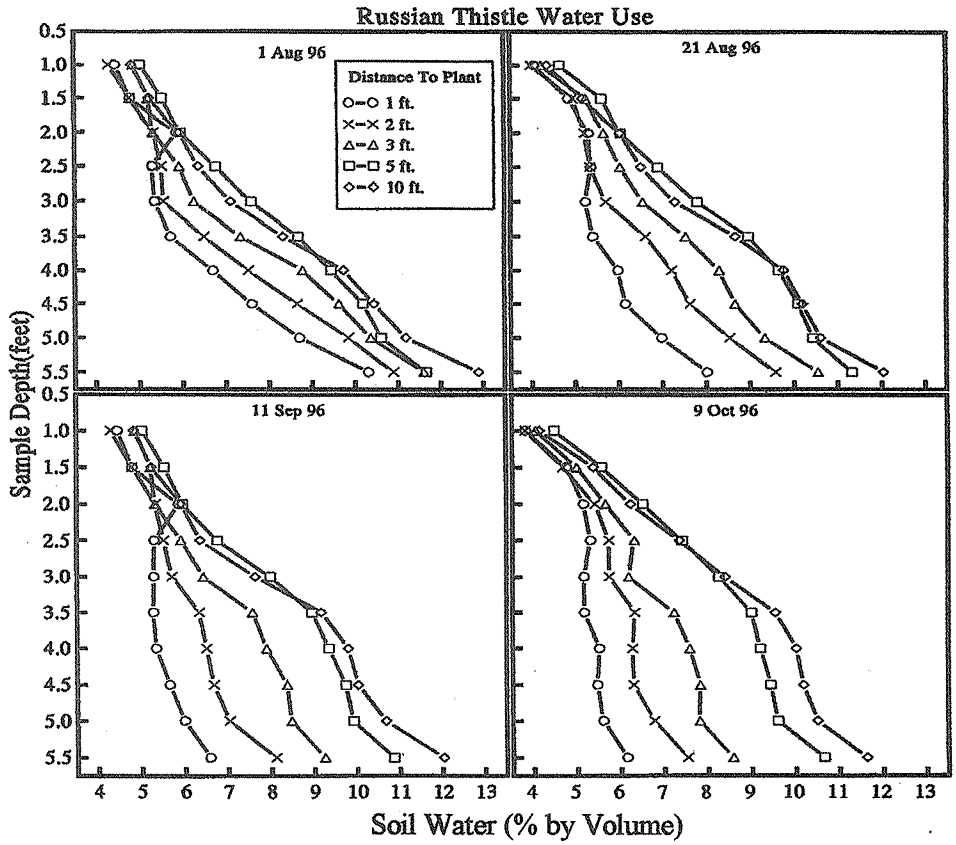

Fig. 3. Russian thistle water extraction at 1, 2, 3, 5, and 10 feet from the plant to a soil depth of 6 feet on four sampling dates in 1996.

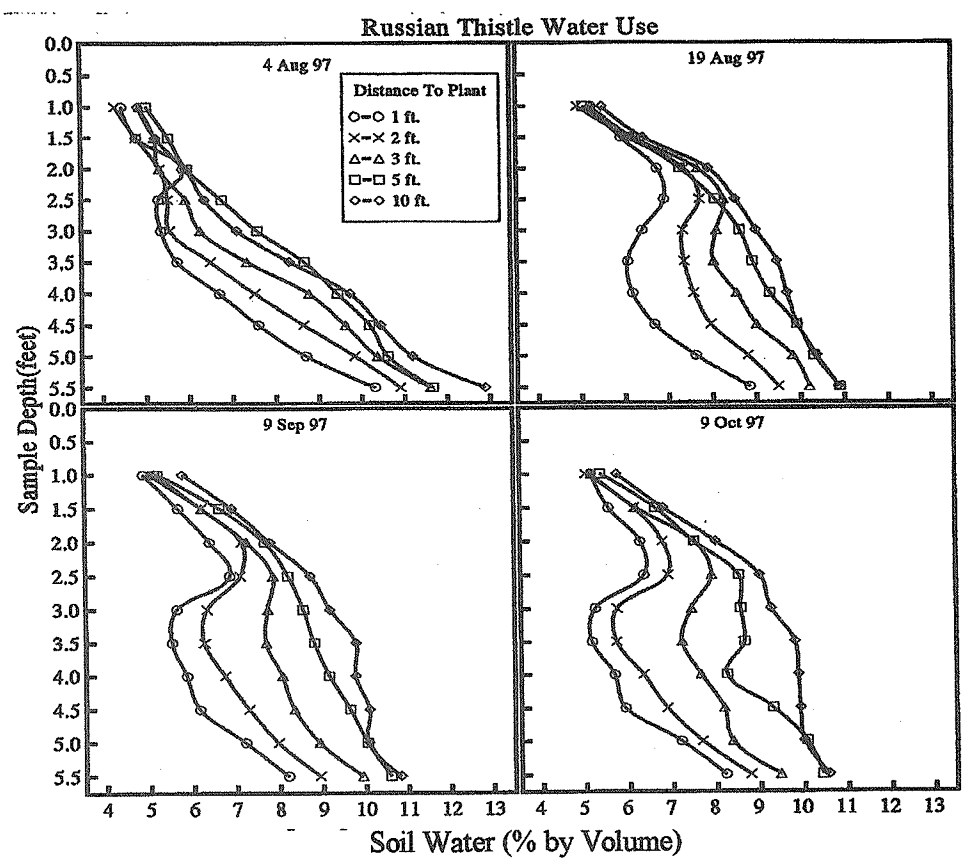

Fig. 4. Russian thistle water extraction at 1, 2, 3, 5, and 10 feet from the plant to a soil depth of 6 feet on four sampling dates in 1997.

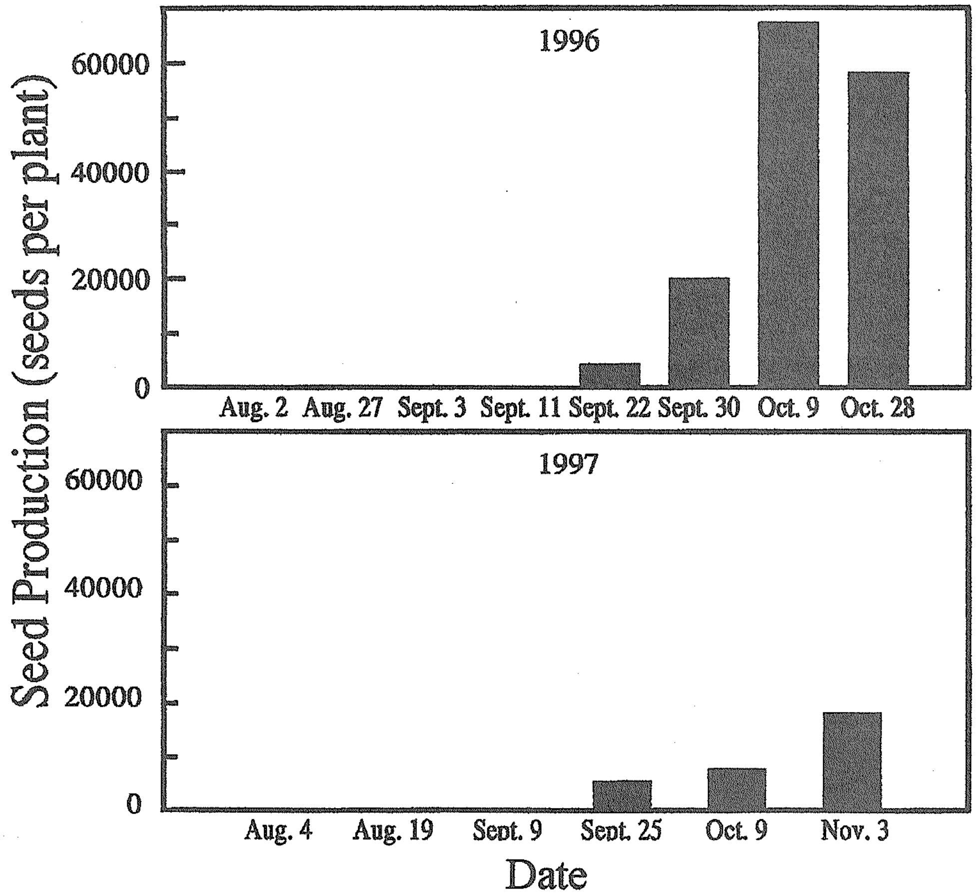

Fig. 5. Average number of seeds produced by individual Russian thistle plants in 1996 and 1997.

CONSERVE RUSSIAN THISTLE SKELETONS IN LOW CROP RESIDUE SITUATIONS

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ABSTRACT

Maintaining adequate residue to prevent wind and water erosion is often difficult in low-precipitation (less than 12 inch annual) wheat-fallow regions of the Pacific Northwest. This is especially true for spring-sown wheat, and for winter wheat in low-moisture conditions. In these situations, Russian thistle (*Salsola iberica*) can be a major weed and often produces more biomass than the crop it infests. In a 4-year study, we measured the effect of three tillage management treatments: *i*) traditional (tillage only); *ii*) minimum (herbicides and tillage), and *iii*); delayed minimum (herbicides and delayed tillage), on retention of above-ground wheat residue and dead Russian thistle plants or "skeletons" during the fallow cycle. Russian thistle infestation occurred two of the four years when winter wheat failed and was replaced by spring wheat. Traditional post-harvest tillage caused most Russian thistle skeletons to be wind blown from plots by late fall, but plants remained anchored in the soil when herbicides were used for post-harvest thistle control. Traditional primary spring tillage with a field cultivator or tandem disc further reduced surface cover compared to minimum tillage treatments. During two fallow cycles where Russian thistle infested the previous spring wheat crop, thistle skeletons on the soil surface averaged 280 and 40 vs. 1220 and 240 lb/acre in late fall and end of fallow in traditional tillage compared to minimum tillage treatments, respectively. Traditional tillage also reduced surface wheat residue compared to minimum tillage plots on all sampling dates. Russian thistle skeletons can be retained in place using conservation tillage during fallow, where they become an important source of surface cover to combat erosion in years when crop residues are extremely low.

INTERPRETIVE SUMMARY

Growers in low-precipitation dryland areas of the inland Pacific Northwest practice a wheat - fallow rotation where only one crop is grown every two years. Maintaining adequate surface residue for erosion control is often difficult. In low crop production years, Russian thistle is a major weed which can produce more dry matter by grain harvest than the wheat crop it infests. In a 4-year tillage management study, we consistently retained the most residue during fallow using minimum tillage practices compared to traditional tillage. In addition to wheat residue, we retained dead Russian thistle plants as an important source of surface cover using minimum tillage, whereas thistles were wind-blown from the field or buried with traditional tillage. Results show the value of conserving Russian thistle skeletons for erosion control in low crop residue situations when thistles are likely to be present in large amounts.

INTRODUCTION

Wind and water erosion are major agronomic and environmental concerns in the low-precipitation (less than 12 inch annual) dryland wheat production region in eastern Washington and north-central Oregon. A biennial wheat-summer fallow rotation has been practiced in this 3.5 million acre region since native bunch grass and sagebrush was plowed in the 1880's. In drought years, or when winter wheat is replaced by a spring crop, residue production is low, and growers frequently have difficulty conserving sufficient surface cover to retard erosion during the subsequent fallow cycle. The most effective management practice for protecting soil from erosion during fallow is to maintain adequate surface residue. Detailed descriptions of the relationship between soil cover and wind erosion loss have been reported. Maximum levels of surface residue during the fall and winter reduces water runoff during the winter and increases over-winter soil water storage which benefits subsequent grain yield. Tillage channels or slots are effective for increasing water infiltration when rain or snow melt occur on frozen soils.

Russian thistle is a summer-annual weed, first reported in the United States in South Dakota in 1877. By the 1890's, the weed had spread to the Pacific Northwest where it quickly became the dominant broadleaf weed in low-precipitation dryland wheat areas.

Russian thistle grows during both the crop and fallow cycles. A uniform and well-established stand of winter wheat will suppress Russian thistle. On the other hand, spring wheat or drought stressed winter wheat are much less competitive and more subject to thistle infestation. Growers plant spring wheat to replace winter wheat because of: *i*) inadequate fall stand establishment; *ii*) winter kill, and; *iii*) the need to control winter-annual grassy weeds. Russian thistle infestation is frequently acute in spring wheat due to less early growth and less canopy closure compared to winter wheat. Spring wheat yield depression due to Russian thistle is most severe during drought years. Russian thistle has an efficient C_4 photosynthetic pathway with high water use efficiency.

Russian thistle rapidly produces dry matter and sets seed after wheat harvest by extracting soil moisture below the available limit for wheat. The optimum time for post-harvest control of Russian thistle is 10-to 14-days after harvest. Growers generally either till the soil with V-shaped sweeps or use herbicides after grain harvest to control Russian thistle. After primary tillage in the spring, rodweeders are used as secondary tillage to control thistles and other weeds. Rodweeders operated at depths greater than 3 inches retain surface residue and roughness more effectively for erosion control compared to shallow depths.

Although Russian thistle often has negative agronomic effects, it has some beneficial attributes. During the dust bowl years in the 1930's, Russian thistle was used as emergency forage for cattle. Protein in Russian thistle hay can be as high as 23%, and the plant has potential as an energy source as processed pellets and compressed fireplace logs.

Because Russian thistle often produces substantial dry matter both before and after wheat harvest, it is possible that the weed could be an important source of surface cover for erosion control during the fallow cycle. No previous research has been reported on possible benefits of Russian thistle in conservation systems. The objective of this study was to: (*i*) document the extent of Russian thistle infestation in marginal wheat production years and; (*ii*) determine if dead thistles can be conserved during fallow as a significant source of surface cover in low crop residue situations.

METHODS AND MATERIALS

A 4-year tillage management study was conducted between August 1993 and September 1997 at the Washington State University Dryland Research Station at Lind, WA. Long-term (82-year) average annual precipitation at the station is 9.5 inches. The soil is Shano silt loam with less than 1% organic matter in the surface 4 inches. Soil depth is greater than 6 feet. Wind tunnel tests have shown that this soil, when left unprotected (i.e, bare, tilled, dry, non-crusted), is one of the most susceptible to wind erosion and suspended dust emissions within the Columbia Plateau of eastern Washington.

The experimental design was a randomized complete block of three tillage management treatments replicated four times. Each plot was 150 by 60 feet, which allowed use of commercial-size farm equipment. Paired adjacent parcels of land were used so that data could be collected from both crop and fallow phases of the study each year.

Tillage Management Treatments

The three tillage management systems compared in this study were: (*i*) *Traditional tillage* - conventional frequency and timing of tillage operations using implements commonly used by growers; *ii*) *Minimum tillage* - conventional frequency and timing of tillage operations, but herbicides were substituted for tillage when feasible and a non-inversion V-sweep implement was used for primary spring tillage, and; *iii*) *Delayed Minimum tillage* - similar to minimum tillage except primary spring tillage with a non-inversion V-sweep was delayed until at least late May. A list of field operations and timing for the study are shown in Table 1.

In traditional tillage, post-harvest tillage was conducted in August of 1993, 1994, and 1995 with overlapping 14-inch-wide V-sweeps to kill Russian thistle by severing the tap root. Russian thistle was not present in August 1996 and post-harvest sweeping was not required. Plots were chiseled in October after fall rains to a depth of 10 inches with straight-point shanks spaced 2 feet apart to create channels for controlling frozen soil runoff during the winter. Plots were sprayed with glyphosate (Roundup) herbicide in late winter to control weeds. Primary tillage was conducted in March with two passes of a duck foot cultivator with an attached harrow, or one pass with a tandem disc (Table 1). Plots were fertilized with anhydrous ammonia nitrogen in late spring and rodweeded three times to control weeds during the summer. Winter wheat was planted in 16 inch rows in early September all years with a John Deere HZ deep furrow drill.

Minimum tillage treatments were sprayed with a nonselective herbicide for post harvest control of Russian thistle in lieu of tillage with sweeps in August (Table 1). In October, the plots were chiseled or subsoiled to depths ranging from 10-to 16-inches with straight-point shanks spaced 4 feet apart (i.e., twice the shank spacing as for traditional tillage). Chiseling was not conducted in 1996. Glyphosate was applied in late winter, and primary tillage was with a non-inversion sweep implement equipped with 32-inch-wide overlapping V-blades. A rotary harrow was attached behind the wide-blade sweep to break up large clods and fill air voids. The plots were rodweeded three times during late spring and summer and fertilized with aqua ammonia nitrogen injected between the rows of the deep furrow grain drill when planting winter wheat in early September.

The delayed minimum tillage treatment was identical to the minimum tillage treatment except that: (*i*) primary spring tillage was delayed until late May or early June, and; (*ii*) only two rodweedings were conducted during late spring and summer.

All treatments were planted at the same time. Due to inadequate fall stands of winter wheat, all plots were replanted to hard red spring wheat in March of 1993 and 1995 (Table 1). Cultivar 'Butte 86' was sown @60 lb/acre in 6 inch rows with a disc drill.

Residue Measurement

Surface residue remaining from the previous crop cycle was measured several times throughout the fallow period by gathering all aboveground dry matter within a 3-ft diameter hoop. Three samples were obtained from each plot. Wheat straw and Russian thistle skeletons were separated, placed in paper bags, and allowed to air dry in a low-humidity greenhouse before weighing. An analysis of variance was conducted for both wheat straw and Russian thistle skeletons on each sampling date. Treatment means were considered significantly different if the P-value was <0.05, using Fisher's protected least significant difference.

RESULTS AND DISCUSSION

Russian thistle produced significant biomass during two crop cycles when spring wheat replaced winter wheat due to inadequate seed zone moisture for stand establishment. Spring wheat residue at the beginning of both the 1993-1994 and 1995-1996 fallow cycles was less than 1300 lb/acre, whereas Russian thistle dry matter was greater than 1550 lb/acre (Figs. 1 and 2). These data agree with other studies showing Russian thistle capable of producing more total dry matter than the spring wheat crop it infests (Young, 1988).

In traditionally-tilled plots, post-harvest tillage reduced surface wheat residue and Russian thistle skeletons compared to minimum tillage where Russian thistle was killed by post harvest application of herbicides (Table 1, Figs. 1 and 2). During the fall and winter, the majority of Russian thistle skeletons were wind-blown from the field in traditionally-tilled plots because the tap root had been severed by the post-harvest sweep operation. Conversely, when herbicide was used for post harvest control in the minimum-tilled treatments, most Russian thistle plants remained anchored in the soil or trapped by standing wheat stubble. (Figs. 1 and 2).

Surface wheat residue and Russian thistle skeletons were always lower in the traditional tillage than in minimum tillage throughout the spring and summer in both the 1993-1994 and 1995-1996 fallow cycles (Figs. 1 and 2). Highest retention of surface residue in the spring was achieved with delayed minimum tillage. Differences in residue levels between minimum and delayed-minimum treatments did not persist until the end of the fallow cycle (Figs. 1 and 2). A benefit of delayed minimum tillage compared to minimum tillage was the need for one less rodweeding operation during the summer (Table 1), which conserves energy and labor.

At the end of the 1993-1994 fallow cycle, only 230 lb/acre of wheat residue and 55 lb/acre of Russian thistle skeletons remained on the soil surface in traditionally tilled plots (Fig. 1). Wheat growers in the dryland areas of the Pacific Northwest are required to maintain a minimum of 350 lb/acre surface residue on highly erodible land in order to participate in government farm programs. With traditional tillage, we were unable to meet this requirement in the 1993-1994 fallow cycle. In contrast, residue compliance was easily met with combined wheat residue and Russian thistle skeletons exceeding 740 lb/acre in the minimum and delayed-minimum tillage treatments. Residue compliance was marginally met (380 lb/acre) with traditional tillage at the end of the 1995-1996 fallow cycle (Fig. 2), but residue was likely reduced a further 20% after planting winter wheat with deep furrow drills (McClellan, 1988). More than 750 lb/acre combined surface cover remained with minimum and delayed-minimum tillage at the end of the 1995-1996 fallow cycle (Fig. 2).

Russian thistle did not infest good stands of hard red winter wheat (cv. 'Buchanan') and soft white winter wheat (cv. 'Eltan') planted in early September of 1993 and 1995, respectively. Residue production from winter wheat exceeded 1800 lb/acre, and we maintained more than 500 lb/acre surface cover with traditional tillage and more than 1,000 lb/acre for the minimum tillage treatments at end of both the 1994-1995 and 1996-1997 fallow cycles (Fig. 3).

SUMMARY AND CONCLUSION

Tillage management affected surface wheat residue and Russian thistle skeleton retention throughout the fallow cycle. In low production years, Russian thistle produced more dry matter at grain harvest than the spring wheat crop it infested. By using herbicides rather than tillage for post harvest thistle control and non-inversion sweeps for primary spring tillage, we consistently retained more wheat residue and Russian thistle skeletons on the soil surface throughout the fallow cycle than was possible with traditional tillage. We could not retain the minimum required quantity of surface residue for erosion control during the 1993-1994 fallow cycle using traditional tillage, but easily meet this requirement using minimum tillage.

Russian thistle did not infest well established stands of winter wheat, and maintenance of adequate surface residue during the subsequent fallow cycle was achieved even with traditional tillage. Conserving dead Russian thistle plants in low crop residue situations can be beneficial for meeting residue requirements and controlling both wind and water erosion.

For a complete list of references used in development of this report contact Bill Schillinger at (509) 659-0035.

Table 1. Calendar of field operations for three tillage systems during four fallow cycles at Lind, WA, 1993-1997.

Date	Traditional tillage	Minimum tillage	Delayed minimum tillage
Aug	Sweep - 12 in. shank spacing. Sweeping was not conducted in 1996.	Herbicide - Glyphosate + 2,4-D @ 1.5 qt./acre in 1993; Glyphosate @ 1.0 qt./acre in 1994 and 1995. Not required in 1996.	Herbicide - Glyphosate + 2,4-D @ 1.5 qt./acre in 1993; Glyphosate @ 1.0 qt/acre in 1994 and 1995. Not required in 1996.
Oct	Chisel - 2 ft shank spacing	Chisel or subsoiler - 4 ft shank spacing. Not conducted in 1996.	Chisel or subsoiler - 4 ft shank spacing. Not conducted in 1996.
Feb	Herbicide - Glyphosate @ 12 oz./acre	Herbicide - Glyphosate @ 12 oz./acre	Herbicide - Glyphosate @ 12 oz./acre
March	Primary tillage - cultivator + harrow (two passes). Tandem disk (one pass) in 1997.	Primary tillage - undercutter + rolling harrow	
April	Anhydrous NH_3 injection @ 40 lb/acre		
May	First rodweeding	First rodweeding	Primary tillage - undercutter + rolling harrow
June	Second rodweeding	Second rodweeding	First rodweeding
July	Third rodweeding	Third rodweeding	Second rodweeding
Sept	Planted to winter wheat @ 40 lb/acre. Replanted to spring wheat @ 60 lb/acre in March 1993 and 1995.	Planted to winter wheat @ 40 lb/acre + aqua NH_3 injection @ 40 lb/acre. Replanted to spring wheat @ 60 lb/acre in March 1993 and 1995.	Planted to winter wheat @ 40 lb/acre + aqua NH_3 injection @ 40 lb/acre. Replanted to spring wheat @ 60 lb/acre in March 1993 and 1995.

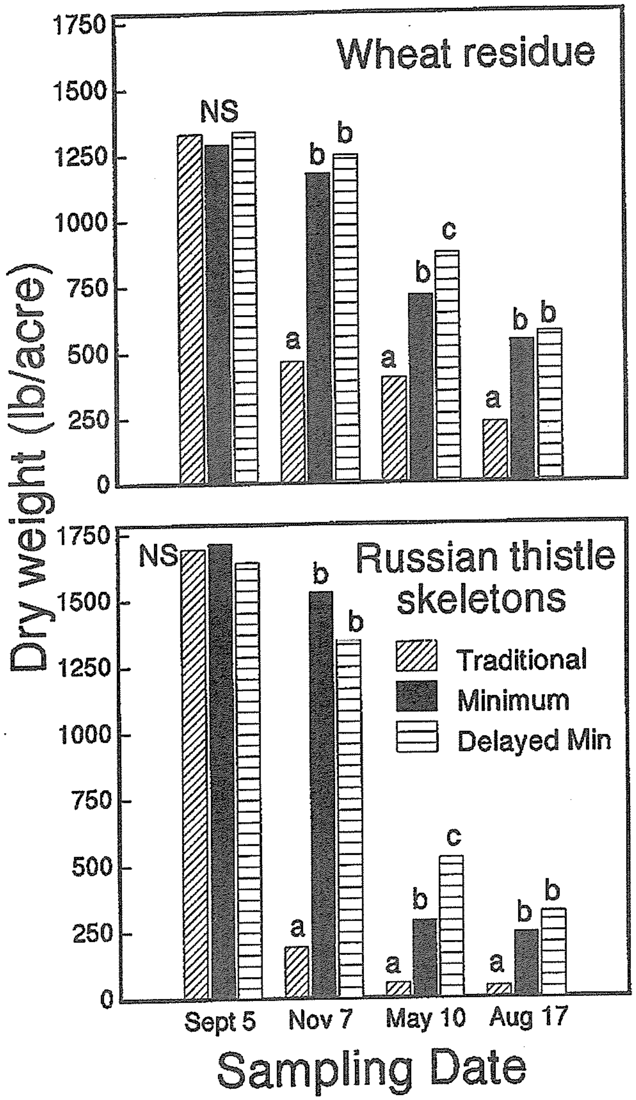

Fig 1. Above-ground hard red spring wheat residue and Russian thistle skeletons during the 1993-1994 fallow cycle as affected by traditional, minimum, and delayed minimum tillage. Different letters within sampling dates indicates significant treatment differences (P < 0.05).

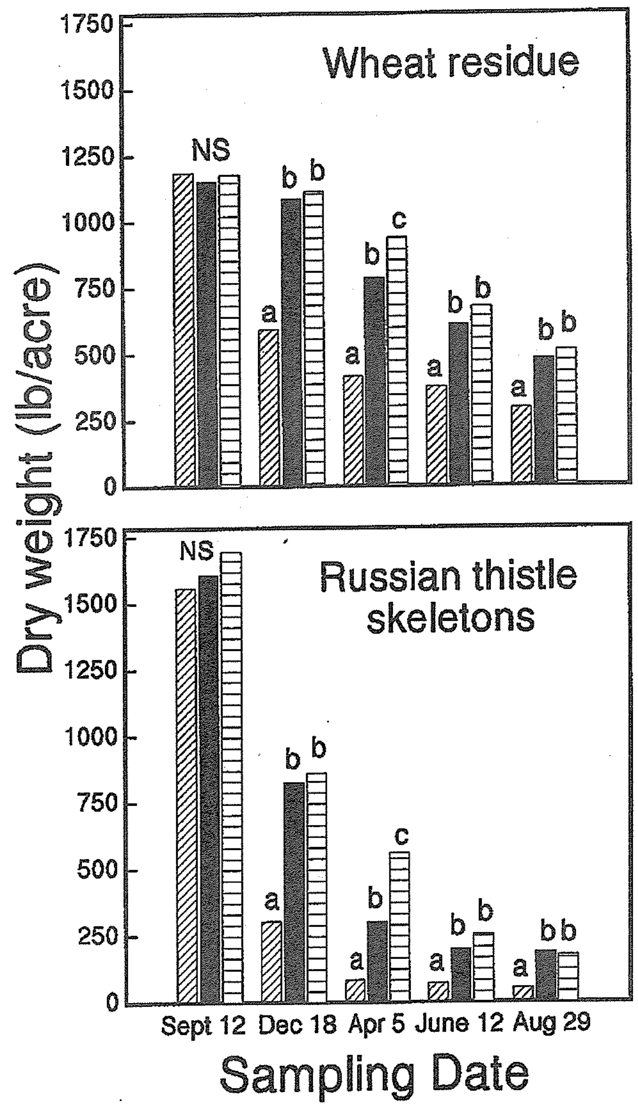

Fig 2. Above-ground hard red spring wheat residue and Russian thistle skeletons during the 1995-1996 fallow cycle as affected by traditional, minimum, and delayed minimum tillage.

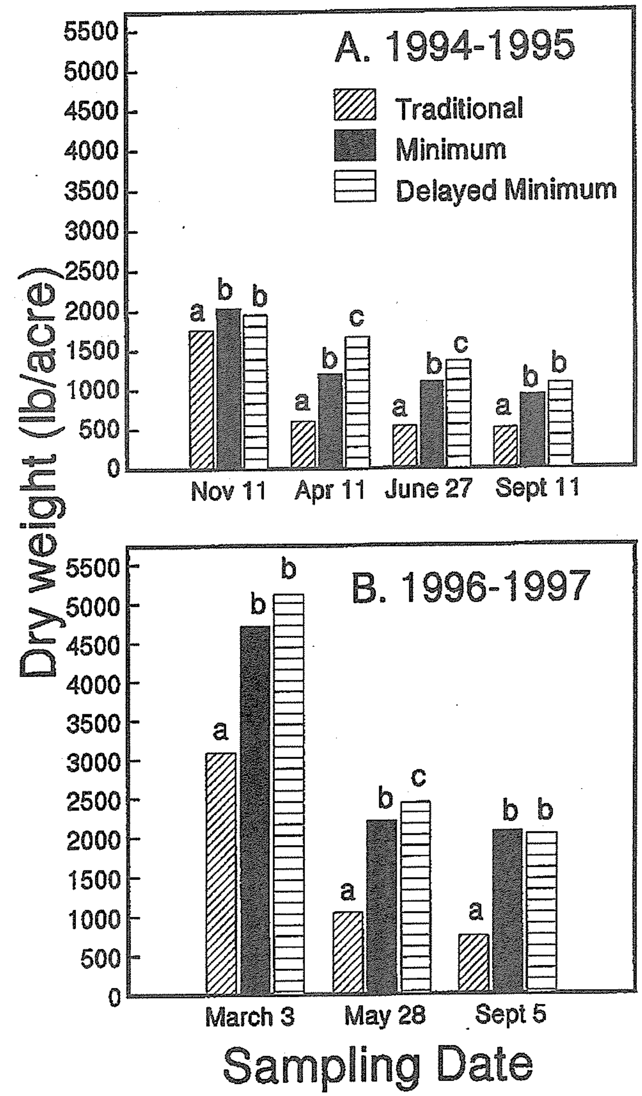

Fig 3. Above-ground hard red winter wheat residue during the 1994-1995 fallow cycle (A), and soft white winter wheat residue during the 1996-1997 fallow cycle (B), as affected by traditional, minimum, and delayed minimum tillage.

NO-TILL ANNUAL CROPPING IN THE HORSE HEAVEN HILLS

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The Horse Heaven Hills in Benton county receives an average of only 6-to 8-inches of annual precipitation, and is the driest wheat production region in the inland Pacific Northwest. Winter wheat - summer fallow is the dominant cropping system in the Horse Heaven Hills. Blowing dust from the coarse-textured summer-fallowed soils in this region is a major soil loss and air quality concern. Growers in the Horse Heaven Hills frequently have difficulty achieving adequate stands of winter wheat in late August because of poor seed zone moisture, deep planting conditions, and soil crusting caused by rain showers before seedling emergence. Cost of reseeding can nullify net profit in this low yield potential region.

In collaboration with Doug Rowell and the Benton County Wheat Growers Association, we began a six-year research project in 1997 to compare no-till annual spring wheat to winter wheat - summer fallow in the Horse Heaven Hills. At our test site on the Rowell farm, long-term winter wheat yields have ranged from 3-to 30-bushels per acre with an average of 20 bushels per acre.

In our study, we plant spring wheat with the USDA-ARS "cross-slot" no-till drill. This drill delivers seed and fertilizer in one pass and causes minimum surface disturbance. Throughout the six-year research period, we will compare annual no-till spring wheat to winter wheat - summer fallow for grain yield, production costs, and net income. In addition, we will measure and compare the two systems for water use efficiency, weed population dynamics, and soil biological and physical parameters. In 1997, "Eltan" winter wheat after summer fallow yielded 28 bu./acre compared to 15 bu./acre for "Kulm" red spring wheat in our annually cropped no-till plots.

If you have questions or would like to learn more about this project, contact Bill Schillinger at 659-0355 or grower Doug Rowell at 894-5309.

ALTERNATIVE ANNUAL CROP ROTATIONS FOR LOW-RAINFALL DRYLAND USING NO-TILL

Researchers: William Schillinger, R. James Cook, Robert Papendick, Roger Veseth, Harry Schafer, Keith Saxton, Robert Gillespie, Ann Kennedy, Joe Yenish, and John Driessen.

Grower Cooperators: Ron Jirava, Ritzville; Brad Wetli, Mansfield.

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

1. Develop long-term rotations which include alternative crops such as yellow mustard and safflower, and measure their effects on root diseases and grain yield of subsequent wheat and barley crops.
2. Document the long-term cumulative effects of minimum disturbance no-till planting practices on physical and biological properties of the surface soil.
3. Demonstrate and promote no-till farming practices and alternative crop rotations to growers and agricultural support personnel.

The Problem: A wheat-summer fallow rotation has been practiced for more than 100 years in low-rainfall dryland areas of the inland Pacific Northwest. Soil organic carbon, and associated soil quality, are declining under the wheat-fallow system because of limited crop residue production, tillage, and the unproductive fallow period. Blowing dust from excessively tilled summer fallow is a major soil loss and air quality concern. In addition, water erosion from fall-planted wheat after fallow is often severe when rain or snowmelt occur on frozen soils. Growers in dryland areas are interested in no-till planting techniques and potential alternative crop rotations which reduce erosion, decrease soil-born diseases of cereals, enhance crop marketing opportunities, and hold potential to increase soil quality.

Precipitation Zone: The low-rainfall (6-to 12-inch annual) dryland area of east-central Washington and north-central Oregon. This zone encompasses 3.5 million cropland acres.

Interpretive Summary: A long-term study was initiated in 1997 to evaluate alternative cropping systems for low-rainfall dryland areas using minimum disturbance no-till. The on-farm experimental sites are in Adams and Douglas counties. We are interested in how a 4-year rotation, which includes two years of cereals followed by two years of broad leaf crops, will effect cereal root diseases, cereal yields, weed ecology, insects, farm economics, and soil quality. In Adams county, where 1997 crop year precipitation was 17 inches (average is 11.5 inches), grain yields of spring wheat, spring barley, safflower, and yellow mustard were excellent. In Douglas county, broadleaf weed infestation in the safflower and yellow mustard was extensive, and grain yield for these crops was poor. We plan to conduct this study for six years at both locations. Data will become increasingly meaningful in future years.

Study Description and 1997 Results

This project, which began in April 1997, is evaluating diverse, annual, no-till cropping systems as a substitute for winter wheat - summer fallow. Research sites are located at the Ron Jirava near Ritzville in Adams county, and the Brad Wetli farm NW of Mansfield in Douglas county. At both sites, a 4-year crop rotation of: spring wheat - spring wheat - safflower - yellow mustard are being evaluated (Table 1). For comparison, annual spring wheat and continuous spring wheat - spring barley are also included in the study (Table 1). Treatments are replicated four times in a randomized block design at each location. Soil and climatological differences between the two sites are shown in Table 2.

Table 1. The seven no-till treatments in the alternative cropping systems research study in Adams and Douglas counties. Each crop in the 4-year rotation (treatments 1- 4) appears each year. Continuous wheat (treatment 5) and continuous wheat-barley (treatments 6 -7) are also included.

	Year			
Treatment	**1997**	**1998**	**1999**	**2000**
1	Spring Wheat	Spring Wheat	Safflower	Yellow Mustard
2	Spring Wheat	Safflower	Yellow Mustard	Spring Wheat
3	Safflower	Yellow Mustard	Spring Wheat	Spring Wheat
4	Yellow Mustard	Spring Wheat	Spring Wheat	Safflower
5	Spring Wheat	Spring Wheat	Spring Wheat	Spring Wheat
6	Spring Wheat	Spring Barley	Spring Wheat	Spring Barley
7	Spring Barley	Spring Wheat	Spring Barley	Spring Wheat

Table 2. Soil and climatological comparisons of the on-farm research sites in Adams and Douglas counties.

	Adams Co. - Jirava	**Douglas Co. - Wetli**
Annual ave. precip.	11.5 inches	10.5 inches
Soil type	Ritzville silt loam	Touhey loam
Soil depth	More than 6 feet	2.5 feet
Elevation	1850 feet asl	2700 feet asl
Slope	Less than 2%	Less than 2%

Adams County: Plots were sprayed with glyphosate herbicide for weed control in early April. Planting was with a Flexicoil 6000 no-till air drill with disc openers spaced 7.5 inches apart. The seedbed had 2,300 lbs/acre of undisturbed year-old hard red spring wheat residue. Over-winter precipitation in 1996-97 was higher than average, and there was 9.4 inches of available water in the six foot soil profile at time of planting. Planting rates were: spring wheat (Penawawa) 70 lbs/acre; spring barley (Baronesse) 70 lbs/acre; safflower 20 lbs/acre; and yellow mustard 7 lbs/acre. Planting of crops was completed between April 17-24. Fertilizer rate, held constant for all crops, was 40 lbs N/acre as aqua NH_3 delivered with coulters between the seed rows, and 8-10-0-7 lbs/acre of N-P-K-S as granules with the seed. Wheat and barley plots were sprayed with 6 ounces of Salvo + one-third ounce of harmony extra with 10 gallons of water per acre in May. Broadleaf herbicides could not be used in the safflower and yellow mustard plots.

Stand establishment (plants/ft^2) was spring wheat 9; spring barley 9; safflower 2.5; and yellow mustard 1.8. We were concerned about the low stand counts in the broadleaf crops, but both yellow mustard and safflower grew rapidly to fill empty niches. Spring wheat and spring barley plots remained weed free throughout the growing season. The main weed species in the yellow mustard and safflower were Russian thistle, lambs quarter, horse tail, and China lettuce, but populations were low, i.e. less than 1 weed per 100/ft^2 for each weed species. Rainfall occurring between planting and harvest was 3.6 inches.

Bumper yields of spring wheat (64 bu/acre) and spring barley (2.3 ton/acre) were harvested from the plots in August. Yellow mustard and safflower yields were also high, exceeding 1400 lbs/acre (Table 2).

Douglas County: Plots were sprayed with glyphosate herbicide in April and planted with the USDA-ARS cross-slot no-till drill on May 1. The cross-slot is an ultra minimum soil disturbance disc drill with 10-inch spacing between seed rows. All crops were planted the same day. Fertilizer rate for all crops was 40 lbs N, 10 lbs P, and 7 lbs S per acre as liquid delivered to the side and slightly below the seed. Seeding rates for spring wheat, spring barley, safflower, and yellow mustard were 70, 70, 20, and 10 lbs/acre, respectively. Wheat and barley were sprayed in June with 2,4-D (we wanted 16 ounces/acre but applied 21 ounces).

Stand establishment (plants/ft^2) was: wheat 11; barley 10; safflower 5; and yellow mustard 7. Unlike the Adams county site, yellow mustard and safflower did not produce many branches and growth was slow throughout the spring and summer. Infestation of Russian thistle, cutleaf night shade, and spiny cocklebur was extensive. At the time of harvest in late September, these weeds had collectively produced 2260 lbs/acre of total dry matter vs. 1280 lbs/acre for yellow mustard; and 1680 lbs/acre total dry matter vs. 2015 lbs/acre for safflower. The slow growth of safflower and yellow mustard points toward possible spray-drift damage by sulfonyurea herbicide. The only herbicides used on the land during the past 5 years are glyphosate, 2,4-D, and Banvel. Yields of all four crops at both locations in 1997 are shown in Table 3.

Table 3. Yields (lbs/acre) of four crops planted no-till in Adams and Douglas counties in 1997. These are first year results of a planned six-year alternative cropping systems project.

	Spring Wheat	Spring Barley	Safflower	Yellow Mustard
Adams Co. (Jirava)	3860	4600	1420	1430
Douglas Co. (Wetli)	1150	2400	630	410

Other measurements: Insect populations in all crops were measured several times throughout the growing season at both sites (Gillespie). Herbicide screening experiments for broadleaf weed control in yellow mustard and safflower were conducted on the Jirava farm (Yenish). Baseline soil samples were collected at both sites and stored for future analysis (Kennedy). Root disease scoring will begin in 1998 (Cook).

EXTENSION OF THE TRADITIONAL WINTER WHEAT/FALLOW ROTATION WITH DIRECT-SEEDED SPRING BARLEY

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Production of winter wheat no more than once in three years in any given field (3-year or longer crop rotations) is well known to help control soilborne pathogens and grass weeds. With conventional seeding, 3-year crop rotations generally have not been possible in the low-precipitation areas (<12-13 inches annually) except in years of higher-than-average winter or spring precipitation when it becomes possible to plant a spring cereal after winter wheat before returning to fallow. Three-year crop rotations in the intermediate-precipitation areas (13-17 inches annually) typically include winter wheat/spring cereal/fallow (i.e., two crops every three years), and those in the high-precipitation areas (18 inches or greater annually) typically include winter wheat/spring cereal/cool-season broadleaf crop such as a pulse or brassica (i.e., crop every year).

Direct seeding, whereby a spring cereal is planted directly into the stubble of winter wheat, offers the potential to extend the traditional winter wheat/fallow (2-year) rotation in the low-precipitation areas to a 3-year or longer rotation while raising the yield potential for spring cereals already used in 3-year rotations in the intermediate- and high-precipitation areas. Research conducted in both the intermediate- (near Dusty) and low-precipitation areas (near Ritzville) of eastern Washington indicates that spring barley is well-adapted to direct seeding and that excellent yields can be expected with any of several different drills that seed and place fertilizer as a one-pass operation. This research is part of a larger effort to increase the cropping intensity in the traditional winter wheat/fallow areas.

Drill Comparisons

Studies were conducted in 1996, and 1997 on the Don and Doug Wellsandt farm near Ritzville that compared two no-till drills with both the conventional (double-disk drill with tillage-prepared seedbeds) and a modified John Deere HZ used as a no-till drill. For the conventional seeding, nitrogen was applied ahead of planting and starter fertilizer with the seed at planting. For the direct seeding, including with the HZ, all fertilizer was applied below the seed at planting. The 1996 study used a John Deere 752 and Flexi Coil 5000 air-seeder and the 1997 study used a Cross Slot and Concord air-seeder. Yields were higher in 1996 than in 1997, but the patterns were similar in both years (Table 1). The highest yields were obtained with conventional seeding in 1996 and with the two no-till drills in 1997. Lowest yields were obtained both years with the HZ drill, apparently because the row spacing (16-inch) was too wide for maximum production. Yields obtained with the two no-till drills were virtually identical both years.

Rhizoctonia root rot is the only serious disease risk identified thus far for spring barley seeded directly into cereal stubble. The severity of this disease based on examination and rating of washed roots was generally less in 1996 than in 1997 (Table 1). Disease severity was least in 1996 with the two hoe-type drills, namely the Flexi Coil 5000 and HZ. In contrast, disease severity was greatest in 1996 with the HZ drill and was similar with the Cross Slot, Concord, and conventional drills.

Influence of Cropping History

The 1996 and 1997 studies were carried out each year in two different fields where the previous crop was winter wheat and spring barley, respectively. In both years, yields of spring barley were higher and the severity of Rhizoctonia root rot was less after spring barley than after winter wheat, regardless of the drill or method of planting (Table 1). As expected, fields in winter wheat the previous year had more crop residue and a greater density of surviving volunteer host plants in the spring; both factors are known to favor Rhizoctonia root rot. It was also more difficult to achieve good stands of spring barley in the winter wheat stubble because of the deep furrows, which would further account for the lower yields in these fields. Direct seeding fields after deep-furrow seeding is more difficult than when the soil surface is relatively smooth, and may require an extra pass to smooth the ridges. Our results suggest that successive crops of direct-seeded spring barley represent no greater and possibly a lower risk than direct-seeded spring barley after winter wheat.

Table 1. Yields and severity of Rhizoctonia root rot of spring barley seeded conventionally or with different no-till drills directly into cereal stubble near Ritzville (Wellsandt farm).

	Winter wheat stubble		Spring barley stubble	
Seeding method	Yield (lbs/A)	Rhizoctonia[1)] (0-8 rating)	Yield (lbs/A)	Rhizoctonia[1)] (0-8 rating)
1996				
Conventional	3290 a	5.4 a	3610 a	1.9 a
John Deere 752(NT)	2730 b	3.9 b	3400 b	1.6 a
Flexi Coil 5000 (NT)	2870 b	5.0 ab	3340 b	2.0 a
John Deere H2 (NT)	2560 b	3.9 b	2730 c	1.6 a
1997				
Conventional	2960 a	4.4 b	3300 a	4.1 c
Cross Slot (NT)	3420 b	4.6 b	3860 b	4.8 b
Concord (NT)	3440 b	4.5 b	3640 b	4.3 bc
John Deere H2 (NT)	2800 a	5.8 a	3040 a	5.7 a

1) These ratings are for the seminal roots only. Plants rated less than 2 have only mild disease, but those rated 4 and above could be seriously impaired unless the secondary roots remain healthy and support continued development and maturity of the plant.

Influence of Clearing Trash from the Seed-Row on Rhizoctonia root rot

A study was conducted in 1997 at two locations near Ritzville and one location near Dusty to determine the influence of clearing trash from the seed row at planting on the development of Rhizoctonia root rot of direct-seeded spring barley. One of the Ritzville locations used the drill strips seeded with the Cross Slot drill (into winter wheat stubble) described above, and the other (into spring barley stubble) used a drill equipped with Acra Plant openers mounted behind fertilizer shanks positioned to place all fertilizer directly beneath the seed at planting. The Dusty location was planted with the drill equipped with Acra-Plant openers but with the fertilizer shanks replaced by the Yetter colter/fertilizer knife. Trash was cleared manually with a garden rake immediately after planting by transferring trash from a narrow zone within each seed row into the space between the rows (9-inch spacing for the Cross Slot and 12-inch spacing for the Acra Plant openers). One treatment included plots fumigated with methyl bromide to reduce the amount of Rhizoctonia root rot.

Clearing trash from the seed row resulted in more tillers, more seminal roots, or both, and less Rhizoctonia root rot (Table 2). Rhizoctonia root rot is favored by cool wet soil conditions likely to occur with trash in the seed row. As expected, fumigation of the soil greatly reduced Rhizoctonia root rot and resulted in higher yields. The yield increases in response to fumigation amounted to 20-25% in plots with trash left in the rows compared with 10-15% in plots with trash cleared from the rows. An analysis of yield components revealed that, while plants in plots with trashy rows produced fewer tillers, they compensated by producing larger heads and heavier kernels (data now shown). The tendency of the plants to compensate later in their development was made possible by the timely seasonal rains in 1997 and the healthy crown roots that essentially carried the crop through to maturity.

Table 2. Influence of trash in the seed row compared to removal of trash from the seed row on numbers of tillers and seminal roots per plant and percentage of seminal roots with *Rhizoctonia* root rot on direct-seeded spring barley.

Treatment	Tillers (No./plant)	Seminal roots (No./plant)	Rhizoctonia root rot (% seminal roots)	Yield lbs/A
	Ritzville; Cross-slot openers; winter wheat stubble			
Clean row	2.7 b	7.9 a	67 b	
Trashy row	3.7 a	6.8 b	81 a	
	Ritzville; Acra-Plant openers; fertilizer shanks; spring barley stubble			
Natural Soil				
Clean row	4.4 ab	6.9 ab	84 a	3060
Trashy row	3.3 c	7.2 a	83 a	3010
Fumigated Soil				
Clean row	4.9 a	6.4 b	54 c	3450
Trashy row	4.2 b	6.9 ab	71 b	3850
	Dusty; Acra-plant openers; Yetter colter/fertilizer knife; winter wheat stubble			
Natural Soil				
Clean row	4.2 a	6.1 a	61 b	3250
Trashy row	3.4 b	5.3 c	80 a	3070
Fumigated Soil				
Clean row	4.4 a	5.9 ab	46 c	3770
Trashy row	4.0 a	5.6 bc	51 c	3680

Variety Performance with Direct Seeding

Thirty to thirty-five advanced lines and varieties of spring barley were direct-seeded into either winter wheat or spring barley stubble on the Robert Wigen farm near Dusty in each of the last three years (1995,1996, and 1997) with the drill equipped with Acra Plant openers and either the narrow shank or Yetter colter ahead of each opener to place all fertilizer directly beneath the seed. Volunteer cereals and grass weed hosts of Rhizoctonia were treated with glyphosate at least 3 weeks before planting each test, which reduces but does not eliminate pressure from this pathogen. Results of some of the more familiar varieties are presented in Table 3. Unfortunately, the data for 1996 are not available.

The 1998 direct-seed, spring barley variety tests have been expanded to include, in addition to the trials at Dusty and Ritzville, a test on Spillman farm on a site planted to spring barley the previous year with 1) heavy surface residue and 2) volunteer spring barley sprayed with glyphosate only 3 days before planting. This test is intended to provide a more severe screen of varieties and advanced lines for resistance or tolerance to Rhizoctonia root rot. A direct-seed spring barley variety test has also been added at Bickleton in 1998.

Table 3. Yields of spring barley seeded directly into stubble of winter wheat (Dusty 1995 and 1997) or spring barley (Ritzville, 1997)

	Dusty-1995 (lbs/A)	Ritzville-1997 (lbs/A)	Dusty-1997 lbs/A
Steptoe	4316	3159	4125
Crest	4006	2524	3788
Harrington	3895		3799
Colter	5023	2718	4260
Baronesse	4158	2955	4373
Meltan	5023	2855	3639
Camelot	4503		4430
Gallatin	3909		3816
Maranna	4841		4023
WA 9792-90	5263		4218

Conclusions

These results indicate that direct-seeded spring barley has potential to lengthen the traditional winter wheat/fallow rotation and increase the intensity of cropping in the low- and intermediate-precipitation areas of the Inland Northwest. Any one of several no-till drills will apparently work satisfactorily, provided the row spacing is no greater than 12 inches and the drill is designed to both place fertilizer as a deep band within the seed row and place seed shallow but uniformly into moist soil. Drills designed to move trash from within to between the rows may provide an additional advantage in years or fields where Rhizoctonia root rot is yield-limiting. Research is continuing on testing varieties, including use of larger drill strips in on-farm tests.

THE WILKE PROJECT: ANNUAL CROPPING, DIRECT SEEDING SYSTEMS FOR THE INTERMEDIATE RAINFALL AREA OF EASTERN WASHINGTON

Diana Roberts, Ed Adams, Tom Platt, Jon Newkirk, Bob Gillespie, Aaron Esser
Ag Horizons Team of WSU Cooperative Extension

Objectives:
This project is a public-private cooperative effort to adapt and develop annual-cropping, direct-seeding systems for the intermediate rainfall area (12 to 17 inches annually) of eastern Washington. The project goal is to demonstrate economically viable rotations, including alternative crops to wheat, that enable annual cropping and improved soil conservation in this region. We anticipate this will be a long-term project with evolving objectives and methods.

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

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

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

<u>Three-year rotation</u>:	<u>Four-year rotation:</u>
Deep Creek (Tom Zwainz)	Reardan (Hal Johnson)
Sprague (Chris Laney)	Egypt (Doug Reinbold)
Wilbur (Bill Dreger)	Harrington (Karl Kupers)

Parameters:
Economics of the rotations are of paramount importance. We will also obtain economic information from conventional cropping systems from three farms adjoining the Wilke Farm. We will track the changes associated with going to direct seeding and annual cropping by collecting data on the Wilke Farm and on-farm sites for soil health and structure, soil moisture, weeds, insects, and diseases, etc.

Extension:
We plan to hold summer tours of the Wilke Farm and on-farm sites. The 1998 Wilke Farm tour will be July 1. We will also publish our findings in Extension publications and present them at winter meetings.

Collaborators:
Cooperators and collaborators in the project include:

- Ag Horizons team of WSU Cooperative Extension,
- ACIRDS (Annual Cropping, Intense Rotation, Direct Seed) group of Lincoln and Spokane County producers
- Lincoln County Conservation District
- Environmental Protection Agency Region10; Columbia Plateau Agricultural Initiative (CPAI)
- McGregor Company
- Western Farm Services
- McKay Seed Company (Almira)
- Monsanto Corporation
- Washington State Department of Fish and Wildlife
- NRCS

Each of these groups participates in different ways. The project includes consensus building training for all cooperators in order to ease the decision-making processes involved with a broad group with diverse perspectives.

We welcome participation in this Wilke Project by interested parties! Contact Diana Roberts at WSU Cooperative Extension Spokane County (509) 533-2048 ext. 111 for further information.

GROWER-INITIATED ON-FARM RESEARCH ON DIRECT SEED CROPPING SYSTEMS IN COOPERATION WITH WSU AND ARS SCIENTISTS, AND OTHER AG SUPPORT GROUPS

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

There is a rapidly growing movement towards direct seed cropping systems in the Northwest and around the world as a way to reduce production costs and improve profitability, erosion control and cropland productivity. Research and grower experience has shown that the success of direct seed systems is greatly enhanced with the use of longer, more diverse crop rotations for more effective pest control and residue management. Northwest growers, researchers and Ag support groups are actively searching for profitable alternative crops and rotations to facilitate this transition to direct seeding systems.

This article will briefly highlight two examples of direct seed cropping systems studies initiated by growers in 1998 in cooperation with their local conservation districts, personnel with other ag support agencies and industries, and a growing list of more than ten WSU and ARS faculty. One study, referred to as the Northwest Crops Project, was conceived by Tracy Eriksen, St. John grower, and is being managed jointly through the Palouse-Rock Lake and Whitman Conservation Districts, and other cooperating Districts. The other study was initiated by Bickleton grower Steve Matsen in cooperation with the Eastern Klickitat Conservation District. Both studies have at least four replications of treatments to permit scientifically interpretable results on pest pressures, soil quality, yields, and economics.

Northwest Crops Project

The primary focus of this direct seed cropping systems study is on comparing a new 4-year crop rotation with a traditional 3-year rotation in this region of winter wheat-spring barley-spring broadleaf. The 4-year rotation of spring wheat-winter wheat-field corn-spring broadleaf has been used successfully under continuously no-till systems on the Dakota Lakes Research Farm in South Dakota. At several of the trial sites, the wheat blocks will be split into winter and spring wheat to permit the comparisons of winter wheat after spring wheat versus after the broadleaf crop, the more common crop sequence in the annual cropping areas of the Inland Northwest.

Unlike the typical on-farm research trials, which include four or more replicates of each treatment in one field, this study has at least one replication on seven different farms (replication by farm). There are currently eight replications of the two rotations under direct seeding. All crops in the two rotations will be planted with field scale equipment at each site each year. The plan is to continue the trials through two cycles of the 4-year rotation. All the sites are in the 15- to 18-inch rainfall zone on Athena soils.

The participating growers are Tracy Eriksen - St. John, Steve Swannack - Lamont, Dan and Steve Moore - Dusty, Randy Repp - Dusty, John and Cory Aeschliman - Onecho, LeRoy Druffel -

Colton, and David and Paul Ruark - Pomeroy. Data collection over the 8-year period will be a collaborative effort involving the growers, conservation district and NRCS personnel and faculty from WSU and ARS. Scientists from about seven disciplines may be involved in helping analyze and interpret data from the trials. Additional project assistance will be available from grants through the conservation districts and ag. companies.

Bickleton Study

This study is intended mainly to help identify one or more broadleaf crops for an area that produces cereals exclusively, either in a wheat-fallow or alternating winter-spring cereal rotation under annual cropping. The study will compare these continuous cereal systems to 3-year rotations including one year of a variety of broadleaf crops.

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

Unlike the Northwest Crop Project, which uses farm sites as trial replicates, the Bickleton study will have all replicates and each crop of each replicate included as a complete study on each farm. The study was launched in 1998 on the Gordon King farm and will be expanded to a second and possibly third farm in 1999.

Collaborative Efforts Offer the Greatest Potential

The variable agronomic, soil and climatic condition across the Northwest present a challenge to the development and adaptation of alternative crops, rotations, and management technologies for direct seed cropping systems. No Northwest group or organization alone can provide the technology needed to make a successful transition to direct seeding across the region. We feel that long-term, collaborative efforts among growers, researchers, conservation districts, Ag industry and Ag support groups provide the greatest potential for rapid development and adaptation of new crops, rotations and management technologies for successful direct seed systems in the Northwest.

DIRECT SEED AND MINIMUM-TILL SYSTEMS FOR GRAIN LEGUMES

Roger Veseth, Tim Fiez, Joe Yenish, Stephen Guy, Donn Thill, John Hammel

Soil erosion can be a serious problem in the Inland Northwest under crop rotations with winter wheat following grain legumes planted under conventional tillage. Even though Palouse growers have made a significant shift towards minimum tillage or direct seeding of winter wheat, surface residue cover following the conventionally-seeded legume crop is often inadequate for erosion control because of the low residue production by grain legumes.

Spring field operations on wet soils for legume establishment under conventional tillage can also result in significant soil compaction from tractor traffic and tillage implements, further increasing erosion potential. In addition to overwinter erosion during the following winter wheat crop, legume fields can be vulnerable to soil erosion during intense rainstorms in the spring and early summer because of the combination of little or no cereal crop residue retained on the soil surface after legume planting and soil compaction from the spring tillage operations.

Surface runoff and soil erosion can both cause yield losses in both the grain legume and winter wheat crops. Water running off the fields is water not stored for grain production. The greatest impact would occur on upper slopes and ridgetops where yields are most limited by available water. Soil loss will reduce the yields of future crops due to loss of soil fertility, water holding capacity, rooting depth and other soil quality and productivity factors. Erosion can also reduce current crop yields by loss of plant stands and reduced plant vigor.

There is also an increasing need to reduce production costs to stay competitive in global markets. One cost-cutting option that growers are exploring is to reduce the number and intensity of tillage operations.

New Tillage Systems Opportunities

Some revolutionary changes in tillage practices for spring dry pea, lentil and other spring grain legumes are underway in the Inland Northwest. They offer exciting potential benefits in soil erosion control, soil quality, yield potential and profitability. Innovative growers and university scientists have combined efforts to develop integrated management systems for direct seeding and other minimum tillage systems for grain legumes and following winter wheat crop.

An increasing number of growers are producing spring legumes with direct spring seeding systems, with or without minimum tillage in the fall. An important development in direct spring seeding of grain legumes is the recent availability of herbicides that offer weed control without soil incorporation or that are applied post emergence.

A 4-year interdisciplinary team research project by scientists from University of Idaho and Washington State University was initiated in 1996 to assist growers in developing integrated management practices for these production systems. The project is partially supported by grants through UI and WSU from the STEEP III (Solutions To Environmental and Economic Problems) conservation farming research program in Idaho, Oregon and Washington. It involves grower-managed on-farm tests as well as university research farm experiments.

The primary goal for growers and scientists is to develop integrated management systems for direct spring seeding of grain legumes. This would retain more of the previous cereal crop residue on the surface and minimize spring soil compaction, thus reducing the potential for runoff and soil erosion, and improving water infiltration. The crop and pest management systems for grain legumes must optimize yield, quality and residue production. These direct seed systems will perform best under 3-year or longer rotation, such as grain legume-winter wheat-spring crop, to improve pest control. In addition, winter wheat planting systems must then continue to retain surface residue from the legume and previous cereal crops, and maintain soil physical conditions for effective water infiltration. The overall goal is to improve erosion control, yield potential and profitability of grain legumes and the following winter wheat crop.

Grower-Managed On-Farm Tests

Two growers were involved in large scale on-farm tests of minimum tillage establishment of pea and lentil with their field equipment in the 1997 crop year. Results of a 1995-97 on-farm test by Wayne Jensen, near Genesee, ID, show the success of minimum tillage for planting spring pea after spring wheat compared to conventional tillage (Table 1). This trial began in the fall of 1995 after a 90 bu/A spring wheat crop. Three tillage systems were evaluated: 1) conventional tillage system of fall moldboard plow - two spring cultivations for herbicide incorporation - seed with conventional double disc drills; 2) minimum tillage system of fall chisel - fall cultivate - spring herbicide application without soil incorporation - direct seed with a John Deere 455 minimum tillage drill with off-set double discs; and 3) fall flail before the system in number 2 above. The trial was seeded to dry peas in mid-March 1996. The entire trial was direct seeded to winter wheat with a Yielder no-till drill in October 1996.

The two minimum tillage systems retained over 52% surface cover from the spring wheat residue through pea seeding compared to 10% with conventional tillage. Minimum tillage pea yields were slightly higher than yields with conventional tillage, but the difference was not statistically significant. Erosion protection overwinter was much higher in the two minimum tillage systems with over 50% surface cover after winter wheat planting compared to 24% in the conventional tillage system. Over 62% of the surface residue in the minimum tillage systems was carryover spring wheat residue, compared to 8% with fall plowing. There was no significant difference in 1997 winter wheat yields as a result of the tillage systems used for previous pea crop.

A 1996-98 repeat of Jensen's 1995-97 trial (without the flail treatment) is in the winter wheat cycle in 1998 crop year. It was established in the fall of 1996 in a nearby field after 70 bu/A spring wheat. Pea yields were not significantly different (Table 2) and the minimum tillage pea planting system retained 47% surface cover after winter wheat planting compared to 30% under conventional tillage.

Table 1. Surface residue retention and yields in under minimum tillage and conventional tillage for pea establishment in a spring wheat-pea-winter wheat rotation, 1995-97, Wayne Jensen, Genesee, ID grower.

Tillage after 1995 spring wheat crop	%Surface residue (post pea planting)	1996 Pea yield (lb/A)	Fall 1996 Post harvest residue (lb/A)			% Surface residue (post winter wheat planting)	1997 winter wheat yield (bu/A)
			Pea only	Wheat only	Pea + wheat		
Fall plow - 2X spring cultivate - seed	10	1120	1169	105	1274	24	67
Fall chisel - fall cultivate - spring direct seed	59	1220	1860	1102	2962	51	69
Fall flail - fall chisel - fall cultivate - spring direct seed	52	1300	1485	728	2342	50	69
LSD (0.05) *	5	NS	689	310	861	10	NS

* Least significant difference among treatment means in a column at the 95% probability level.

Table 2. Surface residue retention and pea yield in 1997 under minimum tillage and conventional tillage for pea establishment in a spring wheat-pea-winter wheat rotation, Wayne Jensen, Genesee, ID grower.

Tillage systems after 1996 spring wheat crop	% Surface residue cover (post fall tillage)	%Surface residue cover (post pea planting)	1997 Pea yield (lb/A)	% Surface residue cover (post pea harvest)	% Surface residue cover (post winter wheat planting)
Fall plow - 2X spring cultivate - seed	12	6	2870	32	30
Fall chisel - fall cultivate - spring direct seed	41	34	2630	50	47
LSD (0.05) *	7	8	NS	14	13

* Least significant difference among treatment means in a column at the 95% probability level.

A 1996-98 field trial was initiated with Art Schultheis near Colton, WA. A field of spring barley stubble was lightly disced in early fall 1996 and chiseled in late fall. Overwinter residue cover was 55%. After a tine harrow operation to smooth the field in spring of 1997, and a herbicide application, the trial was established to compare direct spring seeding after fall tillage versus the traditional system of two field cultivator operations for herbicide incorporation before seeding lentils. The trial was direct seeded to winter wheat in fall 1997and will continue through harvest in 1998. There were no significant differences in pea yields or surface residue through winter wheat planting between the two tillage treatments. Pea yields were about 2,450 lb/A in both treatments.

Eight New Grower On-Farm Tests -- In addition to the on-going field trials, there are eight new on-farm tests underway for 1997-99 by seven Northwest growers with their field equipment. All trials have 4-5 replications of treatments on each farm, include some fall 1997 tillage or residue management treatments, and are in spring pea in 1998. These sites include:

1. Nathan and Steve Riggers west of Nezperce, ID -- following spring wheat with a) fall plow-conventional seed, b) fall disc - direct seed with a Flexi-Coil 5000 hoe air drill, c) spring burn - direct seed, d) direct seed.
2) Eric Hasselstrom near Winchester, ID -- following winter wheat with a) fall flail - direct seed with a John Deere 750 disc drill, b) spring burn - direct seed, c) fall disc - direct seed, and d) direct seed.
3) Randy and Larry Keatts south of Lewiston, ID -- following spring wheat with a) fall disc - direct seed with a Tye disc drill, b) fall subsoil/disc - direct seed, c) fall chisel/harrow - direct seed, d) spring burn - direct seed, and e) direct seed.
4) Art Schultheis near Colton, WA -- following winter wheat with a) fall disc/subsoil - direct seed with a Flex-Coil 6000 disc air drill , and b) direct seed.
5) Richard Druffel and sons south of Pullman, WA -- following spring wheat with a) fall disc/subsoil - direct seed with a Palouse Zero Till disc drill, and b) direct seed.
6) Larry Cochran near Colfax, WA -- following spring barley with a) fall chisel and fall cultivate/harrow - direct seed with AGPRO hoe drill or John Deere 750 disc drill, and b) direct seed.
7) Bob Garrett near Endicott, WA -- following spring wheat with a) fall chisel/harrow - direct seed with Great Plains Solid Stand disc drill, and b) direct seed. A second trial follows winter wheat.

University Research Farm Trials

The UI Kambitsch Research Farm south of Moscow is the site of two project studies. One trial evaluates residue production from two pea and two lentil cultivars, and the durability of the residue across cultivars and four tillage intensities for planting winter wheat: 1) direct seed and fertilize with a no-till drill; 2) direct-shank fertilize - conventional drill; 3) direct-shank fertilize - cultivate/harrow - conventional drill; 4) direct-shank fertilize - 2X cultivate/harrow - conventional drill. In 1997, pea residue production was about twice that of lentil (3,600 v.s.1,650 lb/A) though yields were all in the 1,500 to 2,000 range. There was "adequate" surface residue (30%) after winter wheat seeding only under the no-till and shank fertilize-and-seed systems following peas, and only with no-till following lentils. Data are also being on pest levels, yields and other production consideration. The 2-year trial is being repeated beginning in 1998

The second study will evaluate surface retention of spring wheat and spring barley cereal residue through four different fall 1996 tillage practices of plow, chisel, Paratill (low disturbance subsoiler) and no-tillage, then through the 1998 pea crop and finally through seeding of the 1999 winter wheat that fall. Pea residue and spring grain residue is being separated to determine the relative contributions of each to the amount of residue retained on the surface. Pea and winter wheat pest levels, yields, economics and other factors will also be compared under the different tillage systems. This 3-year trial is being repeated beginning with the spring wheat and spring barley planting in 1997.

Herbicide Trials

Research on management options for herbicides to control weeds in direct seed and minimum tillage systems for legumes are underway beginning in the fall 1997 and spring 1998. A variety of current and potential herbicides will be evaluated under the different tillage system on the UI

Kambitsch Research Farm and across the large plots on four of the grower on-farm tests. Some of the trials include fall v.s spring application and will evaluate weed control in both the peas crops as well as carryover effect on weed control and crop injury in the following winter wheat crops.

Fertility Trials Across Grower On-Farm Trials

A research no-till drill with separate offset coulter-discs as seed and deep band fertilizer openers is being used to evaluate 9 fertility management treatments. These trials are established across the large tillage/residue management plots on 5 of the 8 grower on-farm tests in 1998, 2 sites in Idaho and 3 in Washington. All fertilizer applications are applied as dry deep band applications about 2-3 inches below the seed rows. Applications of 20 lb/A each of N, P_2O_5 and S are applied individually and in combinations. There are two non-fertilized treatments: 1) deep band openers lifted and only seed openers in the ground; and 2) deep band openers set 2-3 inches below seeding depth to evaluate the effect of soil disturbance below the seed row as a possible tool to reduce root disease in direct seed systems for grain legumes.

Growers Invited to Be Involved in Additional On-Farm Trials

There is considerable variation in soils, and year-to-year climatic and production conditions across the grain legume production region. Field trials need to be conducted in as many diverse production environments as possible to identify management systems that are applicable specific production areas. Growers interested in evaluating direct seed and other minimum tillage systems for grain legumes on their farm are encouraged to contact of the project researchers (coauthors of this article). For more information, contact Roger Veseth at 208-885-3686 or e-mail (rveseth@uidaho.edu).

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

R. James Cook, Ron Sloot, and Kurt Schroeder

Direct seeding works best in the Inland Northwest when combined with a 3- or 4-year crop rotation that includes cereal crops alternated with broadleaf crops or chemical fallow and winter wheat no more than every third year. Unfortunately, the Inland Northwest is among the least suited of all wheat- and barley-growing areas in the United States for production of warm-season crops, which greatly limits the number of crops available for rotation with wheat and barley. On the other hand, the Inland Northwest is one of the few areas in the world that is more or less equally suited to production of both winter and spring wheat and barley. These ecological realities and the limited number of economically viable cool-season broadleaf crops available for use in crop rotations within this region can account for why most growers continue to plant two-thirds or more of their land to wheat and barley each year.

A study was undertaken in the fall of 1987 on the Palouse Conservation Field Station near Pullman to study root diseases and evaluate yield trends with continuous direct seeding. The site had already been direct-seeded to winter wheat for five consecutive years (1981-86) and was then chemical fallowed in 1986-87 prior to launching this study. The current (1998) planting therefore represents the 17th consecutive year where the only tillage performed on this site has been with the drill equipped to plant and fertilize as one-pass. During the 10 years that crops were grown with direct seeding since the year of chem fallow, the site has been planted to winter wheat three times, spring wheat five times, spring barley once (1993) and spring peas once (1994)?a total of 14 wheat crops and 15 cereal crops in the past 17 years. Rotations to spring cereals have been essential to manage cheat grass and jointed goat grass. Fumigation plots were included as checks for the first 5 years but were then discontinued. Many replicated seed-treatment, variety, row-spacing, and fertilizer-placement studies have been conducted at the site. The study site has never been burned during the 17 years, but has been planted each year across the direction of the rows of the previous year so as to place maximum amount of seed between rather than within the old stubble rows.

The data in Table 1 represent the untreated (natural soil) and fumigated checks together with five years of data on performance of Apron with either Terrachlor or Dividend for management of Pythium and Rhizoctonia, respectively. For each of these yields, rows have been spaced 12 inches apart and fertilizer has been applied directly beneath the seed as a combination of N (solution 32), P, and S based on a soil test (by McGregor Co) and yield goal (usually 100-110 bu/A for winter wheat and 70-80 bu/A for spring wheat).

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

The lowest yields of winter and spring wheat were in the second (Hill-81 at 57 bu/A in 1989) and third (Penawawa at 49 bu/A in 1990) years respectively. In both of these years, there was a large yield response to Apron-Terrachlor, soil fumigation, or both, further confirming the role of root diseases in these yield depressions. The low yield of Penawawa in 1992 was possibly the result of high temperature during grain fill. The first evidence of take-all decline (the spontaneous disappearance of take-all due to microbiological changes in the wheat rhizosphere) appeared in 1996 and was confirmed by Jos Raaijmakers and Dave Weller in 1997. Starting in the 1995-96 crop year, the site has been used to evaluate the performance of varieties and selections of winter wheat (cooperative with Steve Jones and Jim Anderson) and spring wheat (cooperative with Kim Kidwell).

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

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

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

DIRECT SEED CONFERENCE ANOTHER SIGN OF A NEW ERA IN FARMING ... AND 1999 CONFERENCE PLANS ARE UNDERWAY

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist

There's been a phenomenal increase in the use of direct seeding systems and more diverse crop rotations across the Northwest, America and around the world. Nearly 900 Northwest growers and Ag advisers attended the first Northwest Direct Seed Intensive Cropping Conference on January 7-8, 1998 in Pasco, WA. The Conference would have been even larger, but registration had to be restricted because of space limitations. What is behind this huge interest in direct seeding and alternative cropping systems?

Some important factors driving these changes include: 1) increasing global market competition and the need to reduce costs and improve profitability; 2) new crop rotation flexibility under the 1996 Farm Program; 3) increasing grower and public concern about cropland soil loss by water and wind erosion; 4) greater awareness of the soil quality and productivity benefits of direct seeding and detriments of intensive tillage; and 5) significant advances in management and equipment technologies for direct seeding. The following provides some examples and further explanation.

1) **Competing with the Competition** -- This is the name of the game as NW growers move into an increasingly global marketplace. Direct seeding and other minimum tillage systems offer the potential to reduce production costs and increase profitability.

Some examples of 1997 statistics may help provide some insight into how our national and international competitors are moving towards direct seeding system. The 5% of PNW cropland was under no-till direct seed systems pales in comparison to the U.S. average of 16%, Brazil - 15%, Canada - 18%, Argentina - 28% and western Australia - 30%.

A brief review of the rapid trend towards no-till in Argentina helps illustrate the tremendous growth in no-till direct seed systems. In 1990, there was less than 2% of Argentina's cropland in no-till. That grew to 6% in 1993, 19% in 1996, and 28% in 1997, which is nearly 15 million acres. The 5% of Northwest cropland under no-till in 1997 is about the same as Argentina's 6% in 1993. You could say that we are about four years behind Argentina in adopting more efficient farming technologies. Western Australia is another striking example, growing from 0.1% in 1989 to over 30%, about 10 million acres, in 1997. There are similar trends around the world.

The potential advantage of direct seeding on production efficiency was quite striking on a June 1997 Northwest grower tour in South Dakota. A direct seeding grower was farming about 10,000 acres with two implements, a 100' sprayer and 60' no-till air drill. Custom harvesters did the combining. It would be interesting to compare the input costs of their two-pass operation with the same size farm under conventional tillage, looking at the number of tractors and implements needed, equipment maintenance, fuel, labor and other production costs. If we are going to compete economically, we need to explore the production efficiency potential of direct seeding and other minimum tillage systems.

2) New Rotation Flexibility -- The 1996 "Freedom to Farm Bill" finally gave growers the cropping flexibility needed to develop crop rotations critical to the success of direct seeding systems. For more than 50 years, U.S. Farm Bills have been major obstacles to successful no-till and minimum tillage systems in the Northwest and across the country. Commodity program restrictions largely locked Northwest dryland growers into short crop rotations in order to maintain their wheat base acreage, and high proven yields for winter wheat. To manage weeds and diseases, they were forced to rely on intensive tillage. Early NW attempts at no-till beginning in the 1970's, in their traditional 2-year rotations with winter wheat, often resulted in reduced yields or crop failures due to soilborne diseases and winter annual grass weeds. At that time there was also little research base or grower experience to guide growers in managing these new conservation tillage systems.

3) Effective Soil Erosion Control -- Water and air quality are becoming more important issues, so the urgency for cropland erosion control will increase. It is well documented by research and grower experience worldwide that direct seeding systems can effectively reduce or totally eliminate water and wind erosion. It is important, however, that all crops in the rotation be managed under direct seeding or other minimum tillage systems to optimize erosion control and soil productivity benefits.

4) New Insights into Tillage Impacts and Direct Seeding Benefits -- The results of recent research and long-term grower experiences in North America and around the world are revolutionizing our understanding of the impacts of tillage on soils. Contrary to the long-held belief that returning crop residue to the soil with tillage builds soil organic matter, the real impact of intensive tillage systems is a continual decline in soil organic matter content. Organic matter is a critically important soil component directly related to soil fertility, water holding capacity and infiltration, aggregation and structure, erodibility, biological activity and a long list of other soil properties affecting soil productivity and soil quality.

The increased oxygen level and higher soil temperature present after tillage stimulate intense microbial activity under moist soil conditions. A tremendous amounts of carbon can be released as carbon dioxide during this accelerated microbial decomposition of soil organic matter. The end result is that tillage is biologically burning off soil organic matter faster than it can be built with the addition of new crop residues.

Research shows that no-till direct seeding systems result in very low carbon loss compared to intensive tillage, consequently offering the greatest potential for increasing soil organic matter content over time. The greater and more frequent the soil disturbance, the greater the carbon loss potential. With improved water conservation under direct seeding there is a corresponding higher yield potential. For wheat, it is around 5 to 7 bushels/acre per inch of additional water. The challenge for growers and Ag support personnel is to develop the crop rotations and management systems to control of pests previously controlled by intensive tillage in order to take advantage of the higher yield potential.

5) New Direct Seeding Technologies -- There have been some significant technology advances since Northwest growers began trying no-till drills in the 1970's. Many of the pest problems that occurred during the past 30 years can now be largely avoided because of new research technologies. Here are a few important examples.

Longer, more diverse crop rotations have been shown to be very effective in controlling weeds, diseases and insect pests that often occur in direct seed systems under short crop rotations. Northwest growers, researcher, and industry representatives are scrambling to find profitable alternate crops and crop rotations for the different production areas of the region.

Another big technology advance was identifying the impact and management of the "Green Bridge," which has been a major cause of crop failures or sharply reduced yields in direct seeded spring crops in the Northwest for over 25 years. Northwest research showed that the short time interval between spraying a non-selective herbicide on volunteer and weeds before direct seeding created a "green bridge" for root diseases and some insects to attack the new crop. It can be effectively eliminated by spraying as early as possible before seeding, beginning in the fall if possible, and early spring at least three weeks before seeding. After this early control, late spraying of very low populations of small, late-emerging weeds and volunteer just before seeding will then have little "green bridge" potential for root disease. Uniform distribution of chaff from the combine is also an important starting point in managing the green bridge and other concerns in direct seeding.

Research developments on seeding equipment designs for fertilizer and seed placement have revolutionized equipment for direct seeding. In the early 1970's, there were only about 5 models of "no-till" drills available in the Northwest, none of which had deep fertilizer banding capability. Research has shown that deep fertilizer placement below seed depth and near the seed row can significantly improve yield potential under direct seeding, particularly with cereals after cereals. Today there are over 40 drill models, nearly all with deep fertilizer placement options. Improvements are still needed in hillside performance and residue handling capabilities under some Northwest conditions, but grower now have a large variety of equipment options. There are also numerous examples of excellent grower and industry equipment modifications to improve performance of direct seeding equipment in the region.

1998 Conference Proceedings and Videotapes

The January 1998 Northwest Direct Seed Intensive Cropping Conference featured 48 speakers, including 16 grower, from across the Northwest, Canada and Australia. If you were unable to attend, you can have the next best thing to being there!!!........Conference Proceedings and Videos. The detailed 150-page Conference Proceedings of speaker presentation is available for $10 from: NW Direct Seed Conference, P.O. 2002, Pasco, WA 99320, FAX 509-547-5563, phone 547-5538. The Proceedings can also be accessed through the Internet Home Page "PNW STEEP Conservation Tillage Systems Information Source" (http://pnwsteep.wsu.edu). Videotapes of the seven 2- to 3-hour Conference Focus Sessions are also available for purchase ($15 each) or loan. More than 100 sets of the tapes were sold within three months after the conference. Call the WSU Crop and Soil Sciences Dept. Extension office at 509-335-2915 (or FAX 335-1758) for a complete video series description and order form.

1999 NW Direct Seed Intensive Cropping Conference is Underway

The second Northwest Direct Seed Intensive Cropping Conference will be held on January 5-7, 1999 at the Ag Trade Center and DoubleTree Hotel-City Center in Spokane, WA.

The Conference is being organized as a service to growers by the PNW STEEP III (Solutions to Environmental and Economic Problems) program, a cooperative conservation farming research effort through the University of Idaho, Oregon State University, Washington State University, and USDA-Agricultural Research Service. It will be co-sponsored by over 10 Ag industries, in cooperation with grower organizations, conservation district associations and other PNW Ag support groups and agencies.

The preliminary program has nearly 40 speakers, including researchers and industry representatives and about 15 growers from across the Pacific Northwest, Northern Great Plains, Canada, South America, New Zealand, and other countries.

A commercial "Direct Seed Equipment and Technology Exhibition" will be a new feature of the Conference, providing growers and Ag industry representatives additional opportunities to discuss technology needs and share new innovations. "Ask the Expert - Direct Talk Sessions" with growers, researchers and industry representatives will also provide excellent opportunities for questions and discussions of key topics on your direct seed systems.

Tentative agenda topics include 2- to 3-hour, in-depth "Focus Sessions" on a variety of topics on developing direct seed intensive cropping systems, including:

- National and international trends and experiences
- Agronomics and economics of new crops and crop rotations
- Evaluating the economics of direct seed versus tillage-based systems
- Grower equipment fabrication and modifications
- Starting and surviving the transition to direct seeding
- Direct seed management systems for grain legumes
- Making sense of the row spacing debate
- PNW grower experiences with direct seeding and alternative rotation

To receive a copy of the Conference registration packet when it is available this summer, call the NW Direct Seed Conference office at 509-547-5538, FAX 5563, e-mail (maurer@owt.com). Motel rooms can be reserved at the DoubleTree Hotel-Spokane City Center by calling 509-455-9600. Request special Conference room rates of $55 - one bed for 1 or 2 people; $65 - two beds for 2 people and $75 - two beds for 3 people, plus tax. Reservation space and Conference rates may not be available after December 12, 1998. For more information on the Conference program, participating in the Direct Seed Equipment and Technology Exhibition, or co-sponsoring the Conference, contact Roger Veseth, WSU/UI Extension Conservation Tillage Specialist and Conference Coordinator, at 208-885-6386, FAX 885-7760, e-mail (rveseth@uidaho.edu).

PROFITABILITY ANALYSIS FOR 1995-1997 FOR RESIDUE AND TILLAGE MANAGEMENT IN VERY DRY WHEAT- FALLOW CROPPING SYSTEMS

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This report presents profitability results for the first three crop years of a project at Lind, WA where traditional tillage practices are compared with minimum and delayed minimum tillage practices. The experimental site is in a 9.5" annual precipitation area which has historically produced soft white winter wheat in a summer fallow rotation. Producers generally use tillage rather than herbicides for weed control during the fallow cycle in low rainfall regions because it has lower out of pocket costs. Conventional tillage operations can leave the soil susceptible to both wind and water erosion, especially after low crop production years. Excessively tilled summer fallow fields are particularly prone to wind erosion. Wind erosion not only harms the producer by removing valuable topsoil, but blowing dust presents health hazards to the general public.

Procedures

Minimum tillage and delayed minimum tillage fallow are compared to traditional conventional tillage fallow. Minimum tillage includes the use of herbicides for weed control. Delayed minimum tillage also incorporates the use of herbicides, but it delays spring tillage on fallow until at least mid-May. Paired parcels of land were used so that both crop and fallow portions of the experiment appear each year.

Both of the minimum tillage treatments consistently retain more surface residue during the fallow cycle. These practices allow producers to maintain the minimum 350 lbs/acre of surface residue at the end of a fallow cycle to remain eligible for government transition payments in some areas. These surface residue levels often are not attainable using conventional tillage after low crop production years. Both minimum tillage systems increase over-winter soil water storage efficiency, surface residue retention, and surface cloddiness compared to conventional tillage.

Preliminary Economic Analysis

Costs were based on the actual sequence of field operations used on the Lind research plots; however, the equipment used for cost calculations represent equipment sizes and types typical for the low-rainfall dryland area. Table 1 shows three net return measures for each cropping system: net returns over total, variable and cash costs. After the first three crop harvests of this study, the conventional tillage system was the most profitable by a modest margin using all net returns measures. Conventional tillage outperformed both of the conservation tillage treatments by approximately $5 per rotational acre (see Net Returns over Total Costs comparisons in Table 1). However, all three systems show positive net returns given the 1995-97 average yield results and the utilized three-year average soft white wheat price of $3.92/bu.

Conventional tillage also shows higher net returns over cash costs, at $17.30 per rotational acre. Returns over cash costs exclude all non-cash equipment depreciation and the opportunity cost of money tied up in fixed assets. Labor and land rental costs are included in cash costs. However, Table 3 reports the land and labor costs for the benefit of readers who might wish to exclude one or both of these items from cash costs. Minimum tillage has returns over cash costs of $14.99 per rotational acre and delayed minimum tillage $14.39 per rotational acre. These results are separated by less than $3 per acre from the conventional tillage results of $17.30 per acre.

Net returns over variable cost show similar close results. Conventional tillage generated the highest average net returns over variable costs for the 1995-97 at $58.80 per rotational acre. Minimum tillage ranks second at $56.26, and delayed minimum tillage is third at $53.79.

Net returns over cash cost were also calculated to reflect the current depressed wheat market. The soft white wheat price for April 24, 1998 at the Ritzville elevator($2.94/bu) was used with the average yields in Table 2. As expected, all tillage options yield negative net returns over cash costs under the current market. Conventional tillage is the most profitable at -$10.93 per rotational acre. Delayed minimum tillage follows with a net return of -$13.82 per rotational acre, and minimum tillage ranks third with net returns of -$14.38.

Conclusions

Although preliminary analysis shows a slight economic advantage with conventional tillage, the profitability spread among the three systems is small. On average there was always less than a $6 per acre difference between conventional and minimum tillage systems for all net return measures. Even though minimum tillage slightly outperformed the delayed minimum tillage in all three analyses where average price was used, delayed minimum tillage outperformed minimum tillage when the low current market price was used. This is because minimum tillage incurred higher costs than the delayed tillage system because more field operations were required.

Minimum tillage and delayed minimum tillage systems had similar profit levels in these results. Readers are cautioned that these are preliminary results based on only three years of crop yield data. Future analyses will quantify as possible the long run benefits to producers and the public of increased soil and air quality with the conservation tillage practices. We are hopeful that final results will show that the improved over-winter water storage, surface residue retention, and soil roughness with the minimum tillage systems are worth the few dollars by which minimum tillage profitability fell short of that of conventional tillage for these 1995-97 results.

Table 1. Net Returns ($/ac) over Selected Costs

Tillage System	Rev/Ac*	Cost/Ac Variable	Cost/Ac Cash	Cost/Ac Total	Net Returns Over Cost Variable	Net Returns Over Cost Cash	Net Returns Over Cost Total	Net Returns Over Cost Cash**
Conventional Tillage	112.88	54.08	95.58	104.81	58.80	17.30	8.06	-10.93
Minimum Tillage	117.47	61.21	102.48	114.42	56.26	14.99	3.05	-14.38
Delayed Minimum Tillage	112.83	59.04	98.43	109.97	53.79	14.39	2.86	-13.82

* $3.92/bu = 1996-98 av. price.
** $2.94/bu = 4/24/98 price

Table 2. Annual Average Plot Yields (bu/ac) by Cropping System*

Tillage System	1995	1996	1997	Av.
Conventional Tillage	29.67	58.22	84.89	57.59
Minimum Tillage	31.67	62.11	86.00	59.93
Delayed Minimum Tillage	29.56	61.56	81.89	57.67

* Winter wheat yields reflect 10% moisture and chaff.

Table 3. Land and Labor Costs ($/ac/yr) by Cropping System

Tillage System	Land Cost	Labor Cost
Conventional Tillage	30.79	8.99
Minimum Tillage	31.90	8.65
Delayed Minimum Tillage	30.42	7.93

PROFITABILITY OF A LONG TERM NO-TILL CONTINUOUS SPRING WHEAT FARM IN WALLA WALLA COUNTY

Oumou Camara, Douglas Young, Herbert Hinman, and Dennis Roe
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USDA recently reported that farmers expanded use of no-till nationally from 5.1 to 14.8 percent of cropland between 1989 and 1996. In contrast, use of no-till in the Pacific Region, which includes the Pacific Northwest (PNW), remained around 1 percent and showed comparatively little growth during this period. Some PNW growers have tried no-till on limited areas or for a few years. Also nearly all farmers report some form of residue management in their conservation compliance farm plans. However, the overwhelming majority of cropland in the region is still tilled. Despite the dominance of tillage in PNW dryland farming, a small but visible minority of growers in the region appear to have used no-till with economic success. Some of these growers have spoken at farm meetings and shared their methods with others. For example, no-till farmers shared their experiences with over 800 growers and other interested individuals at the January 1998 STEEP III Direct Seeding Conference in Pasco, WA. It is apparent that successful no-till systems must be tailored to the agro-climatic and business situation of individual growers, so a systematic economic evaluation of successful no-till farms could be useful to potential adopters.

Economic evaluations of no-till and other conservation tillage research experiments have been conducted over the past two decades. However, no long term 100% no-till research trials in the PNW appear to have matched the economic success reported by a few individual no-till farmers. This provides justification for closely examining and documenting the cultural practices, production costs, and economic returns of PNW farmers who have used no-till over an extensive period of time. Research on the economics of no-till is timely as interest in no-till farmer experience and research results has recently surged in the PNW.

PROCEDURES

This paper presents results of costs and returns budgeting based on an extensive interview with a Walla Walla County farmer with 16 years experience growing no-till continuous hard red spring wheat (HRSW) in a 10 inch precipitation zone. This progress report is the first of several intended economic case studies of long term PNW no-till farmers. About half of the first interviews have been completed on this project, but the complete economic analysis including review by the farmer of the results has been completed only for the case study reported here. We are cooperating with another WSU project which is also surveying long term no-till farmers regarding their agronomic practices and no-till adoption considerations. The agronomic and outreach activity of this related project should complement the in depth economic and cost assessment research of our project.

Personal interviews with the no-till farmers collect information on the timing and composition of farming operations; the size, age, annual repairs, and hours of annual use of machinery; speed of operations; type and rates of inputs used; fixed costs such as land costs, taxes, insurance, and overhead; and any other costs or special practices. Production history on crop yield and quality for as many years as records or recollection permit is also collected. The data are then entered on input forms, cross checked with the farmer if necessary, and an enterprise budget is generated using the Cooperative Extension Enterprise Budget Generator in the WSU Department of Agricultural Economics. Preliminary runs of results tables are sent to the cooperating grower for review and possible correction.

Results

The Walla Walla County no-till spring wheat grower farms over 7,000 acres and reported an average yield of 31 bu/ac over the past 16 years. With premiums for protein, the grower reported missing $5/bu for his wheat only two of the past 16 years. Annual records of prices received were not available, but the grower would gross $155/acre at $5/bu and $170/acre at $5.50 /bu. He reported averaging about 8 bu/ac less with HRSW than with soft white winter wheat which often sells for about $1/bu less than high protein HRSW. Table 1 summarizes in detail the grower's estimated variable and fixed costs of production. Table 2 outlines the farmer's costs of operations by calendar month and by type of machinery used.

Production cost results were impressive with estimated average variable costs of only $100.40 per acre and total costs of $149.23 per acre. At the conservative HRSW price of $5/bu, the farmer would net $54.60/acre over variable costs. The break-even selling price to cover variable costs is $3.24/bushel; HRSW must sell for at least this price to cover all variable costs. At $5.50/bu for HRSW net returns over total costs would exceed $20/acre. At today's (April 1998) depressed HRSW price of $4.10/bu the grower would incur a loss of over $20/acre for returns over total costs. The grower responded that our estimated fixed costs and repair costs in Table 1 seemed slightly high, but suggested no specific modifications. It should be noted that the cost figures in these tables are full cost figures in that they include interest cost on operator equity, a $10/hr wage for operator labor, and a 5% return on land value as the cost of land. If growers wish to delete or modify these or other costs for their planning purposes, they may do so by using the "Your Farm" column in Table 1.

Possible benefits from this research will include identifying the relative importance of agronomic factors, site factors, cost management and marketing in profitable no-till farming. This study will pay particular attention to cost control. Preliminary results indicate that efficiency in machinery management is critical to profitable no-till production of spring crops. Short planting windows for spring crops accentuate the importance of excellent machinery maintenance, few or no breakdowns, good timing, appropriate machinery capacity, and good overall speed in drilling and weed control. Also, achieving consistently high grain quality and protein premiums are important to economic success. Other key factors are likely to be learned from the farmers themselves as the study proceeds.

TABLE 1. ITEMIZED COST PER ACRE FOR CONTINUOUS HARD RED SPRING WHEAT GROWN IN THE 8 - 10 INCH RAINFALL AREA OF WALLA WALLA COUNTY, JOHN REA'S FARM.

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST	YOUR FARM
VARIABLE COSTS		$		$	
WHEAT SEED	LB.	.12	100.00	12.00	
ANHYDROUS NITROGEN	LB.	.35	60.00	21.00	
16-20-0-20	LB.	.13	125.00	16.25	
ROUNDUP	QT.	12.00	.63	7.50	
BANVIL	OZ.	.79	.67	.53	
2-4-D	QT.	4.05	.33	1.35	
LABOR(TRAC/MACH)	HOUR	10.00	.99	9.89	
RENTAL COMBINE	HOUR	125.00	.06	7.81	
RENTAL SPRAYER	ACRE	1.50	1.50	2.25	
TRACTOR REPAIR	ACRE	1.94	1.00	1.94	
TRACTOR FUEL/LUBE	ACRE	2.44	1.00	2.44	
MACHINERY REPAIRS	ACRE	7.30	1.00	7.30	
MACHINE FUEL/LUBE	ACRE	2.04	1.00	2.04	
INTEREST ON OP. CAP.	ACRE	2.72	1.00	2.72	
OVERHEAD	ACRE	4.88	1.00	4.88	
TOTAL VARIABLE COST				100.40	
FIXED COSTS		$		$	
TRACTOR DEPRECIATION	ACRE	3.70	1.00	3.70	
TRACTOR INTEREST	ACRE	5.78	1.00	5.78	
TRACTOR INSURANCE	ACRE	.35	1.00	.35	
TRACTOR TAXES	ACRE	1.04	1.00	1.04	
TRACTOR HOUSING	ACRE	.58	1.00	.58	
MACHINE DEPRECIATION	ACRE	8.24	1.00	8.24	
MACHINE INTEREST	ACRE	10.18	1.00	10.18	
MACHINE INSURANCE	ACRE	.61	1.00	.61	
MACHINE TAXES	ACRE	1.83	1.00	1.83	
MACHINE HOUSING	ACRE	1.02	1.00	1.02	
LAND TAXES	ACRE	3.00	1.00	3.00	
LAND COST	ACRE	250.00	.05	12.50	
TOTAL FIXED COST				48.83	
TOTAL COST				149.23	

TABLE 2. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE FOR CONTINUOUS HARD RED SPRING WHEAT GROWN IN THE 8-10 INCH RAINFALL AREA OF WALLA WALLA COUNTY, JOHN REA'S FARM.

						VARIABLE COST						
OPERATION	TOOLING	MTH YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	FUEL, LUBE, & REPAIRS	MACH LABOR	SERVICE	MATER.	INTER.	TOTAL VARIABLE COST	TOTAL COST
					$	$	$	$	$	$	$	$
SWEEP	280HP-75CT, 30'SWEEP	AUG 1996	.05	.06	3.90	1.45	.55	.00	.00	.18	2.18	6.09
SPRAY (50%)	280HP-75CT, RENTAL SPRAYER	NOV 1996	.02	.02	.81	.30	.20	.75	1.50	.18	2.93	3.74
HAUL WATER (50%)	3T TRUCK W/1500 GAL. SLIP TANK	NOV 1996	.01	.02	.24	.15	.20	.00	.00	.02	.38	.62
SPRAY	280HP-75CT, RENTAL SPRAYER	MAR 1997	.03	.04	1.61	.60	.40	1.50	6.00	.28	8.78	10.40
HAUL WATER	3T TRUCK W/1500 GAL. SLIP TANK	MAR 1997	.02	.04	.48	.31	.40	.00	.00	.02	.73	1.21
NO-TILL PLANT	280HP-75CT, 20' NO-TILL DRILL	MAR 1997	.10	.22	11.50	3.90	2.20	.00	49.25	1.85	57.20	68.70
HAUL SEED	3 TON TRUCK	MAR 1997	.02	.03	.48	.31	.33	.00	.00	.02	.66	1.15
SPRAY (33%)	280HP-75CT, RENTED SPRAYER	APR 1997	.01	.01	.54	.20	.13	.00	1.88	.06	2.27	2.80
HAUL WATER (33%)	3T TRUCK W/1500 GAL. SLIP TANK	APR 1997	.01	.01	.17	.11	.13	.00	.00	.01	.25	.42
HARVEST	30' COMBINE	JUL 1997	.06	.07	8.36	2.50	.72	.00	.00	.00	3.22	11.58
HARVEST	30' RENTAL COMBINE	JUL 1997	.00	.07	.00	.00	.72	7.81	.50	.00	11.03	11.03
HARVEST	TWO BANKOUT WAGONS	JUL 1997	.13	.14	1.39	1.16	1.44	.00	.00	.00	2.60	3.99
HAUL	TWO SEMI-TRUCKS & TRAILERS	JUL 1997	.13	.14	3.01	1.93	1.44	.00	.00	.00	3.37	6.38
MISC USE	3/4 TON PICKUP	ANN 1997	.06	.07	.58	.47	.69	.00	.00	.06	1.21	1.80
MISC USE	LABOR PICKUP	ANN 1997	.03	.03	.24	.33	.34	.00	.00	.03	.71	.95
OVERHEAD	UTILITIES, LEGAL, ACCT, ETC.	ANN 1997	.00	.00	.00	.00	.00	.00	4.88	.00	4.88	4.88
TAXES	LAND TAXES	ANN 1997	.00	.00	3.00	.00	.00	.00	.00	.00	.00	3.00
LAND COST	5% OF LAND VALUE	ANN 1997	.00	.00	12.50	.00	.00	.00	.00	.00	.00	12.50
TOTAL PER ACRE			.67	.99	48.83	13.73	9.89	10.06	64.00	2.72	100.40	149.23

PROFITABILITY ANALYSIS FOR 1996 AND 1997 RESULTS OF RALSTON SPRING CROPPING TRIALS

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This report presents economic results for experimental trials conducted at the Ralston, WA site. These trials are designed to conserve soil, protect air quality, and maintain or improve farm profitability. Various crop rotations with reduced or no-till systems are being examined with special emphasis on continuous spring cropping in low rainfall regions.

The traditional winter wheat/ fallow system in this region has historically offered advantages in terms of income stabilization, moisture conservation, economical tillage weed control, efficiencies in seasonal labor and machinery use, and consistencies with acreage bases and established yield provisions of pre-1996 farm programs; however, this summer fallow system has conflicted with important air and soil quality concerns. Dust blowing from fallow and/or from winter wheat fields reduces air quality over large areas downwind from the site and decreases the long-term soil productivity and sustainability of agriculture in these regions. The traditional wheat/fallow system also suffers from certain weeds such as downy brome and jointed goatgrass, and specific diseases such as take-all. Conservation tillage with continuous spring grains or with spring grains/winter wheat rotations will reduce fallow, increase protective residue cover to conserve soil and protect air quality, reduce the incidence of winter annual grass weeds, and decrease soil borne diseases. However the transition to spring crops may increase income risk due to moisture deficits, cause weed species and pathogen shifts, and create fertility management challenges which merit focused research to make spring cropping a viable option in low rainfall regions of the Pacific Northwest.

Historically, spring wheat has been used only as a "rescue crop" in low rainfall regions when winter wheat fails due to frost damage or severe weed infestations. Consequently there has been little research devoted to continuous spring wheat in these areas as a deliberate rotation. Because spring wheat typically yields about two thirds as much as winter wheat and has higher annual costs and yield variability, sharp management is necessary to make annual spring wheat profitable. However, two economic factors might improve the profitability prospects for spring wheat. First, the 1996 Farm Bill eliminated the requirement that farmers maintain plantings within historical base acreages of wheat or barley to be eligible for government payments. Now, growers are eligible for transition payments through 2002 regardless of their grain acreages. Secondly, hard red spring wheat with 14 percent protein has generally commanded price premiums of roughly $1 per bushel compared to soft white wheat; these premiums, if consistently attained, can help offset the lower yields of spring wheat. Also developing Best Management Practices (BMP's) may increase spring wheat production an estimated 5-8 bushels per acre.

Procedures

The experimental trials examined in this study 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/fallow; b) no-till soft white spring wheat/ chemical fallow; c) continuous no-till hard red spring wheat; and d) no-till hard red spring wheat/ no-till spring barley rotation. This preliminary economic analysis is based on the first two years (1996 and 1997) of this five year study. Readers are cautioned that weather patterns in 1996 and 1997 were relatively favorable to spring wheat yields.

Costs are calculated based on the actual sequence of operations conducted on the research plots but assuming typical farm-scale machinery for the region. Actual fertilizer, herbicide, seed and other input rates are averaged over the 1996 and 1997 rates used in the experiment for each crop and rotation. Actual yields from the experiment were averaged over both years. All cost and revenue figures are presented 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.

Preliminary Economic Results

Table 1 shows various return measures for each cropping system. The crop prices and average yields underlying these results are presented in Tables 2-3. Based only on these 1996 and 1997 results, the first two years of this study, the traditional soft white winter wheat/fallow system (SWWW/fallow) was the most profitable in terms of returns over total cost. This was the only system based on plot results to exhibit positive returns over total costs at $5.84 per rotational acre. The continuous hard red spring wheat system (cont. HRSW) with 13.23 percent protein ranked second at -$5.97 per rotational acre. The soft white spring wheat/chemical fallow system (SWSW/fallow) ranked third at -$15.14 per rotational acre. The hard red spring wheat/spring barley system (HRSW/SB) with 13.8 percent protein ranked fourth at -$17.27 per acre. Poor barley yields during the 1997 substantially reduced this system's profitability (see Table 2).

Table 1 also presents returns over variable costs. Variable costs exclude equipment fixed costs, land costs, and overhead. The continuous HRSW and the traditional winter wheat/ fallow system exhibited the highest net returns over variable cost, at $66.31 and $60.25 per rotational acre, respectively. Land costs, based on typical crop share rents, were a relatively high contributor to fixed costs for cont. HRSW which explains the reversal in rankings for SWWW/fallow and cont. HRSW between returns over total costs and returns over variable costs. All of the tested cropping systems exhibited positive returns over variable costs. The HRSW/SB ranked third with net returns over variable cost at $46.27 per rotational acre, $20 below the continuous HRSW, while the SWSW/fallow system ranked a distant fourth at $21.12 per rotational acre.

Returns over cash costs represent the return over all cash costs. Non-cash costs such as equipment depreciation, equipment housing and the opportunity cost of money tied up in machinery are excluded from the fixed costs. However, the land cost share rent and labor costs are included in cash costs. The land and labor costs used in this calculation are presented in Table 4 if the reader wishes to exclude them. The traditional winter wheat fallow system continues to be the best performer with a return of $17.87 per rotational acre. Continuous HRSW ranks second at $9.04, HRSW/SB third at -$2.65, and the SWSW/chemical fallow system ranks fourth at -$6.47 per rotational acre. These results were calculated with the average cost and yield figures presented in Tables 2 and 3.

Additional calculations were made to reflect net returns if HRSW reached the 14 percent protein level. While the HRSW results at Ralston failed to achieve 14 percent protein in 1996 and 1997, it is useful to examine the added profitability from reaching this goal. With 14 percent protein, the continuous HRSW system would rank first by all return measures. The HRSW/SB system would also exhibit improved return figures if the 14 percent protein level could be obtained. This system would exhibit positive returns over cash costs at $0.54 compared to $-2.65 when the actual protein level of 13.8 percent was used.

Potential returns over cash costs were also calculated to reflect the current depressed market situation. April 24, 1998 Ritzville elevator prices were used with the average crop yields from Table 2 to compute these net returns. All of the systems exhibited negative returns, but the continuous hard red spring wheat at the 14 percent protein level offered the highest returns to the producer under these conditions. Even if the average protein level of 13.23 percent is reached this system would compare favorably to the SWWW/ fallow system.

Conclusions

These preliminary results show promise for continuous spring cropping systems, particularly if the 14 percent protein level can be reached for HRSW. During the first two years of this study the HRSW plots have not consistently reached the 14 percent protein level. Even if the 14 percent protein level is not reached, the continuous HRSW system compares favorably to the traditional winter wheat fallow system. The spring wheat yields obtained through this study are probably above average due to favorable precipitation levels which occurred during 1996 and 1997. To remain competitive with the traditional winter wheat-fallow rotation, achieving high protein HRSW will be extremely useful, especially if spring wheat yields were to average lower than those observed in these results over the long run. Potential gains in future yields due to higher levels of soil retention would also increase the value of the spring cropping options. Other work has also shown public valuation for higher levels of air quality.

Table 1. Net returns over selected production costs ($/ac/yr), Ralston, 1996 and 1997 average results.

Rotation***	Rev/Ac (94-98 av. Revenue Price)	Cost/Ac Variable Cost	Cost/Ac Cash Cost	Cost/Ac Total Cost	Net Returns Over Cost Variable Cost	Net Returns Over Cost Cash Cost	Net Returns Over Cost Total Cost	Net Returns Over Cash Cost (4/24/98 price)
SWWW/fallow***	139.75	79.50	121.88	133.91	60.25	17.87	5.84	-17.06
SWSW/ chem fallow***	109.57	88.45	116.04	124.71	21.12	-6.47	-15.14	-33.86
Cont HRSW***								
13.23 av % protein*	217.03	150.72	207.99	223.00	66.31	9.04	-5.97	-21.38
14 % protein**	231.82	150.72	207.99	22300	81.10	23.82	8.82	-6.60
HRSW/SB***								
13.8 avg % protein*	185.51	139.24	188.16	202.78	46.27	-2.65	-17.27	-39.38
14 % protein**	188.70	139.24	188.16	202.78	49.46	.54	-14.08	-31.76

* Actual plot data
** Goal protein level
*** SWWW = soft white winter wheat
SWSW = soft white spring wheat
HRSW = hard red spring wheat
SB = spring barley

Table 2. Annual Plot Yields*

Crop /Rotation	1996	1997	AVG.
SWWW (bu /ac): SWWW/fallow	78.11	64.44	71.28
SWSW (bu/ac):SWSW/chem fallow	51.00	60.78	55.89
HRSW (bu/ac): Cont. HRSW	40.05	55.33	47.69
HRSW (bu/ac): HRSW/SB	42.78	55.67	49.23
SB (tons/ac): HRSW/SB*	1.81	1.03	1.42

* All wheat yields reflect 10% moisture and chaff and barley yields reflect 7.5% moisture and chaff.

Table 3. Average Crop Prices

Crop	Prices 1995-1998 Av.	Prices 04/24/98
SWWW ($/bu)	3.92	2.94
SWSW ($/bu)	3.92	2.94
HRSW 14% protein ($/bu)	4.86	4.09
SB ($/ton)	85.44	74.00

Table 4. Land and labor costs ($/ac/yr) by cropping system

Tillage System	Land Cost	Labor Cost
SWWW/fallow	32.62	10.95
SWSW/chem. fallow	19.11	9.76
Cont. HRSW	51.04	13.29
HRSW/SB	41.45	12.73

HOW COUNTY AVERAGE DATA CAN UNDERESTIMATE FARM LEVEL RISK: A DOUGLAS COUNTY WA WHEAT PRODUCTION EXAMPLE

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Risk is pervasive in agriculture due to weather, pests, crop prices, and other unpredictable factors. Correctly measuring risk at the farm level is difficult, however, because of a lack of good farm data on the variability of crop yields. Multi-year yield records from individual farms are often confounded by crop rotation shifts and changing production technology that make risk inferences problematic. Crop yield time series from government sources are typically aggregated to the county or state level. Yield time series from controlled experiments are often available for only a few years and may not represent farm level conditions. Yields can be synthesized for any number of years with computerized simulation models which reflect random weather, but these simulated results should desirably be validated against farm data. Furthermore, many simulation models do not incorporate all sources of farm level yield variation such as diseases, insects, weeds, and natural disasters. Good survey-based farm level data, especially of more than a few years duration, are rare. Our objective in this paper is to compare wheat yield and income risk estimates from a Douglas County farm to estimates from county average yields over the same period.

Comparison

Annual average winter wheat yields were collected from a Douglas County, WA farmer for the 23-year period, 1972-1994. Yields were obtained for two leased 1200 ac parcels located 5 miles apart in a 9-12 inch annual rainfall zone of central Douglas County. All the farmer's land remained in a soft white winter wheat-summer fallow rotation with relatively uniform cultural practices during 1972-1994. Due to cropshare leasing arrangements, the farmer kept accurate yield records for each parcel. Annual yields for the two farm parcels and for the average Douglas County winter wheat yields for 1972-94 are plotted in Figure 1. The county average yields are drawn from Washington Agricultural Statistics. Both the county average and the farm yields over 1972-94 period were variable, but the county average yields exhibit considerably less variability. Both farm parcels experienced a complete crop failure in 1973, but the county average yields always remained substantially above zero.

Descriptive statistics for farm and county wheat yield and net revenue are shown in Table 1. The coefficient of variation (CV) of winter wheat yield equaled 41 percent for the farm data and 29 percent for the county average data over the 1972-94 period. Farm net revenue variation as measured by CV exceeded county net revenue variation by 25 and 86 percent for farm parcels 1 and 2, respectively. The results in Table 1 are consistent with statistical theory and with similar variability comparisons in the literature for corn, soybeans, oats, wheat, and tobacco in Indiana and Kentucky. In all studies, the use of county average data seriously understated farm level crop yield and revenue variability. Due to its availability, it is tempting to use county or other aggregated data to make inferences about the riskiness of cropping systems intended for farmers.

However, one should recognize that published aggregated data will generally underestimate farm level risk.

Farm and subfarm yield data may become more available in the future through the growing use of electronic yield monitors, other precision farming technologies, and computerized record keeping systems. Research on cost effective systems for collecting and preserving farm level data will aid managerial decisions.

Table 1. Descriptive Statistics for Farm Level and County Level Winter Wheat Yield and Net Revenue for Douglas County, Washington, 1972-94.

Statistic	Parcel 1	Parcel 2	County
Yield per Harvested Acre (bu/ac)			
Mean	45.09	32.52	36.13
Standard Deviation	18.54	13.46	10.48
Minimum	0	0	18.8
Maximum	83	62	51.8
Coefficient of Variation	41	41	29
Standardized Inflation-Adjusted Net Revenue ($/acre)			
Mean	73.52	34.69	54.10
Standard Deviation	130.27	91.74	76.69
Coefficient of Variation	177	264	142

See next page for Figure 1

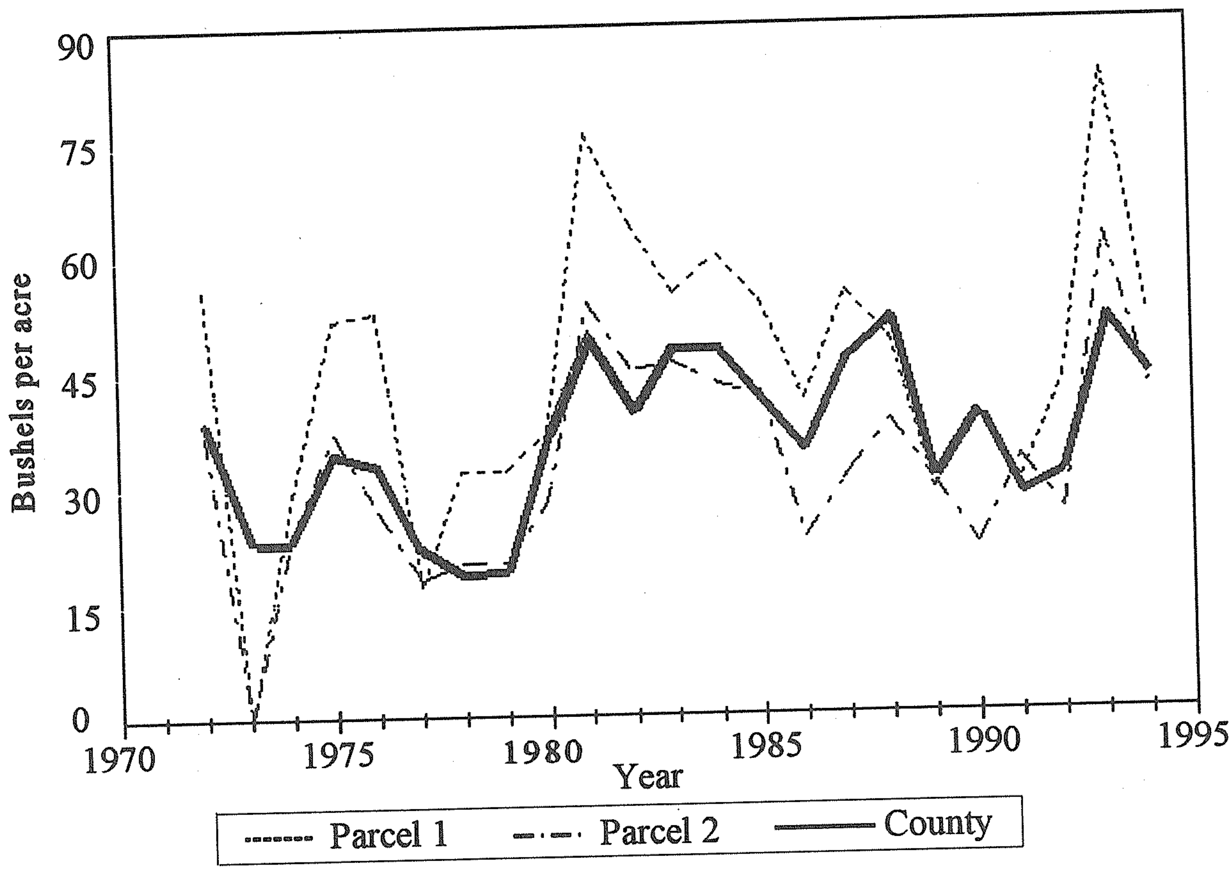

FIGURE 1. Winter wheat yields for parcel 1, parcel 2, and Douglas County average, 1972 - 94