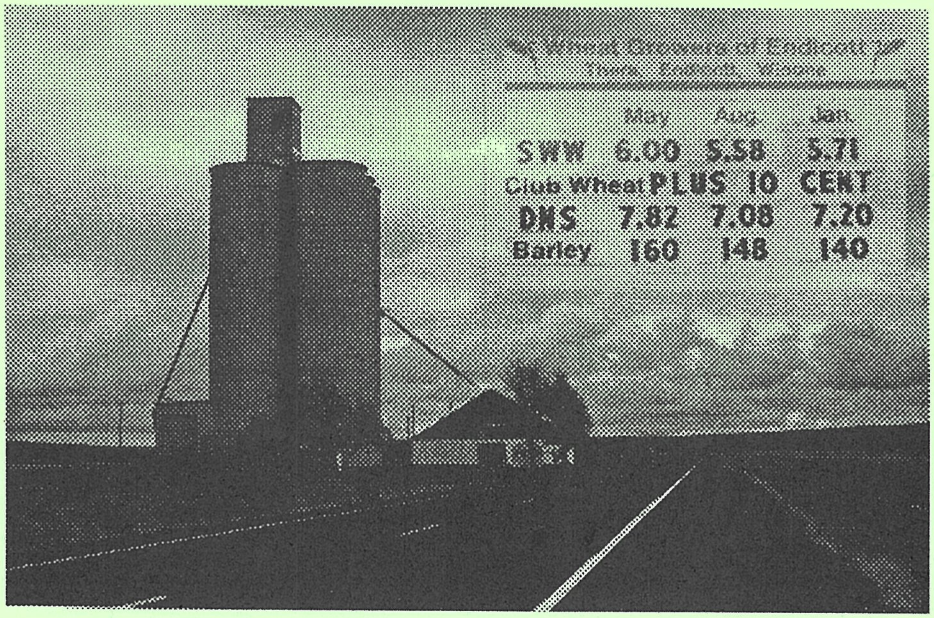
COOPERATIVE EXTENSION
Washington State University
Department of Crop and Soil Sciences

Technical Report 96-3



1996 Field Day Proceedings: Highlights of Research Progress

Dryland Research Unit, Lind
June 13,1996

Palouse Conservation Research Station, Pullman
June 27,1996

Spillman Farm, Pullman
July 11,1996

Edwin Donaldson, Editor

Contributing agencies; Washington State University, U.S. Department of Agriculture and Department of Crop and Soil Sciences
Cooperative Extension programs and employment are available to all without discrimination

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George Young	Dayton
Russ Zehner	Genesee, ID
Bob/Don Zimmerman	Almira

HISTORY OF THE DRY LAND RESEARCH UNIT

On April 1, 1915, Experiment Station Director I. D. Cardiff announced the establishment of the Adams Branch Experiment Station. It was "created for dissemination and conduction of demonstrations and experiments in the semiarid portion of the state".

Adams County has played an important part in the history of the station. The county donated $6,000 to start the station and the land has been donated by the county. In the early '30s, during the depression, Adams County kept the station alive with a small appropriation until the College could fund the operation again. In 1965, Adams County deeded 318 acres to Washington State University; two acres were previously deeded, to make a total of 320 acres in the Dry Land Research Unit.

The first superintendent was the late Dr. M. A. McCall. 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 70 years this station has followed this policy of studying the problems associated with the 8 to 12 inch rainfall area.

In 1947 the station was named the Dry Land Experiment Station. This name was changed again in 1965 to the Dry Land Research Unit. In 1972 the administration of the station was moved into the Department of Agronomy and Soils. Although the administration was changed, the station is still devoted to dry land research. This experiment station has the lowest rainfall of any research station devoted to dry land research in the United States.

The present facilities include a small elevator which was constructed in 1937 for grain storage. A modern office and attached greenhouse were built in 1949 after the old office quarters were burned. In 1960 a 40' x 80' metal shop was constructed with WSU general building funds. In 1964 an addition to the greenhouse was built with a Washington Wheat Commission grant of $12,000 to facilitate breeding for stripe rust resistance. In 1966 a new deep well was drilled, testing over 430 gallons per minute. A pump and irrigation system were installed in 1967. The addition of a 12' by 60' trailer house, and improvements in 1966 and 1967 amounted to over $35,000, with more than $11,000 of this from Wheat Commission funds and the remainder from state funds. In 1983 a new seed processing and storage building was completed, 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. The old machine storage, built shortly after the station was established, was removed in 1985.

The major portion of the research has centered on wheat. Variety adaptation, wheat production management including weed and disease control, and wheat breeding are the major programs of research in recent years. Twenty acres of land can be irrigated for research trials. The primary purpose of irrigation on the Dry Land Research Unit is not to aid in the development of hard red winter wheats for higher rainfall and irrigated agriculture, but to speed up and aid in the development of better varieties for the dry land wheat summer fallow region. Although many varieties of wheat have been recommended from variety trials by the station, Wanser and McCall were the first varieties developed on the station by plant breeding.

Since 1916 an annual field day has been held to show farmers and interested businessmen the research on the station. This year marks the 80th field day. Visitors are welcome at any time, and their 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.

The climatic conditions in the low rainfall area of Eastern Washington, commonly called the Big Bend Area, are unique when compared to Great Plains wheat producing areas. As shown in Table 1, about 90% of the rainfall occurs from September 15 to June 30. This rainfall pattern coincides with the normal winter wheat growing season. In most wheat production areas outside the Pacific Northwest a spring-summer rainfall pattern occurs. The efficiency of the moisture utilization is greater under our rainfall pattern with evaporation-transpiration rates during the months of maximum precipitation.

Table 1. Average temperature and precipitation a Dryland Research Unit, Lind.

	MONTHLY AVERAGE TEMPERATURE (F)				PRECIPITATION (IN)			
	1995		30 YEAR AVE		30 YR	MONTHLY	ACCUM	DEVI-
MONTH	MAX	MIN	MAX	MIN	AVE.	1995	1995	ATION
JANUARY	40	26	35	22	1.11	1.87	1.87	0.76
FEBRUARY	50	32	44	28	0.83	1.06	2.93	0.23
MARCH	54	32	53	30	0.71	2.21	5.14	1.50
APRIL	55	34	62	34	0.68	0.95	6.09	0.64
MAY	73	43	72	41	0.81	0.33	6.42	-2.45
JUNE	77	49	81	47	0.65	1.67	8.09	2.56
JULY	87	52	90	53	0.27	0.60	8.69	2.22
AUGUST	82	56	88	52	0.42	0.24	8.93	-1.75
SEPTEMBER	80	49	79	45	0.49	0.81	9.74	1.65
OCTOBER	58	34	65	37	0.75	1.10	10.84	1.46
NOVEMBER	50	33	46	30	1.18	1.19	12.03	1.00
DECEMBER	36	25	38	25	1.31	1.89	13.92	1.44
		1996				1996		
JANUARY	31	22	35	22	1.11	1.61	1.61	1.45
FEBRUARY	39	22	44	28	0.83	1.50	3.11	1.81
MARCH	52	30	53	30	0.71	0.41	3.52	-1.73
APRIL	63	37	62	34	0.68	1.00	4.52	1.47

Climatic measurements are made daily with standard US Weather Bureau instruments. Data recorded are maximum and minimum temperature, daily precipitation, relative humidity, daily wind movement, and daily evaporation. In addition, automatic instruments make continuous record of soil and air temperatures and precipitation.

Table 2. Temperature and precipitation at Palouse Conservation Field Station, Pullman, 1995

Month	Monthly Avg. Temperature(F) Max.	Min.	Precipitation (in) 30-Yr Avg.*	Monthly	Total Accum.	Deviation from Avg. Monthly	Accum.
1995							
January	37.9	27.8	2.89	2.57	2.57	- .32	- .32
February	45.8	30.4	2.09	1.49	4.06	- .60	- .92
March	47.7	31.9	1.96	2.04	6.10	+ .08	- .84
April	55.0	35.0	1.58	1.65	7.75	+ .07	- .77
May	65.8	42.4	1.52	.89	8.64	- .63	-1.40
June	68.0	45.9	1.49	2.05	10.69	+ .56	- .84
July	79.9	51.6	.53	.95	11.64	+ .42	- .42
August	77.7	47.5	.95	1.13	12.77	+ .18	- .24
September	75.9	45.8	.99	.81	13.58	- .18	- .42
October	53.5	36.7	1.61	2.28	15.86	+ .67	+ .25
November	47.6	35.3	2.64	3.59	19.45	+ .95	+1.20
December	36.5	26.3	3.07	2.96	22.41	- .11	+1.09
TOTAL	57.6	38.0	21.32		22.41		+1.09
1996							
January	35.3	25.5	2.89	3.76	3.76	+ .87	+ .87
February	39.2	22.0	2.09	4.62	8.38	+2.53	+3.40
March	46.1	31.3	1.96	.64	9.02	-1.32	+2.08
April	55.2	38.0	1.58	4.58	13.60	+3.00	+5.08
TOTAL			8.52		13.60		+5.08
1995 CROP YEAR Sept. 1994 thru June 30, 1995			19.84		21.96		+2.12

*Thirty year average for precipitation, 1951-1980

1995 WINTER WHEAT

S.S. Jones, P. Reisenauer, S. Lyon, E. Donaldson, D. Moser, M. Cadle,
B. Miller, A. Yildirim, X. Cai, R. Allan, T. Murray, J. Cook, R. Line,
C. Morris and P. Goldmark

Varieties

The 1994-95 hard red winter wheat trials were conducted at 4 sites in east-central Washington. Eleven cultivars were evaluated at each location.

Varieties tested included: 7 released public varieties from Washington and Idaho, 1 public variety from Washington being considered for release, 1 public variety from Kansas and 2 private varieties.

Conditions for fall planting and emergence were extremely poor at the 7 sites selected. Sufficient soil moisture for germination was at a minimum depth of 6 inches at all locations where the cooperator followed historical planting dates. Subsequent light rainfall caused enough soil crusting shortly after planting to further hamper emergence. Cooperators at other nursery sites waited for a significant fall rain and had to plant extremely late in the year. As a result, very poor stands were established at all locations. Lind Dry was reseeded late and Harrington and Waterville were abandoned. Finley had to be abandoned just before harvest due to a hailstorm.

Average yields for the hard red winter wheats ranged from 36.9 bu/a (Karl) to 50.4 bu/a (Quantum Hybrid 542). Test weights varied from 58.4 lbs/bu (Symphony) to 62.9 lbs/bu (Hatton).

Soft white and club wheat varieties were grown on 10 sites. Rod was the highest yielding variety over the 10 locations however it suffers from low tests weights averaging 57.5. Cunningham, an irrigated nursery, had severe eyespot disease. Madsen yielded 132 bu/ac under this test. In the club wheats Hyak, WA 7622 and WA 7770, all with eyespot resistance, all yielded over 100 bu/ac.

Breeding

This fall, early generation lines with very high levels of resistance to Cephalosporium stripe will be planted in the field for disease screening. The ultimate result of this testing will be the release of varieties with resistance to the disease. Several years of selection will be needed. Working with Peter Goldmark, we are over 1/3 of the way to the release of an Eltan that has resistance to eyespot disease. Jim Cook has identified wild wheat lines of ours that have good resistance to Take-all and Rhizoc. We are also over 1/3 of the way to release of a hard white and a hard red Eltan.

1995 HARD RED WINTER WHEAT

VARIETY	YIELD (BU/A) LIND DRY	LIND IRR. EARLY	HORSE HEAVEN	CONNELL	VARIETY MEAN
BLIZZARD	43.4	80.2	35.1	32.0	46.0
BONNEVILLE	36.4	74.8	34.2	34.1	43.3
BUCHANAN	42.8	80.4	32.7	35.8	46.3
HATTON	39.8	76.5	35.3	34.3	44.9
KARL	41.2	57.1	29.3	24.0	36.9
MERIDIAN	38.9	75.1	32.7	29.9	42.5
QTHYB542	41.7	85.7	41.3	40.1	50.4
SYMPHONY	39.0	**	32.3	34.3	35.2**
WA7773	36.5	75.8	28.2	32.7	41.6
WANSER	39.9	69.8	29.4	28.9	40.6
WESTON	38.7	74.8	33.9	30.5	42.9
MEAN	39.8	75.0**	33.1	32.4	42.9**
CV %	8.7	9.0	14.5	26.2	14.3
LSD @ .10	3.4	7.7	4.7	8.5	3.0

VARIETY	TEST WEIGHT (LBS/BU) LIND DRY	LIND IRR. EARLY	HORSE HEAVEN	CONNELL	VARIETY MEAN
BLIZZARD	60.7	62.7	60.5	62.2	61.5
BONNEVILLE	60.9	61.8	60.5	61.5	61.1
BUCHANAN	59.8	61.7	58.6	61.3	60.3
HATTON	61.8	64.1	61.6	62.8	62.5
KARL	61.3	60.0	60.7	61.3	60.9
MERIDIAN	60.6	62.5	60.2	61.3	61.1
QTHYB542	60.6	62.4	59.3	62.1	61.0
SYMPHONY	58.0	**	56.9	60.3	58.4**
WA7773	60.6	63.3	61.7	61.9	61.8
WANSER	60.9	61.6	60.1	61.6	61.0
WESTON	61.2	62.9	60.5	62.3	61.7
MEAN	60.6	62.3**	60.0	61.7	61.1**
CV %	1.4	1.5	1.5	1.8	1.6
LSD @ .10	0.9	1.1	0.9	1.1	0.5

PLANT HEIGHT (IN) LIND DRY	LIND IRR. EARLY	HORSE HEAVEN	CONNELL	VARIETY MEAN	VARIETY
30	42	28	30	32	BLIZZARD
31	42	30	32	33	BONNEVILLE
30	43	30	31	33	BUCHANAN
29	41	29	31	32	HATTON
30	34	25	28	29	KARL
25	37	25	27	28	MERIDIAN
28	41	31	32	33	QTHYB542
23	**	27	26	26**	SYMPHONY
29	43	30	34	33	WA7773
30	40	30	32	33	WANSER
31	44	32	32	34	WESTON
29	41**	29	31	32**	MEAN
6.0	5.8	5.3	7.7	6.7	CV %
1.8	2.8	1.6	2.5	1.1	LSD @ .10

***** Means do not include Lind Irrigated data for Symphony.***
Location mean derived from reported varieties/lines only - does not include all nursery entries
Analysis method - General Linear Models Proceedure

1995 STATE/EXTENSION WINTER WHEAT

B.C. Miller, P. E. Reisenauer, S.S. Jones, R.E. Allan and E. Donaldson

The 1994-95 state/extension wheat variety evaluation trials were established at 12 winter locations in a total of 8 counties. Twenty-nine varieties were included in the trials. Also included in the winter trials were 15 equal part blends of 6 major varieties. These results will be available following the second year of study. 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. As a result of cooperative efforts with WSU breeders, all varieties evaluated in this testing program were also evaluated in the WSU breeders testing programs at Pullman, Lind, Ritzville, Walla Walla and Cunningham.

Fall planting conditions were very poor at most locations due to the extremely dry summer and fall. Most nurseries were planted later than usual, as the cooperators were waiting for some late fall rains that did not materialize. Creston and Reardan were the only sites that had moisture to plant into. This resulted from a heavy June rain that was local to those areas. An early spring hot spell may have injured some of the winter wheat in the marginal production areas, but the higher than usual and very timely rains throughout the growing season allowed for excellent grain quality and yields. Due to the above normal precipitation harvest was delayed and rains early in the harvest season set up conditions for sprout damage, but for the most part no damage of any consequence was realized.

The winter site at Dusty was abandoned as it never recovered from the winter and the early heat spell. The Bickleton winter nursery had very poor stand establishment, suffered winter injury, was infested with Cephalosporium stripe and was abandoned. Anatone was also abandoned as a yield trial. The rains through the season promoted several germinations of goatgrass. The nursery was, however, harvested as a study to determine varietal abilities to compete with the weed. Mayview suffered some hail damage and varietal responses were evident. At Moses Lake leaf rust, stripe rust and mildew were evident in the winter nursery.

The first planting at Lind failed and was planted later when moisture conditions were adequate. The Ritzville nursery suffered some crusting resulting in uneven stands but filled in later due to the higher than normal precipitation. Walla Walla was severely lodged with some disease and stand problems. The Cunningham nursery was devastated by Cercosporella foot rot. Severe lodging as well as very reduced yields occurred in varieties\lines that did not include Madsen parentage.

This year the general quality of the grain was excellent and yields were well above average.

Further agronomic information from these trials are summarized over a two year period and reported in the winter Washington State Crop Improvement Seed Buying Guide.

1995 WSU WINTER WHEAT VARIETY TRIALS
YIELD (BU/A)

VARIETY	LIND DRY	RITZVILLE	WALLA WALLA	MAYVIEW*	DAYTON	CUNNINGHAM	LAMONT	PULLMAN LATE	FARMINGTON	FAIRFIELD	ST. JOHN	CRESTON	REARDAN	MOSES LAKE	VARIETY MEAN
Soft White															
BASIN	40.3	68.2	100.2	95.1	81.6	108.7	87.2	93.1	89.6	103.3	103.6	104.1	115.1	123.7	92.3
CASHUP	37.0	65.9	111.4	101.0	85.7	96.5	95.8	98.8	100.6	109.3	102.8	100.5	123.3	132.8	95.3
DAWS	41.2	74.9	93.4	72.9	78.4	72.9	78.6	86.2	89.5	101.2	99.4	103.8	114.1	115.6	85.9
ELTAN	43.7	76.0	50.0	90.9	70.2	49.8	82.7	94.6	78.2	106.5	105.0	103.1	134.7	106.6	84.1
GENE	30.3	68.3	100.2	63.5	71.6	83.1	65.9	86.1	77.0	62.5	64.9	93.4	96.4	120.3	76.0
HILL 81	43.2	75.9	97.9	77.3	78.9	68.6	93.3	92.3	106.2	105.2	108.3	103.8	114.7	118.6	89.6
KMOR	41.3	75.1	79.8	83.2	81.5	66.3	93.1	94.4	101.5	116.0	112.3	114.2	126.0	111.1	90.9
LAMBERT	29.7	80.4	80.4	69.4	62.8	76.6	83.5	97.1	93.6	102.8	98.4	110.1	104.2	118.8	84.6
LEWJAIN	45.2	76.7	74.9	86.9	78.1	65.8	83.4	102.2	89.7	107.2	102.9	106.5	125.4	106.9	88.4
MACVICAR	38.1	75.7	79.1	76.9	69.5	85.5	93.3	104.8	105.9	107.4	103.4	112.8	101.1	122.6	89.7
MADSEN	41.2	75.1	103.5	76.0	77.8	132.4	81.9	93.1	105.5	103.7	98.8	97.0	104.7	112.0	92.1
NUGAINES	37.7	73.7	81.5	80.3	66.8	61.0	78.3	88.8	100.1	96.4	96.7	82.5	105.1	113.9	81.6
ROD	44.1	66.2	59.6	95.0	100.7	76.5	110.0	101.1	111.4	113.3	122.9	119.2	137.1	129.2	96.7
STEPHENS	39.6	70.0	109.2	76.8	73.3	100.7	88.1	85.5	99.7	93.8	93.6	104.5	96.0	112.2	87.0
W-301	33.4	71.9	99.6	62.9	72.9	93.8	86.7	93.0	98.7	101.0	97.7	109.2	92.3	117.9	86.5
WA7663	46.4	81.9	86.6	82.5	88.4	82.2	110.9	99.7	109.0	100.7	112.5	107.6	123.3	129.0	94.9
WA7686	41.7	69.4	113.8	68.2	86.1	123.2	91.7	96.4	97.4	107.3	108.5	93.6	109.6	123.4	93.5
WA7690	43.7	75.4	79.3	60.7	80.0	104.7	88.3	86.5	116.2	109.5	108.2	109.8	117.0	123.8	91.3
WPB 470	36.5	74.4	107.5	88.3	93.0	86.4	78.2	87.5	91.7	85.6	94.4	112.5	109.7	136.6	90.0
WPB BANNER	40.5	63.4	96.1	60.5	74.8	99.1	86.4	94.0	87.5	96.3	90.6	94.2	93.2	123.3	84.6
White Club															
HILLER	45.2	58.9	85.2	54.7	90.2	61.3	103.9	96.5	89.1	99.8	113.3	114.2	117.3	128.0	87.8
HYAK	41.5	61.8	99.2	66.6	85.5	100.4	74.3	100.9	83.3	91.8	93.6	105.6	106.5	109.0	86.5
RELY	44.6	82.4	64.2	75.2	83.5	63.5	87.8	94.5	82.8	94.9	101.2	111.3	115.4	116.9	85.8
ROHDE	39.6	76.7	83.7	78.5	83.3	60.3	96.8	88.3	87.8	103.8	105.6	94.8	111.5	122.7	86.5
TRES	42.3	80.7	49.2	72.4	80.9	48.7	93.9	96.6	87.6	91.2	103.1	108.8	107.8	122.6	83.6
WA7622	37.1	60.3	102.4	75.1	86.7	104.6	92.5	80.9	97.2	100.6	100.0	95.0	109.3	113.3	88.1
WA7697	41.3	65.1	103.4	86.3	75.7	74.3	88.0	94.9	85.5	99.6	104.1	108.1	113.3	121.0	88.4
WA7770	44.4	63.7	96.0	78.9	92.9	103.4	85.1	99.4	87.9	101.4	107.2	114.9	112.9	117.4	92.2
Hard White															
WPB 422	42.3	68.9	73.3	54.8	70.4	**	101.7	88.5	90.0	95.2	91.3	102.4	103.0	121.7	83.2**
MEAN	40.5	71.6	71.6	76.2	80.0	84.0**	85.0	93.6	94.5	100.3	101.5	104.7	111.7	119.7	88.2**
CV %	12.2	14.6	17.2	9.7	11.0	21.6	16.5	18.8	8.9	7.0	13.3	9.0	7.3	8.1	15.7
LSD @ .10	5.2	5.2	16.9	8.7	10.3	18.8	16.5	17.9	11.5	8.2	15.8	11.2	9.6	11.4	7.3

* Hail Damage

*** Means do not include Cunningham data for WPB 422.*

Location mean derived from reported varieties/lines only - does not include all nursery entries

Analysis method - General Linear Models Proceedure

1995 WSU WINTER WHEAT VARIETY TRIALS
TEST WEIGHT (LBS/BU)

VARIETY	LIND DRY	RITZVILLE	WALLA WALLA	MAYVIEW	DAYTON	CUNNINGHAM	LAMONT	PULLMAN LATE	FARMINGTON	FAIRFIELD	ST. JOHN	CRESTON	REARDAN	MOSES LAKE	VARIETY MEAN
Soft White															
BASIN	59.1	61.2	55.4	57.1	60.6	59.0	57.9	57.3	60.1	61.3	59.1	61.4	60.4	57.9	59.2
CASHUP	61.4	62.1	57.2	58.3	62.2	58.2	60.7	58.2	60.7	61.5	60.2	60.8	60.6	58.1	60.0
DAWS	60.8	61.6	56.6	57.4	61.4	54.8	60.0	58.9	60.8	61.8	60.2	61.5	61.7	58.6	59.7
ELTAN	60.9	60.5	54.3	59.2	60.4	53.6	59.6	58.9	57.9	61.0	59.8	59.8	60.1	56.6	58.9
GENE	58.0	60.3	54.2	54.2	57.7	57.8	56.4	56.1	56.6	58.7	57.2	59.4	59.4	58.2	57.6
HILL 81	59.9	63.2	59.0	58.1	60.8	55.5	60.1	58.3	60.7	60.8	60.6	61.5	60.0	60.1	59.8
KMOR	59.2	60.6	53.2	57.3	59.7	54.2	59.0	57.8	58.2	60.2	59.1	59.6	58.8	56.7	58.2
LAMBERT	54.7	61.3	58.3	56.9	60.1	56.9	58.3	55.3	59.8	60.7	59.8	60.7	58.3	59.4	58.5
LEWJAIN	60.6	61.7	57.2	57.9	61.6	54.0	59.8	59.0	59.5	61.3	59.9	61.8	60.9	57.8	59.5
MACVICAR	58.6	61.8	56.5	56.7	60.1	56.1	59.6	58.2	60.1	61.1	59.5	61.2	58.8	59.3	59.1
MADSEN	59.6	61.9	57.9	57.3	60.3	60.1	59.3	57.7	60.1	60.7	59.8	61.7	59.8	59.7	59.7
NUGAINES	61.1	62.6	57.2	57.0	62.2	55.2	61.1	59.2	61.8	61.6	60.2	62.3	61.4	60.0	60.2
ROD	58.4	60.4	53.5	56.2	57.2	55.4	57.7	57.1	58.3	59.9	57.7	58.6	58.2	55.3	57.5
STEPHENS	59.1	60.9	58.7	56.3	59.7	58.2	57.6	57.3	59.4	59.3	58.7	61.3	57.4	59.0	58.8
W-301	57.7	60.8	60.5	56.6	60.3	58.7	59.4	58.1	59.8	60.4	59.1	61.1	57.4	59.4	59.2
WA7663	58.0	59.3	54.9	55.9	57.1	53.8	57.5	56.5	57.8	60.0	58.4	58.0	57.9	55.4	57.2
WA7686	58.6	60.2	57.1	56.0	60.1	58.6	58.6	56.4	59.5	59.2	59.3	60.3	58.2	58.8	58.6
WA7690	59.1	61.4	58.4	58.3	60.9	58.6	59.5	58.3	61.2	61.2	60.3	62.0	61.2	58.0	59.8
WPB 470	62.2	63.7	61.3	59.0	63.0	61.2	61.6	59.2	61.5	62.3	60.8	64.3	62.6	62.8	61.8
WPB BANNER	59.7	61.5	57.3	57.1	60.4	58.7	59.3	57.8	59.1	60.4	59.4	61.2	59.5	60.4	59.5
White Club															
HILLER	56.8	59.6	54.1	54.3	58.7	52.3	57.2	55.5	56.9	58.7	57.6	59.0	57.2	56.8	56.8
HYAK	59.0	61.8	57.8	55.0	60.3	56.6	58.5	56.3	57.6	59.7	57.2	61.6	59.4	59.4	58.6
RELY	58.6	61.2	57.4	57.5	59.2	53.6	58.3	57.9	59.5	61.5	59.6	60.5	59.2	59.8	58.8
ROHDE	60.3	62.5	59.2	58.9	62.2	55.6	59.5	58.5	60.2	62.3	60.7	61.7	60.1	60.2	60.1
TRES	58.2	61.9	55.6	57.2	60.8	55.4	59.2	58.2	59.2	61.9	59.5	61.4	60.2	60.6	59.2
WA7622	57.6	59.1	57.2	54.9	58.5	58.0	57.9	56.3	58.1	60.2	58.2	60.0	57.6	58.4	58.0
WA7697	60.3	62.9	61.3	58.1	62.1	57.5	58.4	58.0	59.7	60.4	60.1	62.6	60.5	59.9	60.1
WA7770	56.9	60.5	55.2	56.1	59.4	58.8	57.4	56.6	58.0	59.9	58.3	60.5	59.4	58.2	58.3
Hard White															
WPB 422	61.0	62.0	55.8	58.5	60.7	**	60.4	58.4	59.4	61.7	59.7	62.2	59.8	59.8	60.1**
MEAN	59.2	61.3	57.0	57.0	60.3	56.7**	59.0	57.6	59.4	60.6	59.3	61.0	59.5	58.8	59.1**
CV %	1.5	2.4	3.9	1.3	1.2	3.3	1.9	1.8	1.3	1.2	1.5	1.0	1.3	2.5	2.4
LSD @ .10	1.0	1.5	3.0	0.9	0.8	1.9	1.3	1.1	1.3	0.8	1.0	0.7	0.9	1.8	0.8

*** Means do not include Cunningham data for WPB 422.*
Location mean derived from reported varieties/lines only - does not include all nursery entries
Analysis method - General Linear Models Proceedure

1995 WSU WINTER WHEAT VARIETY TRIALS
PROTEIN (%)

VARIETY	LIND DRY	MAYVIEW	DAYTON	LAMONT	FARMINGTON	FAIRFIELD	ST. JOHN	CRESTON	REARDAN	MOSES LAKE	VARIETY MEAN
Soft White											
BASIN	12.2	10.7	10.5	10.6	10.0	9.2	11.4	8.6	8.9	11.6	10.4
CASHUP	12.9	11.2	11.0	10.9	9.4	9.3	11.8	7.8	8.5	12.0	10.6
DAWS	12.4	12.0	10.9	11.1	10.6	9.4	11.8	8.8	8.9	12.3	10.9
ELTAN	12.9	11.2	11.0	10.6	10.9	8.9	12.3	8.0	8.6	13.0	10.8
GENE	13.2	12.7	11.8	11.5	11.4	11.1	12.6	9.5	10.4	12.3	11.7
HILL 81	13.2	11.6	11.6	12.1	10.2	9.3	12.5	9.4	8.9	12.2	11.2
KMOR	12.6	11.2	11.1	11.0	9.8	8.9	12.1	8.2	8.4	11.9	10.6
LAMBERT	11.7	11.1	11.5	11.2	10.2	9.2	11.8	8.9	8.9	11.9	10.7
LEWJAIN	13.1	11.6	11.0	10.6	10.0	8.9	12.3	8.8	8.8	12.9	10.9
MACVICAR	13	11.5	10.9	10.6	10.5	9.4	11.5	8.3	8.7	11.7	10.7
MADSEN	13.3	12.1	11.5	11.0	10.5	9.4	12.5	10.1	9.7	13.1	11.4
NUGAINES	12.6	11.3	11.4	11.2	9.8	9.0	11.7	9.5	8.8	11.5	10.8
ROD	12.8	10.9	9.7	10.4	10.1	8.9	11.7	7.8	8.4	13.0	10.4
STEPHENS	13	11.4	11.3	10.9	10.4	10.1	11.5	9.1	9.7	12.4	11.1
W-301	13.1	11.1	11.3	10.6	10.5	9.7	11.7	8.9	9.7	12.4	11
WA7663	12.4	11.6	10.6	11.0	10.2	9.4	12.0	7.8	8.0	12.5	10.6
WA7686	13.8	11.7	11.3	11.2	10.3	9.6	12.4	9.1	9.4	12.0	11.2
WA7690	13.6	11.7	11.3	11.9	11.0	9.5	13.1	9.4	9.2	13.0	11.5
WPB 470	14.3	12.4	11.4	12.2	11.5	10.9	13.1	9.4	9.5	13.2	11.9
WPB BANNER	12.6	11.6	11.9	11.7	10.8	10.1	11.9	9.2	9.9	12.2	11.2
White Club											
HILLER	11.6	11.4	10.4	11.0	10.3	9.7	11.2	8.4	8.9	11.8	10.5
HYAK	12.6	11.8	11.1	11.3	11.9	9.6	12.1	9.5	9.1	12.5	11.2
RELY	12.1	12.1	10.7	10.5	11.8	10.0	12.2	8.2	8.8	12.2	10.9
ROHDE	12.6	11.7	11.0	10.7	11.1	9.9	12.4	8.3	8.6	12.3	10.9
TRES	12.6	11.6	10.7	11.0	10.9	9.8	12.0	8.7	9.0	12.1	10.9
WA7622	13.5	11.8	10.8	11.0	11.0	9.6	12.6	8.5	8.9	12.5	11.1
WA7697	12.2	11.2	11.1	10.2	11.1	9.7	11.8	8.8	9.2	11.9	10.8
WA7770	13	11.6	11.0	11.3	10.8	9.6	12.4	9.0	9.4	12.4	11.1
Hard White											
WPB 422	12.4	11.6	11.3	10.9	10.4	10.0	12.3	9.0	9.3	12.7	11.1
MEAN	12.8	11.6	11.1	11.1	10.6	9.6	12.1	8.8	9.1	12.4	11.0
CV %	4.0	3.5	6.7	14.6	5.3	7.0	3.2	8.3	5.8	3.7	6.8
LSD @ .10	0.6	0.5	0.9	1.9	1.0	0.8	0.5	0.9	0.6	0.5	0.4

Location mean derived from reported varieties/lines only - does not include all nursery entries

Analysis method - General Linear Models Proceedure

USDA-ARS WHEAT BREEDING AND GENETICS

R.E. Allan, J.A. Pritchett and L.M. Little

Progress in Breeding Club Wheat. 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. It is likely they have a second gene from a French variety 'Cappelle'. They exceeded the yield of Hyak by 18% in our foot rot inoculated tests. These lines also have resistance to all USA stripe rust races. They possess high yield potential and out-yielded Hiller and Rohde by 10% across all 1995 ARS trials. Several other club selections with high yield potential, excellent club quality and multiple gene resistance to stripe rust are in the final evaluation stages. These lines each have 3 to 4 resistant genes and one gene is derived from wild emmer. The wild emmer gene confers resistance to all USA biotypes of the stripe rust pathogen.

Club wheat selections from the Oregon program were evaluated for resistance to foliar diseases and strawbreaker foot rot. The material included 70 elite and 110 advanced lines. Over 50% of the elite lines had the biochemical marker which tags the strawbreaker foot rot gene that occurs in Madsen. Nearly 30% of these lines carried resistance to the most prevalent races of stripe rust and 10% were resistant to powdery mildew. Based on their overall disease, quality and agronomic performance we have 36 of the OSU lines in our advanced 1996 yield tests.

Semidwarf Club Wheat to Supplant Hyak. A new bearded semidwarf club selection (WA7752) has been approved for release. WA7752 has moderate resistance to strawbreaker foot rot, leaf rust, powdery mildew and partial tolerance to Cephalosporium stripe. WA7752 has exceeded the yields of other semidwarf clubs in 18 WSU tests by 2 to 15%. In ARS tests it has out-yielded other semidwarf club varieties by 2 to 20%. WA7752 has emergence characteristics similar to other semidwarf club varieties but does not emerge as well as Moro from deep planting. Based on the severe 1991 freeze, WA7752 is similar to Moro, Tres and Paha for coldhardiness. It is more hardy than Rohde and Rely but less hardy than Hyak. Although taller than most semidwarf club varieties, WA7752 has better straw strength and generally has less lodging.

WA7752 is being released to replace Hyak. It has better club wheat quality for most of the important quality traits. It excels most clubs for test weight, flour yield, and milling score. It is an improvement over Hyak for absorption, mixing time, viscosity, cookie diameter and top grain score. It tends to have higher protein content (0.5%) and grain hardness than other clubs. Unlike Hyak, WA7752 has the three glutenin protein subunits that are associated with traditional club wheat quality.

Grain samples of WA7752 were submitted to the Federal Grain Inspection Service in order to determine whether WA7752 would grade as a club wheat based on kernel morphology. Eleven samples were submitted that had been grown at 1 to 5 locations during 1991 to 1995. Samples of Rely, Tres and Paha were also included. The inspectors consistently graded WA7752 as a club wheat. Rely, Tres and Paha also were consistently graded as club wheats. These encouraging results indicate that club wheat classification of WA7752 based on kernel morphology should not be a problem.

Semidwarfs for Low Rainfall Area. The Rht_8 Balkan semidwarf gene should prove to be very useful in developing club wheats for the low rainfall areas where Moro is adapted. We have shown that this gene does not adversely affect emergence. Six Rht_8 semidwarf club lines having plant heights 6 to 13% shorter than Moro had emergence characteristics, coleoptile lengths, and seedling growth rates identical to Moro. These lines out-yielded Moro 5 to 30% in our 1995 tests.

Improving Tall Wheats. We have identified 7 tall clubs and 3 soft white winter common selections that emerged comparable to Moro and surpassed its yield potential. All of the lines were better than Moro for straw strength and stripe rust resistance.

About 20% of our early generation lines are tall clubs. Their selection was based on straw strength, rust resistance, low sedimentation score and test weight. Several tall clubs were identified among the 180 Oregon State club selections that we evaluated in 1995. We advanced 8 of these lines to our 1996 tests.

Removing semidwarf genes from well adapted semidwarfs has potential for developing wheats for the low rainfall zones where emergence is a problem. Some tall non-semidwarf versions of Stephens and Nugaines were equal to Moro for emergence rate, percent stand, coleoptile length, and seedling growth rate. They had mean yields 13 to 40% greater than Moro in 1995 tests.

Promising Semidwarf Gene. In addition to its neutral effect on emergence, the Balkan (Rht_8) semidwarf gene may have another advantage. Club wheat selections with this gene have very compact heads. This characteristic may help reduce mis-classification by grain inspectors of certain club varieties that have semi-compact heads.

Converting Winter Wheats to Spring Wheats. Spring-sown yield tests of paired comparisons between the four spring growth habit genes indicated that the Vrn_1 gene produced the highest yield potential followed by the Vrn_3, Vrn_2 and Vrn_4 genes in that order. Winter wheat varieties differed as to which *Vrn* gene produced the greatest yield potential. The Vrn_3 gene was best in Daws but the Vrn_1 gene was best in Paha. Three of the genes (Vrn_1,Vrn_2,, Vrn_3) were equally effective in Wanser. These results confirm that specific growth habit genes can cause different adaptive features in our wheat varieties.

Effect of *Vrn* Genes on Wheat Quality. Differences were noted between the soft white wheat quality attributes of spring and winter NILs when grown from fall plantings. The winter NILs had slightly higher protein contents, absorption levels and mixing times than the spring NILs. The winter NILs tended to have softer texture than the spring NILs. More testing is needed to confirm whether quality differences between spring and winter NILs are real. If these results are confirmed, it could mean that the vrn_1 allele for winter growth habit on chromosome arm 5AL is linked to undesirable soft wheat quality genes.

A Potent Dwarfing Gene. The Karkagi dwarf gene (Rht_{12}) warrants use in our breeding program. This gene reduces plant height by 40% in non-semidwarf varieties and 30% in semidwarf varieties. Rht_{12} enhances yields by 20% in varieties prone to lodging such as Moro and Brevor. It reduces yield by 15% in varieties not prone to lodging (Nugaines, Daws). Importantly the Rht_{12} gene causes no deleterious effect on emergence.

Related Effects of the Club Gene. We obtained an additional six test-years of data on our club vs. lax NILs, which completes our database on the effects of the club © locus on adaptation, stress tolerance and quality characteristics of wheat. To date our results have shown that NILs with the club gene can either negatively or positively affect yield and quality components depending on the location and season. A major discovery has been that the C allele has a deleterious effect on yield when placed in common-type wheats. Apparently our adapted club wheats have genes associated with the C allele that compensate for the otherwise negative effects that it causes. These genes are not present in common wheats.

Breeding for Earliness. It is essential to exploit a wide range in heading dates when developing varieties for our diverse agronomic zones. Among Paha NILs varying 10 days in heading date, NILs that were 10 days earlier than Paha had the highest yield potential under summerfallow. Under recrop NILs 8 days earlier than Paha had the highest yields. Genes for earliness are simply inherited making it easy to breed varieties that head and mature early.

Cooperation. Cooperative research includes emergence testing several selections with W. Schillinger, off-station yield trials with S. Jones and conversion of winter wheats to spring wheats with K. Kidwell. We also cooperate with T. Murray and S. Jones on breeding wheats resistant to strawbreaker foot rot and Cephalosporium stripe. We work with K. Simmons on coldhardiness and preharvest sprouting research. R.F. Line contributes by testing reactions of advanced lines to several foliar diseases and C.F. Morris contributes by overseeing wheat quality evaluations.

IMPROVEMENT OF WINTERHARDINESS IN WHEAT

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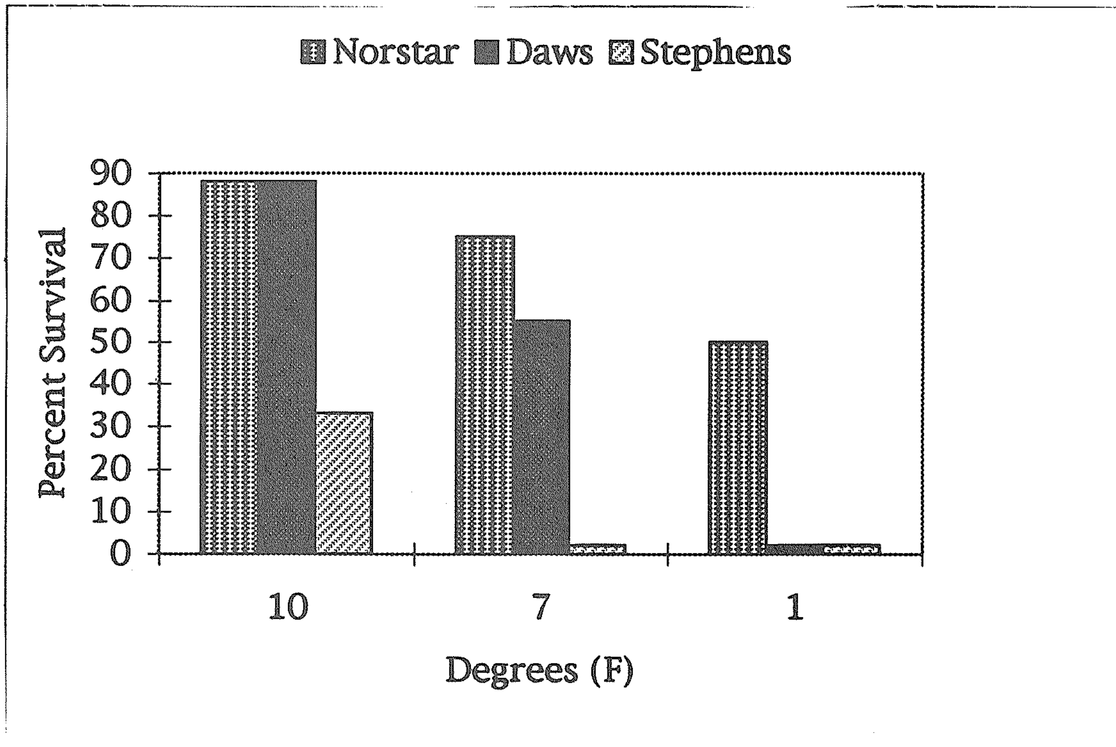
Problem: Cold injury is the most important environmental problem of winter wheat in Washington. There are some varieties with high levels of winterhardiness such as Daws and Eltan, however we estimate that 70% of present acreage is planted in varieties that are vulnerable to cold injury. Club wheat varieties are especially vulnerable to winterkill. In 1991, over 70% of the winter wheat was killed by extreme cold.

New selection program: We have initiated a new research program to test and select for winterhardiness year around. Since we know that some Washington wheats are more winterhardy than others, there is genetic potential for improvement of all cultivars. Also, more winterhardy varieties are available from Canada, Russia and China. A chamber with freezing simulation control has been purchased for this project with a grant from the Washington Wheat Commission. This new growth chamber is enabling us to develop a freezing simulation test to assess winter hardiness under environmentally controlled conditions rather than to rely on winter field survival. In the test, seedling crown tissues are subjected to a range of freezing temperatures. After freezing the crowns are transferred to warmer temperatures and the percentage survival (regrowth) is measured. In our first experiments we have compared the very cold tolerant Canadian variety Northstar with Daws and Stephens. In our freezing simulation test (Fig. 1), Stephens has the lowest survival percentage after cold temperature treatment. Daws is more tolerant and Northstar has the highest survival percentage. These freezing simulation test results correlate well with winter field survival ratings. This correlation indicates that the freezing simulation test can be used for winterhardiness selection year around and this type of test should considerably speed up our selection for increased winterhardiness.

New molecular tools: Genes that influence coldhardiness have been mapped in wheat and barley by U.S. and U.K. scientists. From those scientists we have now obtained DNA probes linked to coldhardiness. These DNA probes have the potential to speed up our genetic selection for winterhardiness in PNW varieties. We are now assessing the potential of these DNA probes as selection markers for improving winterhardiness in Pacific Northwest wheat varieties.

Breeding for winterhardiness: Crosses with coldhardy soft white winter wheat including Eltan, Hiller and Jacmar have been made. The crossed plants will be selfed to allow a recombination of alleles (genes) in subsequent generations of offspring. These offspring will be tested for hardiness levels. Results of these tests will indicate the potential for improving hardiness levels by crossing favored Washington varieties. Additionally we intend to initiate efforts to transfer by backcrossing the winterhardy wheats to spring Vrn_1 near isogenic lines of Daws, Stevens, and other varieties already developed in this project.


Norstar
Daws
Stephens
90
80
70
60
50
40
30
20
10
0
Percent Survival
10
7
1
Degrees (F)

EMERGENCE OF SOFT WHITE WINTER WHEAT VARIETIES FROM DEEP PLANTING

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Introduction: Growers in winter wheat - fallow areas need varieties with the ability to emerge under conditions of poor seed zone moisture, high temperature, and deep planting. We conducted a study in 1994 and 1995 to evaluate the emergence capability of several commercially available soft white winter wheat varieties. Our goal is to: 1) develop numerical emergence ratings for winter wheat varieties under an assortment of seeding conditions in low-rainfall areas and; 2) aid breeding efforts to develop new varieties for low-rainfall dryland areas.

Study Description: Nine soft white winter wheat varieties were evaluated in 1994 and 1995 at the WSU Dryland Research Station at Lind (9.5" annual rainfall) and the Bob and Mark Kramer farm near Harrington (11.5" annual rainfall). Varieties tested were common wheats (Eltan, Lewjain, Madsen, Rod) and club wheats (Hyak, Moro, Rely, Rohde, and Hiller). Hiller was released in 1995. Current year seed was obtained both years from a nursery at Lind and screened to obtain uniform-sized kernels. One hundred seeds of each variety were planted in 8-ft row sections with a deep furrow plot drill. We planted each variety 12 times at each location.

Seed zone moisture content was measured in 1-inch increments to a depth of 12 inches at time of planting from several locations within the plot area. Emergence was measured by counting individual plants at 24-hour intervals beginning 6 days after planting.

Results and Discussion: Planting conditions in 1994 were the driest many eastern Washington wheat growers had ever experienced, whereas 1995 planting conditions were excellent. Under both dry and wet planting conditions, with and without pre-emergence soil crusting, we found consistent emergence differences among varieties. Moro always emerged the fastest from deep seeding and produced the best stand. Lewjain, Eltan, Rohde, and Madsen had acceptable emergence characteristics but, in general, lagged significantly below Moro. Rod averaged in the middle of the pack. Hyak, Rely, and Hiller performed poorly for both speed of emergence and ability to emerge.

Club wheat is grown almost exclusively in low-rainfall areas where emergence is a critical for achieving good yield and erosion control. Rohde, an Oregon release, has acceptable emergence but lacks the winter hardiness required for many eastern Washington locations. Hyak, Rely, and especially Hiller are poor emergers. Moro has several disease, quality, and agronomic weaknesses and needs to be replaced. These results highlight the need to evaluate emergence capability during variety development.

In conjunction with evaluating emergence of varieties, this project is also assisting the club wheat breeding program identify promising numbered lines as potential Moro replacements.

SPRING WHEAT BREEDING AND GENETICS

K.K. Kidwell, M.A. Davis and G.B. Shelton

Nearly half a million acres of spring wheat were planted in the state of Washington in 1995, and many predict that spring grain acreages will increase as more growers include spring crops in rotations aimed at eliminating disease and/or weed problems that plague winter wheat and current crop management systems are altered to reduce soil erosion. The long term goal the spring wheat breeding program at WSU is to develop high yielding varieties with excellent quality characteristics and beneficial disease and insect resistances so that spring wheat becomes a competitive, principal crop in the PNW. On-going efforts to develop varieties for four market classes of spring wheat, including soft white, hard red, hard white and spring clubs, continue. Improving yield potential, end-use quality, rust resistances and resistance to Hessian fly (HF) and Russian wheat aphid (RWA) are emphasized in the breeding and selection program.

Improve Efficiency: During the winter of 1995/1996, F_1 seed harvested from the 1995 field crossing block was advanced in the greenhouse. Resulting F_2 seed was harvested in April, 1996, then this seed was planted in the field at Spillman Farm in early May. F_3 seed will be harvested from these plots in the fall of 1996. By using greenhouse facilities, we accomplished what it typically takes two years to complete in a field based breeding program within a ten month period.

Grain Yield: Several spring growth habit genes have been identified in wheat, and at least three of these are known to be controlled by single, dominant genes. Results from other studies indicated that genotypes carrying double dominant spring growth habit genes mature earlier and have higher yield potential compared to lines with only one spring growth habit gene. By pyramiding specific combination of spring growth habit genes into a single line, grain yields of spring varieties may improve. Currently, we do not know which growth habit gene(s) are carried by spring wheat line adapted to the PNW.

Near-isogenic lines carrying different spring growth habit genes were crossed, in the greenhouse, to 60 spring varieties or advanced breeding lines to determine which gene (or genes) is carried by each genotype. Crosses were made in April and August of 1995. F_2 seed increases for a majority of these crosses were completed by April, 1996. Segregation analyses of F_2 families for spring vs. winter growth habit will be conducted in the field at Spillman Farm during the summer of 1996.

End-Use Quality: Enhancing end-use quality is essential to improving the marketability of wheat grown in Washington. We are investigating the feasibility and effectiveness of selecting for quality factors in early generation lines based on HMW glutenin storage protein banding patterns and microsedimentation values.

Microsedimentation tests of whole grain flour from entries in the 1994 Commercial, Tri-State and preliminary spring wheat nurseries were completed in May of 1995, and analyses of F_4 and F_5 breeding lines were finished by early July. Results were entered into the field book, and these data were considered when selections were made in the field in late summer of 1995.
Microsedimentation analyses of the 1995 crop was completed in February, 1996, and HMW

glutenin evaluations of over 100 spring wheat varieties from the PNW and Australia were completed in January, 1996. This information is being used to select parents to cross in the greenhouse and the field to develop agronomically superior lines with excellent end-use quality.

Insect Resistances: Although crop losses associated with Hessian fly (HF) and the Russian wheat aphid (RWA) have been minimal in Washington to date, researches speculate that infestations will increase as more growers incorporate minimum tillage into their crop management systems due to increased surface residues levels. Currently, only a few HF resistant spring wheat varieties are available, and all of these carry the same resistance gene. No adapted RWA resistant varieties have been released to date. To improve the levels of HF and RWA resistance, lines carrying different resistance genes to both pests are being used as parents in the crossing program. The goal is to combine resistances to both insects into a single cultivar. In addition to conventional crossing procedures, backcross breeding is being used to rapidly transfer HF and RWA resistance genes into adapted germplasm.

A. Hessian Fly Resistance: F_1 genotypes carrying eight different HF resistance genes were advanced in the greenhouse in the spring of 1995. These lines were backcrossed to the spring wheat parent used in the original cross, and were hybridized to other F_1 lines that carried a different resistance gene or an agronomic trait of interest. Resulting F_1, F_2 and BC_1 seed was harvested in July. Due to lack of greenhouse space, advancement of these lines was postponed until May, 1996. Eighty lines carrying HF resistance genes will be advanced in the greenhouse this summer, then BC_3 seed will be sent to Dr. Jim Hatchett at Kansas State University for screening. Lines carrying HF resistance genes that are affective against the WA biotype will be advanced through backcross breeding.

B. Russian Wheat Aphid Resistance: Three hundred unadapted spring wheat lines carrying RWA resistant genes were planted in Pullman in an observation nursery in March of 1995. We identified several genotypes with acceptable levels of resistance to stripe and leaf rust that appeared to be better adapted to this growing environment. These lines will be crossed to adapted varieties in the greenhouse during the summer of 1996. Resulting F_1 lines will be advanced in the greenhouse for several backcross generations, then BC_3 seed will be sent to Oklahoma for screening and selection. Resulting progeny will be screened for RWA resistance and the cycle will be repeated until the recurrent parent phenotype has been recovered along with the resistance trait.

Hard White Spring Wheat: In anticipation of a high market demand for hard white wheat, efforts to develop adapted HWS varieties have expanded, and additional germplasm sources have been incorporated into the breeding program. Based on results of HMW glutenin evaluation, parental combinations have been selected to optimize end-use quality and agronomic performance. The time required to develop hard white spring varieties has been accelerated by advancing early generation materials in the greenhouse, and separating white from red seed in segregating grain lots. Dr. Morris (WWQL) has agreed to assist with early generation evaluation of end-use quality and noodle color potential of our hard white materials.

Winter/Spring Club Conversion Project: The most efficient method for developing adapted spring club varieties is to convert adapted winter club wheats to spring types, and to convert adapted soft white common spring lines to spring clubs. Since club head type and spring growth habit are simply inherited, these traits can easily be manipulated through backcross breeding. First generation crosses were made in the winter club wheat and spring wheat field crossing blocks at Spillman farm during the summer of 1995. Seven winter club lines (Moro, Hiller, Paha, WA7770, WA7697, WA7793 and WA7752) were crossed, as female parents, to 11 spring wheat varieties (Alpowa, Wawawai, Whitebird, ID488, Vanna, Calorwa, WA7766, WA7803, WA7807, K8605101 and K9305213). Resulting F_1 seed from 61 winter-spring crosses was planted in the greenhouse in December, 1995. Pollinations to produce the BC_1 generation for selected crosses was completed in February, 1996. Residual F_2 seed was channeled into the standard field breeding programs for the winter club and spring wheat projects. BC_1 seed was planted in the greenhouse in May, 1996. Winter parents are being used as the recurrent parent in the backcrossing program for the winter club conversions, and progeny with spring growth habit, club head type and club quality are selected for advancement in every generation. Backcrossing will continue for 4 to 6 generations, then promising lines will be evaluation in replicated field trials.

The same winter club and spring wheat lines used in the club conversion scheme were used for the soft white spring conversion project. In this case, the spring lines were used as the female parent. F_1 seed from 50 spring-winter crosses was planted in the greenhouse in December, and seed from BC_1 crosses was harvested in April, 1996. The spring parent is being used as the recurrent parent for these conversions.

In addition to winter club by spring crosses, crosses were made between five adapted soft white winter varieties (Eltan, Lewjain, Madsen, Rod and Stephens) and three superior soft white spring lines (Alpowa, Wawawai and ID488) to convert several prominent adapted winter common wheats to spring types. Crosses to generate the BC_1 of these materials were made in the greenhouse during February, and seed from the BC_2 will be generated in the greenhouse this summer.

1995 STATE/EXTENSION SPRING WHEAT VARIETY TRIAL RESULTS

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Twenty-five spring wheat varieties were evaluated at fourteen locations in eastern Washington during the 1995 growing season. Fertilizer rates, planting conditions, precipitation levels and harvest dates for each location are listed in table 1. Grain yields, test weights and protein contents for entries grown at locations with less than 16 inches of average annual rainfall, between 16 and 20 inches, greater than 20 inches and under irrigation are listed in tables 2, 3, 4 and 5, respectively. Due to favorable moisture conditions throughout the growing season, grain yields and test weights were generally higher than average. Additional performance information for certified spring wheat varieties can be found in the "1996 Certified Seed Buying Guide for Barley and Wheat, Spring Varieties," published by WSU and the Washington State Crop Improvement Association.

Locations with Less than 16 Inches of Average Annual Rainfall
Lind Annual Cropped Nursery: Grain yields ranged from 27 to 36 bu/a for entries in the Lind annual crop nursery (Table 2). Yields of soft white entries averaged 33 bu/a, whereas, the hard red lines averaged 29 bu/a. Soft white entries Centennial (36 bu/a), Edwall (36 bu/a) and ID488 (35 bu/a) were the highest yielding lines in this trial. Hard white lines ID377S and WA7778 had reasonably high grain yields (30 and 34 bu/a, respectively); however, test weights of these entries were below 60 lb/bu. Test weights of grain samples collected from this trial generally were lower than values recorded at other locations (See Tables 2 - 5) even though test weights of several lines exceeded 61 lb/bu. Protein contents of grain from all soft white and hard red entries were higher than 12% and 14%, respectively.

Lind Fallow Nursery: Grain yields were approximately 22% higher in the Lind fallow nursery (40 bu/a) compared to the Lind annual cropped trial (31 bu/a). Soft white entries (average = 42 bu/a) in the fallow nursery produced approximately 12% more grain than the hard red lines (average = 37 bu/a). ID488, Centennial, Edwall and Penawawa averaged over 44 bu/a at this site, and test weights of all entries exceeded 60 lb/bu (Table 2). Protein contents of grain from all soft white entries were greater than 12%, and all hard red protein values exceeded 14%. Spillman (39 bu/a) was among the highest yielding hard red entries and had a grain protein content of 15.8%.

Bickleton: Due to wet soil conditions resulting from heavy spring rains, this trial was not planted until May 28th. Even though grain yields of most varieties were fairly high (52 bu/a), test weights and protein levels were well below average. Whitebird (65 bu/a) and Klasic (60 bu/a) were the highest yielding entries in the trial, and Alpowa, Centennial, ID488, WA7766 and ID377S had test weights greater than 60 lb/bu. Grain from all soft white entries were less than 11% protein, and protein contents of all hard red entries were below 12.5%.

Dusty: Grain yields at Dusty ranged from 48 to 70 bu/a (Table 2). Average grain yields of soft white lines (66 bu/a) were more than 18% higher than average grain yields of hard red varieties (54 bu/a). Test weights of Alpowa, OR8510 and ID377S exceeded 62 lb/bu, and protein contents

(54 bu/a). Test weights of Alpowa, OR8510 and ID377S exceeded 62 lb/bu, and protein contents for all soft white entries except for Wadual 94 were below 11%. Westbred 926 was the only hard red line with a grain protein value greater than 14%.

Lamont: The average grain yield at this site was 65 bu/a, and ID488 (75 bu/a) , Vanna (73 bu/a), Westbred Sprite (71 bu/a) and ID377S (71 bu/a) were the highest yielding entries (Table 2). Test weights of WA7766, Wawawai, OR8510, ID377S and Klasic exceeded 61 lb/bu. Protein contents of grain from all soft white entries were below 11.5% and none of the grain protein values from hard red lines exceeded 13.6%.

General Conclusions: ID488, a Russian wheat aphid resistant Centennial backcross line from the University of Idaho, had the highest average grain yield (56 bu/a) and the lowest average grain protein content (10.8%) across locations in the less than 16 inch rainfall zone. Spillman and WA7764 were the highest yielding hard red lines with an average of 48 bu/a. Alpowa, a recent WSU release, consistently produced high test weight grain (averaged of 61.7 lb/bu) and had low protein levels at a majority of these sites (Table 2). Westbred 936 was the only hard red variety with an average grain protein content of 14% across locations.

Locations with 16 to 20 Inches of Average Annual Rainfall

Mayview: In early July, a hail storm damaged this nursery. Early maturing varieties, such as Butte 86, were severely injured; therefore, yield values may not accurately reflect the yield potential of these varieties under more optimal conditions. Average grain yields of soft white spring wheats (59 bu/a) were nearly 20% higher than yields of hard red entries (48 bu/a) at this site (Table 3). Pomerelle was the highest yielding entry at 72 bu/a which was 17 bu higher than the nursery average. Experimental line OR8510 was the highest yielding hard red entry at 55 bu/a. In spite of the hail damage, test weights of most lines exceeded 60 lb/bu, and Alpowa, ID488, Wawawai, Express, ID377S and Klasic had test weights exceeding 62 lb/bu. Alpowa and Vanna had the lowest grain protein levels among soft white varieties (10.1%), and Butte 86 and Express were the only hard red lines with protein contents above 14%.

Dayton: Average yields for soft whites entries were 79 bu/a, whereas, hard reds lines produced only 69 bu/a (Table 3). Pomerelle and the experimental hard white line, ID377S, were the highest yielding varieties (88 and 87 bu/a, respectively). Klasic and Westbred Sprite had test weights exceeding 61 lb/bu, and ID488 had the lowest protein content at 9.6%. Westbred 936 was the highest yielding hard red variety (79 bu/a); however, Express was the only hard red line with a 60 lb/bu test weight. Butte 86, OR8510 and Westbred 926 had grain protein contents of 14% or more.

Reardan: Soft white entries averaged over 81 bu/a at this location, whereas, hard red varieties yielded only 70 bu/a (Table 3). Penawawa (89 bu/a), Wakanz (86 bu/a) and ID377S (84 bu/a) were the highest yielding soft white entries, and OR8510 (75 bu/a) was the highest yielding hard red line. Hard white lines ID377S and Klasic had test weights exceeding 64 lb/bu. Centennial had the lowest grain protein content (9%) of the soft white varieties, and Express had the highest protein percentage for any hard red line (13.5%).

St. John: The mean grain yield at the St. John nursery was 82 bu/a; however, Alpowa and ID488 produced 96 and 92 bu/a, respectively (Table 3). Alpowa also had the highest test weight (62.4 lb/bu) and the lowest protein percentage (10.1%) of any variety grown at this site. Express, WA7764, Westbred 926 and Westbred 936 were the highest yielding hard red entries (77 bu/a each), and OR8510, Butte 86 and Westbred 936 had test weights above 61 lb/bu. Westbred 926, Butte 86, Express, Westbred 936 and WA7764 all had grain protein contents greater than 14%.

General Conclusions: Penawawa (82 bu/a) and Pomerelle (81 bu/a) had the highest yield averages at nurseries in the 16 to 20 inch rainfall zone (Table 3). The hard white line ID377S had a yield average of 77 bu/a, and average test weights of this line and Klasic exceeded 62 lb/bu. Centennial and Vanna had the lowest average protein percentages at 10.6%. Westbred 936 was had the highest yield average (69 bu/a) among hard red lines; however, none of the hard red varieties averaged over 14% in grain protein content across locations.

Locations with More than 20 Inches of Average Annual Rainfall

Fairfield: Average grain yields of hard red entries (71 bu/a) were 7% lower than soft white entries (76 bu/a) in the Fairfield nursery (Table 4). ID377S (85 bu/a) and WA7766 (84 bu/a) were the highest yielding entries, and these lines also had the highest test weights (63.1 and 62.1 lb/bu respectively). All soft white entries had grain protein contents less than 11%, and Pomerelle and Whitebird had the lowest protein percentages (8.8%). Wampum (78 bu/a) and WA7764 (77 bu/a) were the highest yielding hard red varieties; however, protein contents of all hard red entries were less than 12%. The hard white line ID377S had the highest grain yield, the highest test weight and the lowest grain protein level of any entry grown at this site.

Pullman: Average grain yield in the Pullman nursery were 93 bu/a with the soft white and hard red lines averaging 96 and 90 bu/a, respectively (Table 4). The hard white line ID377S was the highest yielding entry at 102 bu/a. Pomerelle, ID488, Vanna, Wawawai and WA7778 produced 100 bu/a or more, and ID488 and Wawawai had test weights exceeding 63 lb/bu. Pomerelle and Alpowa were the only two soft white entries with protein contents below 12%. Westbred 936 (96 bu/a), Spillman (95 bu/a) and OR8510 (94 bu/a) were the highest yielding hard red lines, and grain from all hard red varieties except Wampum were equal to or greather than 14% protein. Heat stress during grain fill may have elevated grain protein levels at this location.

Farmington: On July 9th, high winds accompanied by hail passed over this site resulting in minor plant injury and lodging. In spite of this, grain yields at this site averaged 98 bu/a (Table 4). Alpowa was the highest yielding entry at 121 bu/a which was 23 bu higher than the nursery average. ID488 had the highest test weight (62.3 lb/bu); however, many entries had test weights below 60 lb/bu. All soft white entries except for Wadual 94 had grain protein contents of less than 12%. OR8510 was the highest yielding hard red variety (100 bu/a), and Butte 86 and Westbred 926 were the only hard red lines with grain protein contents greater than 14%.

General Conclusions : WA7778 (97 bu/a) , WA7766 (96 bu/a) and Centennial (95 bu/a) were the highest yielding entries in locations with more than 20 inches of average annual rainfall. ID488 had the highest average test weight (62.3 lb/bu), and Pomerelle had the lowest average protein level (10.3%). Westbred 936 was the highest yielding variety (89 bu/a), and OR8510 had the highest average test weight (61.6 lb/bu) among hard red entries. Butte 86 was the only hard red line with grain protein contents averaging over 14% across locations. Even though the yield potential of hard red and soft white varieties were more similar in higher rainfall zones, it is very difficult to consistently achieve protein contents of 14% or more in hard red grain in these environments.

Irrigated Nurseries

Moses Lake: This nursery was planted under a center pivot irrigation system. As a result of over-head irrigation and high winds, many of the varieties lodged which may have adversely affected these results. Average grain yields of soft white and hard red entries were 118 and 115 bu/a, respectively (Table 5), and ID488 was the highest yielding entry (146 bu/a). Klasic, the shortest variety in the nursery, did not lodge and grain from this line had the highest test weight (62.2 lb/bu) of any entry in the trial. Test weights for a majority of the other entries in this nursery were below 60 lb/bu. Grain protein contents for all soft white entries were greater than 12%. OR8510 was the highest yielding (128 bu/a) hard red entry, and grain from all hard red lines had protein contents greater than 14%. Butte 86 and OR8510 had test weights exceeding 60 lb/bu and grain protein contents of more than 16%.

Royal Slope: The mean grain yield of the Royal Slope nursery was 119 bu/a and there was only a 5% difference in the yield averages of soft white (121 bu/a) and hard red (115 bu/a) varieties (Table 5). Penawawa and Vanna were the highest yielding varieties with 138 and 135 bu/a, respectively, and soft white lines Pomerelle, ID488, Vanna and Centennial had protein contents below 12%. WA7764 (124 bu/a) and Wampum (122 bu/a) were the highest yielding hard red entries, and all hard red lines except for OR8510 and Wampum had grain protein contents of 14% or more. Test weights for all entries in this trial were above 61 lb/bu.

General Conclusions: ID488 (134 bu/a) and Vanna (131 bu/a) had the highest yield averages in irrigated trials (Table 5). The soft white line Pomerelle had the lowest average protein percentage (11.9%), whereas, the hard red line Butte 86 had the highest average grain protein content (16%). Express, OR8510 and Westbred 936 were the highest yielding hard red varieties, and all hard red lines had protein contents exceeding 14%. With proper fertilization and water management, it is possible to produce hard red spring wheat with excellent yield potential, high test weights and 14% grain protein contents under irrigation.

Table 1. Fertilizer rates, planting information, precipitation levels and harvest dates for 1995 spring wheat variety trials.

Rainfall Zone (inches)	Trial Location	Previous Crop	Base Fertilizer (lb/acre)			Planting					Precipitation after planting (inches)	Harvest Date
			N	P	S	Date	Seeding Rate* (lb/acre)	Planter Type	Row Spacing (inches)	Soil Moisture** (inches)		
< 16	Lind Annual	Winter Wheat	15	0	12	14-Mar	60	Double Disk	6	4.4	4.4	27-Jul
	Lind Fallow	Fallow	15	0	12	17-Mar	60	Double Disk	6	6.1	4.0	28-Jul
	Bickleton	Spring Barley	40	0	0	28-May	90	Hoe	9	5.5	2.9	18-Sep
	Dusty	Winter Wheat	70	0	12	11-Apr	90	Double Disk	6	8.2	3.8	4-Aug
	Lamont	Winter Wheat	50	0	15	11-Apr	90	Double Disk	6	8.5	3.6	22-Aug
16-20	Mayview	Spring Barley	80	0	15	17-Apr	70	Double Disk	6	9.1	3.8	25-Aug
	Dayton	Spring Barley	70	0	12	30-Mar	90	Double Disk	6	8.3	Not Available	4-Aug
	Reardan	Winter Wheat	60	0	10	25-Apr	70	Double Disk	6	9.4	4.0	6-Sep
	St. John	Winter Wheat	70	0	10	24-Apr	90	Double Disk	6	9.6	3.6	22-Aug
> 20	Fairfield	Winter Wheat	64	8	6	24-Apr	70	Double Disk	6	7.2	6.3	12-Sep
	Pullman	Peas	76	0	15	3-Apr	70	Double Disk	6	9.6	7.1	22-Aug
	Farmington	Winter Wheat	60	0	10	1-May	90	Double Disk	6	8.5	4.4	30-Aug
Irrigated	Moses Lake	Potatoes	235	0	50	21-Mar	90	Double Disk	6	Not Available	2.6	8-Aug
	Royal Slope***	Alfalfa	240	0	25	21-Mar	90	Double Disk	4	8.83	2.6	9-Aug

* Starter fertilizer (7 lb N, 21 lb P2O5) was applied with the seed at all locations except Reardan, Fairfield and Royal Slope where no starter was used.

** Values reflect moisture levels in a 4 ft soil profile at every location except Bickleton where a 3 foot soil profile was analyzed.

*** 140 lb K2O and 1 lb Boron was applied with the base fertilizer.

Table 2. Grain yields, test weights and whole grain protein levels of selected 1995 spring wheat variety trial entries from locations with less than 16 inches of average annual rainfall.

Variety	Seed Statis*	Yield*** (bu/acre) Lind Dry Annual**	Yield Lind Dry Fallow**	Yield Bickleton	Yield Dusty	Yield Lamont	Yield Averaged Across Locations	Test Weight (lb/bu) Lind Dry Annual**	TW Lind Dry Fallow**	TW Bickleton	TW Dusty	TW Lamont	TW Averaged Across Locations	Protein (%) Lind Dry Annual**	Protein Lind Dry Fallow**	Protein Bickleton	Protein Dusty	Protein Lamont	Protein Averaged Across Locations
Soft White																			
Alpowa	R	31	42	49	**69**	64	51	61.7	62.5	60.4	62.7	61.0	61.7	12.9	12.9	9.1	10.0	9.8	10.9
Centennial	A	**36**	**44**	50	**65**	**68**	**53**	60.7	62.3	60.0	62.0	60.4	61.1	13.6	12.7	9.3	10.3	9.8	11.1
Edwall	A	**36**	**44**	57	**67**	65	**54**	57.6	60.7	57.8	59.5	58.2	58.8	13.1	12.6	9.7	10.2	10.1	11.1
ID488	E	**35**	**45**	57	**69**	**75**	**56**	60.0	62.6	60.2	62.3	61.0	61.2	12.9	12.5	9.1	9.9	9.8	10.8
Penawawa	A	33	**44**	51	63	**70**	**52**	60.1	61.8	58.3	61.9	61.0	60.6	12.9	12.4	9.5	10.2	9.3	10.9
Pomerelle	A	**34**	42	59	**67**	65	**53**	61.7	63.1	58.6	61.4	58.7	60.7	13.2	12.6	9.8	10.0	9.7	11.1
Vanna	A	**34**	**43**	54	**68**	**73**	**55**	59.9	61.4	58.3	61.7	60.2	60.3	13.3	12.9	9.4	9.6	9.6	11.0
WA7766	E	33	42	53	**66**	62	51	61.0	62.2	60.2	61.8	61.7	61.4	13.5	13.5	9.4	10.7	9.9	11.4
Wadual 94	B	29	38	48	61	65	48	58.2	60.6	58.5	61.5	60.7	59.9	15.7	15.2	10.8	11.5	11.4	12.9
Wakanz	A	31	40	44	**70**	**67**	50	59.2	61.6	56.3	61.5	60.1	59.7	13.5	13.1	10.4	10.3	10.2	11.5
Wawawai	F	**34**	42	50	**64**	64	51	61.5	62.4	58.7	62.1	61.4	61.2	13.1	13.6	10.5	10.9	10.6	11.7
Westbred Sprite	A	32	42	58	**64**	**71**	**53**	59.8	61.4	57.9	61.8	60.4	60.3	13.7	13.5	9.3	10.6	10.4	11.5
Whitebird	A	**34**	41	**65**	**65**	**69**	**55**	61.9	62.7	59.1	61.7	60.6	61.2	13.6	12.8	9.4	10.1	9.2	11.0
Club																			
Calorwa	F	29	38	55	53	63	48	58.6	61.4	55.9	61.4	59.9	59.4	12.7	12.7	10.2	11.4	11.5	11.7
Hard Red																			
Butte 86	A	30	36	44	51	54	43	61.2	62.1	57.9	61.8	60.4	60.7	14.7	15.5	11.7	13.3	13.4	13.7
Express	A	29	37	42	56	58	44	60.9	61.8	57.4	61.6	60.3	60.4	15.5	15.8	11.4	12.7	13.3	13.7
OR8510	E	27	34	49	56	61	46	62.2	61.8	58.2	62.7	62.0	61.4	15.3	15.5	11.6	12.8	12.2	13.5
Spillman	A	32	39	47	57	64	48	58.3	60.7	57.1	60.5	59.9	59.3	14.9	15.8	11.1	12.3	12.0	13.2
WA7764	E	29	37	54	57	63	48	60.2	60.7	58.3	60.5	59.3	59.8	14.3	15.1	11.7	13.0	12.2	13.3
Wampum	A	31	40	47	56	63	47	57.8	60.7	56.8	59.5	59.3	58.8	14.2	14.2	10.3	11.8	11.3	12.4
Westbred 926	A	29	35	48	48	57	43	61.8	62.3	59.1	60.9	60.4	60.9	15.3	15.7	10.6	14.0	13.0	13.7
Westbred 936	A	28	38	50	50	65	46	60.2	61.7	56.5	61.0	60.3	59.9	15.1	15.5	12.1	13.7	13.6	14.0
Hard White																			
ID377S	F	30	41	54	63	**71**	**52**	58.9	62.1	60.2	62.6	61.2	61.0	15.9	15.3	9.9	10.9	11.5	12.7
Klasic	A	27	38	**60**	29	59	43	60.1	63.1	57.8	61.6	61.7	60.9	14.5	14.2	10.5	15.4	12.2	13.4
WA7778	E	**34**	41	50	62	**67**	51	58.2	60.5	56.6	60.2	59.7	59.0	14.9	14.4	10.3	10.6	10.9	12.2
Mean		31	40	52	60	65	50	60.1	61.8	58.2	61.4	60.4	60.4	14.1	14.0	10.3	11.5	11.1	12.2
CV %		7.5	5.5	9.2	9.3	12.0	21.6												
LSD @ .10		2.7	2.6	5.6	6.5	9.2	4.6												

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

**Mean values for these locations were derived from selected nursery entries. Data from experimental lines and historical checks were not reported.

*** The highest yield value per location is outlined, and values in bold type do not differ significantly from the highest value within each location.

Table 3. Grain yields, test weights and whole grain protein levels of selected 1995 spring wheat variety trial entries from locations with 16 to 20 inches of average annual rainfall.

Variety	Seed Statis*	Mayview**	Dayton	Reardan**	St. John	Averaged Across Locations	Mayview**	Dayton	Reardan**	St. John	Averaged Across Locations	Mayview**	Dayton	Reardan**	St. John	Averaged Across Locations
		----- Yield*** (bu/acre) -----					-------- Test Weight (lb/bu) --------					------------ Protein (%) ------------				
Soft White																
Alpowa	R	56	80	**83**	**96**	**79**	62.6	59.2	60.5	62.4	61.2	10.1	10.8	11.9	10.8	10.9
Centennial	A	59	71	79	**87**	74	61.9	60.3	62.8	61.8	61.7	11.6	10.4	9.0	11.4	10.6
Edwall	A	58	**78**	**83**	**88**	**77**	58.4	56.5	60.5	58.7	58.5	12.4	11.4	10.0	11.4	11.3
ID488	E	62	**84**	72	**92**	**78**	62.7	60.7	60.6	61.5	61.4	11.5	9.6	10.7	10.9	10.7
Penawawa	A	65	**84**	**89**	**91**	**82**	61.3	59.7	62.2	62.3	61.4	12.1	11.9	11.1	10.8	11.5
Pomerelle	A	**72**	**88**	81	85	**81**	61.6	57.7	58.8	60.6	59.7	11.3	10.5	9.9	11.0	10.7
Vanna	A	62	**83**	75	86	**77**	61.5	60.3	61.3	60.9	61.0	10.1	10.5	11.1	10.6	10.6
WA7766	E	57	74	79	**88**	74	61.9	57.5	62.4	60.7	60.6	11.5	11.3	11.1	11.8	11.4
Wadual 94	B	55	68	80	77	70	60.6	58.7	59.2	61.5	60.0	12.1	12.5	13.2	12.5	12.6
Wakanz	A	52	**80**	**86**	**87**	76	60.3	58.8	62.8	60.8	60.7	12.1	11.5	11.1	11.4	11.5
Wawawai	F	46	75	81	**88**	73	62.0	57.5	61.9	61.8	60.8	10.8	12.0	12.1	11.9	11.7
Westbred Sprit	A	58	**79**	78	82	74	61.4	61.1	62.1	60.3	61.2	11.7	10.3	10.6	11.7	11.1
Whitebird	A	61	**81**	81	86	**77**	61.7	58.2	60.8	60.3	60.3	11.5	10.5	9.9	11.4	10.8
Club																
Calorwa	F	58	69	62	81	67	60.9	59.5	61.5	60.9	60.7	11.8	11.6	10.8	11.7	11.5
Hard Red																
Butte 86	A	31	65	65	69	58	60.7	57.6	62.0	61.2	60.4	14.1	14.9	11.7	14.4	13.8
Express	A	53	72	71	77	68	61.8	60.7	61.6	59.1	60.8	14.3	13.4	13.5	14.4	13.9
OR8510	E	55	62	75	75	67	62.2	58.3	61.6	61.6	60.9	13.6	14.2	12.9	13.5	13.6
Spillman	A	49	73	70	75	67	60.6	57.6	62.3	59.6	60.0	13.0	13.1	10.8	13.8	12.7
WA7764	E	50	75	69	77	68	59.3	57.8	58.4	58.6	58.5	13.5	12.8	13.0	14.1	13.4
Wampum	A	50	61	67	67	61	60.3	56.2	61.7	58.8	59.3	12.0	12.8	9.1	12.8	11.7
Westbred 926	A	50	67	71	77	66	61.1	57.2	62.1	60.6	60.3	13.6	14.4	12.6	14.5	13.8
Westbred 936	A	48	**79**	72	77	69	61.4	59.1	61.5	61.2	60.8	13.1	13.7	12.2	14.2	13.3
Hard White																
ID377S	F	54	**87**	**84**	83	**77**	62.2	60.0	65.1	61.7	62.3	11.8	12.0	10.5	12.1	11.6
Klasic	A	53	71	64	67	64	62.0	61.8	64.2	62.4	62.6	12.6	12.2	12.0	12.7	12.4
WA7778	E	53	**79**	81	83	74	59.3	58.0	60.9	60.1	59.6	12.1	11.4	9.9	11.6	11.3
Mean		55	75	76	82	72	61.2	58.8	61.6	60.8	60.6	12.2	12.0	11.2	12.3	12
CV %		10.0	13.5	8.4	9.9	16.2										
LSD @ .10		6.3	11.9	7.5	9.5	5.4										

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

**Mean values for these locations were derived from selected nursery entries. Data from experimental lines and historical checks were not reported.

*** The highest yield value per location is outlined, and values in bold type do not differ significantly from the highest value within each location.

Table 4. Grain yields, test weights and whole grain protein levels of selected 1995 spring wheat variety trail entries from locations with more than 20 inches of average annual rainfall.

Variety	Seed Statis*	Fairfield**	Pullman**	Farmington	Averaged Across Locations	Fairfield**	Pullman**	Farmington	Averaged Across Locations	Fairfield**	Pullman**	Farmington	Averaged Across Location
		Yield*** (bu/acre)				Test Weight (lb/bu)				Protein (%)			
Soft White													
Alpowa	R	76	86	***121***	***94***	60.8	62.0	60.5	61.1	9.7	11.7	10.3	10.6
Centennial	A	***79***	***99***	***106***	***95***	60.8	62.4	61.7	61.6	9.8	12.4	10.6	10.9
Edwall	A	64	***93***	100	86	58.7	60.1	58.5	59.1	10.3	12.3	11.1	11.2
ID488	E	74	***100***	***108***	***94***	61.2	63.3	62.3	62.3	9.3	12.2	10.2	10.6
Penawawa	A	74	***93***	102	***90***	59.1	61.7	60.9	60.6	10.0	12.4	11.0	11.1
Pomerelle	A	73	***101***	103	***92***	58.5	61.6	59.1	59.7	8.8	11.5	10.5	10.3
Vanna	A	***80***	***100***	103	***94***	60.3	60.8	61.0	60.7	9.4	12.1	10.4	10.6
WA7766	E	***84***	***99***	***106***	***96***	62.1	62.6	59.4	61.4	10.2	12.5	10.8	11.2
Wadual 94	B	75	***91***	97	88	61.0	61.8	59.7	60.8	10.8	14.0	13.1	12.6
Wakanz	A	***79***	***99***	103	***94***	59.2	61.4	60.3	60.3	10.3	12.5	10.9	11.2
Wawawai	F	75	***100***	94	***90***	61.4	63.0	60.6	61.7	10.8	12.6	11.4	11.6
Westbred Sprit	A	***79***	***91***	96	89	60.0	61.7	59.7	60.5	10.2	12.8	11.5	11.5
Whitebird	A	73	***98***	100	***90***	59.4	62.2	60.6	60.7	8.8	12.4	10.5	10.6
Club													
Calorwa	F	61	77	93	77	58.6	61.7	60.2	60.2	10.3	12.4	11.5	11.4
Hard Red													
Butte 86	A	64	82	74	73	60.7	61.5	60.8	61.0	12.3	15.5	15.6	14.5
Express	A	68	***92***	95	85	60.6	62.0	59.7	60.8	11.4	15.1	13.8	13.4
OR8510	E	68	***94***	100	87	61.3	62.5	61.1	61.6	11.3	14.3	13.3	13.0
Spillman	A	66	***95***	96	85	59.5	59.9	58.7	59.4	12.8	14.1	13.8	13.6
WA7764	E	***77***	***91***	93	87	58.1	60.9	57.7	58.9	9.6	15.0	13.7	12.8
Wampum	A	***78***	***91***	89	86	59.4	60.9	58.4	59.6	11.3	13.6	13.1	12.7
Westbred 926	A	69	80	87	79	61.0	62.0	58.9	60.6	11.5	15.8	14.3	13.9
Westbred 936	A	74	***96***	98	89	61.1	62.3	60.4	61.3	11.1	15.1	13.6	13.3
Hard White													
ID377S	F	***85***	***102***	92	***93***	63.1	62.5	60.0	61.9	11.0	14.1	12.2	12.4
Klasic	A	61	80	89	77	60.0	62.9	61.8	61.6	11.3	15.0	13.0	13.1
WA7778	E	***79***	***100***	***111***	***97***	57.5	60.8	59.4	59.2	10.2	13.1	11.0	11.4
Mean		73	93	98	88	60.1	61.8	60.1	60.7	10.5	13.4	12.1	12.0
CV %		9.8	10.8	14.4	15.1								
LSD @ .10		8.4	11.7	16.7	6.7								

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

**Mean values for these locations were derived from selected nursery entries. Data from experimental lines and historical checks were not reported.

*** The highest yield value per location is outlined, and values in bold type do not differ significantly from the highest value within each location.

Table 5. Grain yields, test weights and whole grain protein levels of selected 1995 spring wheat variety trial entries in irrigated nurseries.

Variety	Seed Statis*	Moses Lake	Royal Slope**	Averaged Across Locations	Moses Lake	Royal Slope**	Averaged Across Locations	Moses Lake	Royal Slope**	Averaged Across Locations
		---Yield*** (bu/acre) ---			--Test Weight (lb/bu) --			------ Protein (%) ------		
Soft White										
Alpowa	R	126	129	127	59.7	64.7	62.2	13.5	12.5	13.0
Centennial	A	117	115	116	60.2	64.4	62.3	12.6	11.9	12.3
Edwall	A	116	117	117	54.4	61.9	58.2	12.9	12.2	12.6
ID488	E	**146**	121	**134**	60.6	64.5	62.6	12.2	11.4	11.8
Penawawa	A	117	**138**	**128**	58.4	64.5	61.5	13.3	12.4	12.9
Pomerelle	A	109	127	118	56.2	61.8	59.0	12.5	11.2	11.9
Vanna	A	127	**135**	**131**	59.4	63.4	61.4	13.3	11.8	12.6
WA7766	E	103	117	110	57.5	64.1	60.8	13.1	12.5	12.8
Wadual 94	B	125	112	118	58.7	62.9	60.8	14.4	13.7	14.1
Wakanz	A	114	123	118	57.1	62.5	59.8	13.2	12.5	12.9
Wawawai	F	104	113	109	58.5	63.8	61.2	13.2	12.9	13.1
Westbred Sprit	A	95	121	108	54.0	63.0	58.5	14.2	12.6	13.4
Whitebird	A	**135**	109	122	60.2	63.1	61.7	12.4	12.2	12.3
Club										
Calorwa	F	118	106	112	58.8	62.0	60.4	12.3	11.6	12.0
Hard Red										
Butte 86	A	103	104	104	60.7	63.2	62.0	16.4	15.5	16.0
Express	A	123	116	120	60.0	62.6	61.3	15.6	15.3	15.5
OR8510	E	128	114	121	60.9	63.9	62.4	14.2	13.9	14.1
Spillman	A	109	113	111	57.9	61.8	59.9	15.4	14.0	14.7
WA7764	E	111	124	118	55.2	62.4	58.8	16.1	14.9	15.5
Wampum	A	107	122	115	58.1	63.2	60.7	15.0	13.8	14.4
Westbred 926	A	112	110	111	59.1	62.0	60.6	15.6	14.7	15.2
Westbred 936	A	123	116	120	58.9	62.2	60.6	14.6	14.2	14.4
Hard White										
ID377S	F	101	125	113	57.6	65.3	61.5	14.7	14.2	14.5
Klasic	A	**137**	113	125	62.2	64.0	63.1	14.1	13.9	14.0
WA7778	E	131	125	**128**	58.3	61.3	59.8	12.9	12.8	12.9
Mean		118	119	119	58.5	63.1	60.8	13.9	13.1	13.5
CV %		8.6	5.9	8.1						
LSD @ .10		11.7	8.2	6.6						

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

**Mean values for these locations were derived from selected nursery entries. Data from experimental lines and historical checks were not reported.

*** The highest yield value per location is outlined, and values in bold type do not differ significantly from the highest value within each location.

BARLEY IMPROVEMENT RESEARCH

S.E.Ullrich, C.E. Muir, J.A. Clancy, J.S. Cochran, A. Kleinhofs,
D. von Wettstein, V. Jitkov, F. Han, B.C. Miller, E. Donaldson, P.E. Reisenauer,
J.A. Froseth, R.L. Line, *and* R.J. Cook

Cultivar Development/Variety Testing

The latest WSU winter barley cultivar release is *Hundred*, which is a high yielding semi-dwarf 6-row feed type. Hundred has had consistently high yields across eastern Washington (Table 1). The latest WSU spring barley cultivar is *Crest*, a 2-row spring malting type with high yield (Table 2), good kernel quality, and good feed quality. Two new releases for 1996 include a 6-row hooded hay type (WA 7999-88) (Table 3) and a new 2-row hulless type (WA 11045-87) (Tables 4 and 5). These new cultivars are considered specialty barleys for niche markets. WA7999-88 is expected to replace Belford which was released by WSU in 1943.

Whereas winter and spring and 2-row and 6-row types are bred and/or evaluated, emphasis is on spring types. This emphasis is due to northwest barley breeding program collaboration. For spring barley in 1995, 103 crosses were made. In 1996, plants will be selected from 102 segregating F_3 populations (50-100/population) from previous years' crosses. In addition, there are 103 F_2 populations in the field and 50 F_3 single seed descent populations in the greenhouse. Lines will be selected from approximately 6,000 head and plant rows including homozygous doubled haploid (from anther culture) plant rows. There are 32 24-entry preliminary yield trials planted at Spillman Farm this year; the entries of which mostly came from 1995 head/plant rows. The more advanced lines are tested in 18 30- to 100-entry major yield trials at Spillman and throughout eastern Washington. In addition, there are six spring barley yield trials conducted by Ed Donaldson and Pat Reisenauer and there are 10 grower-conducted on-farm tests in 7 counties in 1996 coordinated by Kevin Anderson of Great Western Malting Company.

The winter barley program is much smaller in scope with reliance on the Oregon State University program for new breeding line development for evaluation in Washington. In 1995-96, there are about 500 winter barley plots and about 7,000 spring barley plots in total. Vadim Jitkov and Judy Cochran are field research technologists working with the program. Carl Muir, long-time field technologist in the program, retired December 31, 1995. He has been working part time in 1996. Barley performance in 1995 was presented in the September 1, 1995 *Greensheet* and the October 1995 *Wheat Life* for winter barley and December 15, 1995 *Green Sheet* for spring barley small plot trials and in the January 1, 1996 *Wheat Life* for on-farm tests.

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 are conducted in the Department of Animal Sciences primarily by John Froseth.

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. Barley stripe rust 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, and now at WSU. 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 all the above mentioned pests.

Application for Biotechnology

Anther culture techniques have been used to develop doubled-haploid lines (DHL) from F_1 plants from crosses in the breeding program. This is a rapid (~1 year) method for developing homozygous (true breeding) breeding lines. Traditionally near homozygous lines are developed after several years of allowing the progeny of crosses to segregate from F_2 through $F_{5\text{-}8}$. The advantages of DHLs are rapid development of breeding lines for selection and testing and early initial selection and testing of true breeding lines (non-segregating lines) vs. selection of lines still segregating. Cultivar development time can be cut by 1/3-1/2 using HDLs. In 1995, 500 DHLs from 20 crosses were in the field for selection. Lack of funding has terminated these efforts on barley.

Collaboration in the North American Barley Genome Mapping Project involves work on several fronts with Andy Kleinhofs, Janet Clancy, and Feng Han. The first comprehensive map developed from Steptoe/Morex is being applied to quantitative trait locus (QTL) analysis and molecular marker assisted selection uses relevant to cultivar development. We are verifying QTL identified and developing markers suitable for selection in the breeding program. Initially, we are concentrating on the dormancy trait in Steptoe and several malting quality traits in Morex. Mapping populations from the Harrington/TR306 and Harrington/Morex crosses are also being evaluated. 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. The proanthocyanidin-free barley project has been a long-time collaboration. The transformation project will see the first transformed plants in the field this year.

Table 1. Winter barley yield averages through 1995, lb/a (% Kamiak).

Variety	Pullman 12 Yr	Pomeroy 10 Yr	Walla Walla 10 Yr	Lind Irr 5 Yr	Extension 71 LOC-Yr
Hundred	6150 (124)	4900 (124)	4800 (107)	4750 (176)	4550 (115)
Hesk	6200 (125)	5000 (126)	4800 (107)	4550 (168)	4500 (114)
Boyer	5550 (112)	4750 (120)	5050 (112)	4150 (154)	4350 (110)
Showin	5450 (110)	4800 (122)	5150 (114)	4350 (161)	4250 (108)
Kamiak	4950 (100)	3950 (100)	4500 (100)	2700 (100)	3950 (100)

Table 2. Spring barley yield averages through 1995.

Variety	Pullman 15 Yr	Garfield 15 Yr	Walla[2] 11 Yr	Lincoln Co. 11 Yr	Connell 8 Yr	Lind 11 Yr	Fairfield 5 Yr	Mean 76 LOC-Yr
		Lb/A (%)						
Crest	4895(102)	3263 (98)	3530(96)	2920(105)	1920 (107)	1829 (98)	3450 (97)	3582 (99)
Steptoe	4819(100)	3313 (100)	3690(100)	2791(100)	1790(100)	1858 (100)	3563 (100)	3627 (100)

Table 3. Six-year average performance of spring barley hooded lines grown at Pullman, 1989 and 1991-95.

	---------- *Forage Yield* ----------							--- *Grain Yield* ---	
Variety	Head Date	Height (inches)	LOD (%)	Wet Wt T/A	% BELF	Dry Wt T/A	% BELF	L/A	% BELF
Belford x Columbia (#7999-99)	172	37	4	11.2	113	3.9	115	3455	122
Stepford	168	38	8	9.0	91	3.4	100	3142	110
Belford	168	40	16	9.9	100	3.4	100	2844	100

Table 4. Hulless barley performance.

	Variety	Head d from 1/1	Height (inches)	LOD (%)	Test Wt (Lb/Bu)	------- Yield ------- Lb/A)	%
Pullman							
5-Year /Ave	*WA11045-87*	175	35	0	59	4228	113
1991-95	*Condor*	176	34	0	61	3732	100
	Scout	175	38	2	57	3609	97
13 Locations	*WA11045-87*	---	33	7.5	57	3696	105
1995	*Condor*	---	30	6.3	58	3535	100

Table 5. Hulless barley performance, 1995.

	---------- Production Zone, Lb/A ----------				
Variety	2000-3000	3000-4000	4000-5000	>5000	Mean
11045-87	2095 (83)	3065 (86)	3743 (91)	5264 (96)	3696 (91)
Condor	1994 (79)	2870 (80)	3579 (87)	5099 (93)	3535 (87)
Gallatin	2536 (100)	3565 (100)	4114 (100)	5494 (100)	4073 (100)

1995 STATE/EXTENSION WINTER BARLEY

B.C. Miller, P.E. Reisenauer, S.E. Ullrich, C.E. Muir and J.S. Cochran

The 1994-95 winter barley variety evaluation trials were conducted at 6 locations in eastern Washington. Twenty winter barleys were evaluated at all locations. Varieties in the testing program included all significant released public varieties from the Pacific Northwest and public varieties from the tri-state region being considered for release. As a result of cooperative efforts with the WSU breeders all varieties evaluated in this testing program were also evaluated in the WSU breeder's testing program.

Fall planting conditions were very poor at all locations due to the extremely dry summer and fall. Most of the nurseries were planted later than normal as the cooperators were waiting for late fall rains that never materialized. As a result, very poor stands were established and three of the six locations were eventually abandoned. The Pomeroy site was harvested although stands were uneven. When harvest area was adjusted to normal the data were acceptable. The Walla Walla site suffered from extreme lodging and this was reflected in the yields and test weights. Fairfield appeared to be uneven yet throughout the growing season it recovered and reliable data were obtained. Dusty and Bickleton never recovered from the poor stand establishment. The nursery at Asotin was acceptable but the constant rains through the growing season brought on several flushes of goatgrass and the nursery was abandoned for yield results. It was, however, harvested by Dr. Ogg's USDA-ARS weed program to evaluate the competitive abilities of the winter barley varieties with goatgrass.

Average yields for the winter barley ranged from 4691 lbs/acre (Kamiak) to 6407 lbs/acre (1997-87). With timely rains, the test weights were much higher than last year, the lowest test weight being 46.4 lbs/bushel. Two named varieties Kamiak and Gwen and two numbered varieties averaged greater than 50 lbs/bushel.

Further agronomic information from these trials are summarized over a two year period and reported in the winter Washington State Crop Improvement Seed Buying Guide.

1995 WSU WINTER BARLEY VARIETY TRIAL

YIELD (LBS/A)

VARIETY	WALLA WALLA	FAIRFIELD	POMEROY	PULLMAN	VARIETY MEAN
1794-89	5132	4981	5071	7683	5594
1869-89	3896	5594	5361	7860	5468
1872-89	4324	4908	6152	7763	5677
1975-86	3929	6042	7087	8090	6131
1996-87	5354	5610	7059	8185	6483
1997-87	5720	5469	6900	7636	6407
2677-89	6087	4596	6597	7359	6196
2687-90	5297	4986	6498	7594	6054
BOYER	4335	5844	5865	6806	5590
EIGHT-TWELVE	4293	4372	6187	4099	4838
GWEN	4801	5033	4755	6454	5164
HESK	3963	5111	6295	7445	5589
HUNDRED	3733	5382	6152	6553	5353
KAMIAK	3793	4795	5045	5404	4691
KOLD	4587	5225	6166	7590	5789
O1900119	4778	5054	5255	8001	5621
O1908184	4046	4968	7502	7079	5874
O1917265	4870	4430	5018	7958	5444
O1917349	4800	3882	6070	7057	5449
SHOWIN	5737	5027	7124	6756	6215
NURSERY MEAN	4674	5065	6108	7169	5681
CV (%)	18.6	8.7	9.2	12.6	12.8
LSD @ .10	831	522	540	1071	378

TEST WEIGHT (LBS/BU)

VARIETY	WALLA WALLA	FAIRFIELD	POMEROY	PULLMAN	VARIETY MEAN
1794-89	48.7	47.1	50.6	47.6	48.7
1869-89	47.4	48.4	50.6	48.1	48.7
1872-89	47.6	48.0	50.9	47.1	48.6
1975-86	45.7	46.4	48.3	44.8	46.4
1996-87	48.5	47.4	48.5	47.0	48.0
1997-87	48.2	47.7	49.7	49.8	48.9
2677-89	47.4	45.6	47.5	44.6	46.5
2687-90	49.1	48.7	50.9	49.2	49.6
BOYER	47.1	47.1	48.8	48.3	47.8
EIGHT-TWELVE	47.9	48.2	51.3	47.0	48.8
GWEN	50.6	49.3	51.8	50.7	50.7
HESK	46.3	46.7	48.9	48.4	47.6
HUNDRED	46.2	45.9	48.2	47.8	47.1
KAMIAK	49.9	50.2	52.3	46.5	50.0
KOLD	47.1	48.1	50.2	48.5	48.5
O1900119	47.7	46.8	49.3	45.7	47.6
O1908184	46.0	47.3	50.0	46.5	47.6
O1917265	49.9	48.5	51.2	50.7	50.2
O1917349	49.3	48.4	51.6	50.5	50.0
SHOWIN	47.7	47.0	47.7	45.0	47.0
NURSERY MEAN	47.9	47.6	49.9	47.7	48.4
CV (%)	2.8	1.1	2.1	*	2.0
LSD @ .10	1.3	0.6	1.0	*	0.5

Analysis method - General Linear Models Proceedure

1995 STATE/EXTENSION SPRING BARLEY

B.C. Miller, P.E. Reisenauer, S.E. Ullrich, C.E. Muir and J.S. Cochran

The spring 1995 barley variety evaluation trials were conducted at 13 spring locations in 7 eastern Washington counties. Twenty-two spring varieties, eight 6-row and fourteen 2-row, were common to all trial locations. The WSU breeder nurseries contained several other numbered lines for preliminary evaluation. Four additional varieties were included at the irrigated Moses Lake site. Varieties in the testing program included all significant released public varieties from the Pacific Northwest, public varieties from the tri-state being considered for release and private varieties entered on a 'fee for entry ' basis.

Other than the Bickleton nursery which was planted late due to rains, planting was completed in a timely manner and conditions were excellent. Higher than usual and timely rains throughout the season allowed for excellent yields and grain quality. The first replicate at Dusty was lost to a heavy summer rain that resulted in severe flooding and soil deposition. The Moses Lake site, as in the past, suffered from extreme lodging. The lower light intensities resulting from the greater cloud cover caused the plants to produce extremely weak straw this year.

Baronesse, the most popular variety statewide was also the second highest yielding of all the named varieties (4454 lbs/acre). Colter was the highest yielding overall at 4495 lbs/acre. The traditional variety Steptoe, held a mid-range ranking in yield (4195 lbs/acre) with a much lower than average test weight (46.8 lbs\bushel). Test weights were exceptional in all other varieties and lines.

Further agronomic information from these trials are summarized over a two year period and reported in the spring Washington State Crop Improvement Seed Buying Guide.

1995 WSU SPRING BARLEY VARIETY TRIAL
YIELD (LBS/A)

VARIETY NAME	BICKLETON	DUSTY	LAMONT	DAYTON	FARMINGTON	ST. JOHN	LIND DRY	MAYVIEW	FAIRFIELD	REARDAN	MOSES LAKE	PULLMAN	ROYAL SLOPE	VARIETY MEAN
Six- row														
9339-91	3022	3152	3453	3196	4663	5159	2514	3710	4596	4514	6504	6138	6943	4453
9908-89	2774	3054	2992	3437	4705	4806	2274	3479	4402	4410	5459	5768	6065	4146
COLTER	2812	2866	3476	4490	4304	4951	2249	4277	4611	4715	6787	6061	6428	4495
MARANNA	2393	3295	3449	4865	4685	4611	2118	4607	4319	4752	5975	4956	5908	4322
MOREX	2613	2852	2832	3175	4082	4188	1970	3889	3932	3647	5288	5292	5681	3822
PAYETTE	2389	2734	3281	4381	4678	4588	1796	3701	4073	4302	5278	5015	6050	4046
STANDER	2821	2955	3465	3874	4205	4088	1712	4122	3863	3703	5362	4847	6477	3981
STEPTOE	2992	2494	3408	4183	4081	4783	2242	4059	4253	4556	5984	4940	6132	4195
Two- row														
7758-89	3229	3396	3682	4227	4395	4710	2236	3374	4446	4518	4697	5959	6805	4300
78AB10274	2888	3382	3644	4108	4006	4297	2420	3517	4349	4314	5229	5792	5134	4097
8625-90	3024	3519	3483	4119	3979	4585	2307	3478	4007	4468	4447	5498	6022	4083
BARONESSE	3041	3652	3766	4986	3999	5047	2402	4490	4575	5059	4663	5684	6332	4454
CHINOOK	2902	3444	3578	4346	3830	4704	2533	3048	4451	4319	5830	6186	6173	4273
CREST	2566	3306	3700	4449	3493	4245	2371	3933	4149	4615	4799	5598	6792	4172
GALLATIN	2760	3461	3546	4328	3925	4600	2311	3663	4349	3370	4756	5913	5814	4073
HARRINGTON	2700	3176	3436	4415	4115	4591	2335	3891	4695	4610	4344	5358	6206	4163
LEWIS	2919	3379	3546	3846	4114	4337	2345	3366	4252	4035	5345	5326	6316	4101
MELTAN	2963	3304	3463	4615	4655	4851	1907	3969	4409	4601	4898	5240	6953	4314
SISSI	3132	3201	3485	4110	4537	4916	1989	3591	3986	4429	4517	5276	6461	4144
TARGHEE	2544	3751	3457	4582	3745	4548	2338	3708	4243	4632	5216	5700	5805	4183
Hulless														
11045-87	2229	3113	2847	3339	3610	3993	1961	3246	4049	3724	4725	4938	6131	3696
CONDOR	2232	2957	2954	3344	3229	3868	1756	2720	3532	3921	4857	4720	5720	3535
NURSERY MEAN	2770	3202	3406	4110	4138	4567	2186*	3720*	4252*	4328*	5226*	5464*	6198*	4138*
CV %	13.5	9.8	13.0	11.3	9.9	7.4	9.5	15.2	10.6	9.8	15.1	7.7	13.1	24.1
LSD @ .10	441	433	522	548	484	398	239	657	518	479	939	486	919	360

* *Mean derived from reported varieties/lines only - does not include all nursery entries*

Analysis method - General Linear Models Proceedure

1995 WSU SPRING BARLEY VARIETY TRIAL
TEST WEIGHT (LBS/BU)

VARIETY NAME	BICKLETON	DUSTY	LAMONT	DAYTON	FARMINGTON	ST. JOHN	LIND DRY	MAYVIEW	FAIRFIELD	REARDAN	MOSES LAKE	PULLMAN	ROYAL SLOPE	VARIETY MEAN
Six- row														
9339-91	47.4	48.5	47.4	50.2	47.9	49.8	49.5	49.1	47.4	51.9	47.2	49.2	52.7	49.1
9908-89	45.1	49.2	46.7	49.9	47.0	49.8	50.0	46.0	47.8	53.1	47.4	47.3	53.0	48.6
COLTER	45.4	48.4	47.2	49.3	45.1	49.7	47.5	47.1	47.7	53.7	48.9	47.5	51.5	48.4
MARANNA	41.3	48.3	46.2	49.1	46.5	48.1	48.1	46.7	48.3	51.8	48.7	46.7	51.5	47.8
MOREX	45.6	49.5	48.4	51.1	47.2	50.4	49.8	48.8	47.8	52.8	48.4	48.0	52.7	49.3
PAYETTE	44.4	48.4	47.3	49.7	48.7	49.3	48.8	48.0	48.1	51.1	50.1	48.0	52.5	48.8
STANDER	47.1	51.1	49.2	53.0	48.3	51.3	50.8	49.6	49.3	52.7	49.4	48.0	53.9	50.3
STEPTOE	45.7	46.6	44.9	49.5	41.9	46.7	48.0	45.3	46.4	49.9	45.9	45.8	52.0	46.8
Two- row														
7758-89	48.2	52.1	51.0	53.4	48.6	51.9	52.3	48.9	51.6	53.6	48.0	52.7	54.4	51.3
78AB10274	48.9	51.8	49.9	51.0	45.5	49.4	48.3	50.1	50.1	54.1	49.2	50.5	53.4	50.1
8625-90	48.9	52.4	50.7	51.5	47.3	51.5	51.0	50.1	50.2	54.9	46.7	50.4	50.9	50.5
BARONESSE	47.6	52.5	50.8	53.0	47.5	51.0	53.7	51.7	52.0	53.9	48.1	52.4	56.2	51.6
CHINOOK	49.9	53.2	51.6	52.8	48.5	50.6	52.6	50.7	52.0	54.9	50.2	51.4	54.7	51.7
CREST	47.7	53.7	51.1	52.2	48.1	51.4	52.0	50.2	51.0	55.6	47.8	52.4	54.6	51.3
GALLATIN	48.6	53.0	52.2	52.8	49.6	52.9	52.3	51.7	52.7	54.3	49.6	53.3	56.3	52.2
HARRINGTON	46.4	51.7	50.8	50.1	47.1	49.9	51.7	49.0	51.4	53.3	46.7	51.7	54.1	50.3
LEWIS	49.5	52.7	51.9	53.1	49.2	52.6	52.0	50.3	52.1	55.4	49.8	52.6	55.2	52.0
MELTAN	48.9	53.3	51.2	53.9	50.9	51.9	53.9	51.7	52.8	55.2	49.4	52.3	54.4	52.3
SISSI	47.6	51.2	51.1	52.8	49.0	50.7	52.7	52.3	50.0	53.8	48.4	52.1	54.6	51.3
TARGHEE	46.9	52.2	50.6	51.7	47.9	50.5	53.5	49.8	52.3	55.2	48.5	52.5	53.7	51.1
Hulless														
11045-87	51.9	58.3	55.6	56.2	53.8	55.5	58.4	57.9	56.8	62.5	52.2	55.5	61.5	56.6
CONDOR	54.8	59.5	56.8	57.6	55.3	57.4	59.4	56.5	57.7	61.0	54.8	57.4	63.5	57.8
NURSERY MEAN	47.6	51.7	50.1	52.0	48.2	51.0	51.6*	50.1*	50.7*	54.3*	48.9*	50.8*	54.4*	50.9*
CV %	3.5	1.6	1.5	2.0	3.0	2.0	*	*	*	*	3.3	*	*	3.4
LSD @ .10	2.0	1.2	0.9	1.2	1.7	1.2	*	*	*	*	1.9	*	*	0.6

** Mean derived from reported varieties/lines only - does not include all nursery entries*

Analysis method - General Linear Models Proceedure

1995 Spring Barley On-Farm Variety Testing Results

Baird Miller, Agronomist
Steve Ullrich, Plant Breeder
Ron McClellan, Agronomist, WSU
Department of Crop and Soil Sciences, WSU

In 1995, the spring barley on-farm variety testing program continued to develop valuable variety performance data for making variety selections. Twenty-two single replicate, on-farm variety tests were established. Growers cooperating in the program seeded and harvested 193 single variety drill strips to evaluate spring barley performance on their farms. The results from each trial location were evaluated and combined with other grower who planted the same set of varieties. Combining the results from multiple farms in production zones allows for the necessary replication to make statistically valid conclusions.

Jerry Johnson started the on-farm spring barley testing program six years ago as part of his Ph.D. research program. The initial objective was to improve prediction of spring barley variety performance for specific growing areas of eastern Washington. This approach to variety evaluation became very popular and has continued since with the active participation by growers, local seed companies, Ritzville Warehouse, Washington State Crop Improvement, Washington Barley Commission, Great Western Malting, Washington State University, USDA-ARS and Nu Chem. Table 1 presents a list of the participants in this year's program and Table 2 summarizes the history of the on-farm testing activity for the last six years.

This program relies on widespread industry participation. Chuck Goemmer with Washington State Crop Improvement Association (WSCIA) and Keith Bailey and Kevin Anderson with Great Western Malting Company obtained the seed for use in the trials. The following contributors for the 1995 on-farm testing program donated certified seed: Camelot spring barley, Spectrum Crop Development; Crest spring barley, R.M.K. Farms/Ken Kilpatrick; Cenex Supply and Marketing (bagging and treating Crest seed), Harrington spring barley, Fairfield Grain Growers; Baronesse spring barley, Whitman County Growers; Steptoe spring barley, Rosalia Producers; Colter spring barley, Great Western Malting. WSCIA Foundation Seed Service transported the seed to the Ritzville warehouse. Warehousing of seed and distribution to the county coordinators was done by Ritzville Warehouse Company. County coordinators from the eight counties were responsible for seed delivery, data and grain sample collection and distribution of results. Ron McClellan organized the residue sampling program and arranged for the collection and transportation of 975 sub-samples from the trial locations. Natural Resources Conservation Service (NRCS) and Conservation District (CD) personnel and extension coordinators participated in the field work for this phase of the project. The samples were stored at the Plant Materials Center in Pullman and NRCS furnished the equipment used for threshing the bundle samples. Personnel from the Agricultural Research Service (ARS) provided assistance during the weighing and threshing of the subsamples. Baird Miller, Steve Ullrich, Ron McClellan, Pat Reisenauer and staff from the seedhouse helped with the processing of the grain samples (test weight, protein, plump and thins), data analysis and summary preparation. Mary Palmer-Sullivan, representing the Washington Barley Commission, was responsible for the overall coordination and communication of the program.

This year, for all the test locations the standard varieties set was: Baronesse, Camelot, Colter, Crest, Harrington and Steptoe. Each county's group of participants had the option of seeding additional varieties of their choice. Great Western Malting Company provided seed to growers choosing to plant several malting varieties: B1215, Chinook, Stander, Tyne and Triumph; and the feed variety Colter. The number of strips at each test location varied from six to 15. The growers established their on-farm test so that the variety drill strips crossed perpendicular to the natural variability (soils and terrain) of the field. This practice assured that each variety strip had an equal opportunity to respond to the field conditions present, without favor, or penalty of one variety over another. Growers were careful about locating the test area so that it was not: 1) bordering a weedy fence line; 2) In or near a bottom land area; and 3) on the contour of a significant slope.

Typically the planted drill strip width was wider than the combine header width. The preferred length of the variety strips varied from 600 to more than 2500 feet. Growers harvested the variety test strips using their own combine. The actual grain yield of each strip was measured using a weigh wagon, or portable scale. The weights were then converted to a per acre yield basis by careful measurement of the length and width to determine the actual harvested area of each variety strip. A grain sample was collected during harvest from each variety and was delivered to Pullman for processing at the WSU seedhouse.

The grain yield, test weight and grain protein from the 1995 samples is summarized in Tables 3, 5, and 7 and for the past six years in Tables 4, 6, and 8. The statewide averages for straw (residue) production, grains yield, test weight and residue to grain ratio results for years 1994 and 1995 are shown on Table 9.

The residue sample project was continued for a second year this season to document the residue to grain production differences among varieties. NRCS, CD, and extension personnel, under the leadership of Ron McClellan, collected two adjacent row samples of two meter lengths from five locations within each strip. More than 975 bundle samples were weighed, threshed and the straw and grain yields determined. In addition 59 samples, from eight locations were shared with Don McCool, USDA-ARS Agricultural Engineer, for use in a study to determine the above ground mature barley plant. This study involves partitioning of the stems within each of the bundle samples into head, seed, leaf, and long straw components. The long straw is being evaluated to determine the percent cover relative to the weight of the straw.

Straw samples were taken from another sub-sample set during threshing and Dr. Ann Kennedy, USDA-ARS Microbiologist, will evaluate the decomposition rate of the straw (residue) from the different varieties. Soil samples were extracted at each of the five subsample sites within each standard variety drill strip from seven of the growers test locations (one location per county, Asotin, Columbia, Garfield, Lincoln, Spokane; and two locations in Whitman) for use in this experiment.

Growers wishing to express their views regarding this program are encouraged to discuss them with members of the Washington Barley Commission. Growers are also encouraged to discuss this program with the county coordinators, extension staff and Baird Miller, Extension Agronomist. Mary Palmer-Sullivan may be contacted at the Washington Barley Commission Office (509 456-4400).

Table 1. 1995 Spring Barley On-Farm Variety Testing Participants.

Grower Cooperators:

Adams: Curtis Hennings
Asotin: Frank Johnson, Carroll Johnson, Pat Wolf
Columbia: Jay Penner, Broughton Land Co. (George Wood), E. C. "Turk" Ely, Randy James
Garfield: David Ruark, Scott Seed Farm, Gary Houser
Kittitas: Pat Clerf
Lincoln: Tom Schultz, Dale Dietrich, Clifford Carstens
Spokane: Gerald Scheele, David Simpson, Gary Belsby
Whitman: Mike and Jerry Stubbs, Gerald Mitchel, Dennis and Brad Pittmann, Dave St. John

Statewide Organization:

Mary Palmer-Sullivan, Washington Barley Commission
Baird Miller, Agronomist, Washington State University
Steve Ullrich, Barley Breeder, Washington State University
Ron McClellan, Agronomist, Washington State University
Chuck Goemmer, Washington State Crop Improvement
Keith Bailey and Kevin Anderson, Great Western Malting Company

Contributors of Certified Seed:

Baronesse: Keith Becker, Whitman County Grain Growers, Inc.
Camelot: Curtis Hennings/Andy Thostenson, Spectrum Crop Development Corp.
Crest: Dean Browning, Cenex Supply & Marketing, Inc.
Harrington: Jackie Tee, Fairfield Grain Growers, Inc.
Steptoe: Dan Curtis, Rosalia Producers, Inc.
Colter/Malt Varieties: Keith Bailey and Kevin Anderson, Great Western Malting Company

Storage and Distribution of Seed to County Coordinators:

Vern Retlinger and Gary Reilly, Ritzville Warehouse Company

Transportation and Distribution:

Greg Vollmer and John Kuehner, WSCIA Foundation Seed Service

County Coordinators:

Adams:	Bill Schillinger	**Lincoln:**	Tom Schultz
Asotin:	Frank Johnson Jim Schroeder	**Spokane/Stevens:**	Paul Peterson Gerald Scheele
Columbia:	Roland Schirman		
Garfield:	Dave Bragg David Ruark	**Whitman:**	John Burns Mark Johnson Dan Curtis
Kittitas:	Tom Hoffman		

Residue sample collection:

Ron McClellan and Roland Schirman, WSU; Charles J. Shawley, Carol Wildman, Paul Ruark, John Kendig, Deborah Penner-Fortner, Sharon Bromiley, Ed Teel, June Johnson, Maryann Sharp, Ron Cooke, Rich Riehle, Ann Swannack, Carl Vennes, David Welk, Steve Sprecher, David Lundgren, Jim Schroeder, Natural Resources Conservation Service; Angela Fields and Brian Sangster, Asotin Conservation District; Jon Jones, Whitman Conservation District.

Residue Partitioning: Don McCool, ARS **Residue Decomposition Rate:** Ann Kennedy, ARS

Soil Testing: Larry Morrow, NuChem **Statistical Analysis and Sample Analysis:** Pat Reisenauer, WSU

Table 2. Summary of Spring Barley On-Farm Variety Testing

Year	Number of single strip samples harvested	Different varieties in test	Final Number of grower/cooperators harvesting strips	Counties
1990	136	5	33	Adams, Franklin, Garfield, Klickitat, Lincoln, Spokane, Walla Walla, Whitman,
1991	241	11	35	Adams, Columbia, Franklin, Garfield, Klickitat, Spokane, Lincoln, Walla Walla, Whitman
992	181	16	25	Adams, Columbia, Franklin, Garfield, Kittitas, Klickitat, Spokane, Lincoln, Whitman
1993	229	22	27	Adams, Asotin, Columbia, Garfield, Kittitas, Klickitat, Spokane, Lincoln, Whitman
1994	197	14	23	Adams, Asotin, Columbia, Garfield, Kittitas, Klickitat, Spokane, Lincoln, Whitman, Stevens
1995	193	20	22	Adams, Asotin, Columbia, Garfield, Kittitas, Spokane, Lincoln, Whitman
Subsamples collected and processed for residue and grain yield.				
1994	1162	14	23	Adams, Asotin, Columbia, Garfield, Kittitas, Klickitat, Spokane, Lincoln, Whitman, Stevens
1995	966	20	22	Adams, Asotin, Columbia, Garfield, Kittitas, Spokane, Lincoln, Whitman

Table 3. 1995 spring barley on-farm variety testing yield performance summarized among production zones.

	Production Zone (lbs/acre)			
Variety	<3000	3000-4000	>4000	Average
	Yield (lbs/acre)			
Baronesse	2679	3750a	4688a	3516a
Camelot	2500	3547b	4227bc	3259bc
Colter	2644	3519b	4453ab	3370b
Crest	2580	3289c	4097c	3181c
Harrington	2569	3413bc	4255bc	3254bc
Steptoe	2725	3569b	4236bc	3367b
Average	2616	3515	4326	3324
LSD(10%)	NS	176	258	138
CV	10.7%	4.6%	4.8%	7.1%
# Locations	7	5	4	16

locations = number of locations included in the analysis

Table 4. Yield Summary for the Spring Barley On-Farm Variety Testing Program.

Variety	1995	1994-95	1993-95	1992-95	1991-95	1990-95
	Yield (lbs/acre)					
			.	.	.	.
Baronesse	3516	2609	.	.	.	.
Camelot	3259	2438	2929	2712	2822	2774
Colter	3370	.	.	.	.	.
Crest	3181	2349	2722	2560	2681	.
Harrington	3254	2349	2867	2647	2738	2695
Steptoe	3367	2513	2927	2764	2893	2873
Average	3324	2448	2861	2671	2784	2781
# Locations	16	41	66	92	132	166

locations = number of locations included in the analysis

Table 5. 1995 spring barley on-farm variety testing weight performance summarized among production zones.

	Production Zone (lbs/acre)			
Variety	<3000	3000-4000	>4000	Average
	Test weight (lbs/bu)			
Baronesse	48.2ab	51.9b	50.1b	49.8b
Camelot	49.2a	52.6a	51.2a	50.8a
Colter	46.5c	49.4c	47.7c	47.7c
Crest	49.5a	52.5a	50.5ab	50.7a
Harrington *	47.9b	51.7b	50.2b	49.8b
Steptoe	45.6c	48.7d	45.8d	46.6d
Average	47.8	51.1	49.2	49.2
LSD(10%)	1.3	0.6	0.8	0.6
CV	2.9%	1.1%	1.3%	2.1%
# Locations	7	5	4	16

* - # of locations is one less than shown

Table 6. Test Weight Summary for the Spring Barley On-Farm Variety Testing Program.

Variety	1995	1994-95	1993-95	1992-95	1991-95	1990-95
	Test weight (lbs/bu)					
			.	.	.	.
Baronesse	49.8	47.9	.	.	.	.
Camelot	50.8	48.9	50.3	49.9	50.8*	50.4*
Colter	47.7	.	.	.	.	.
Crest	50.7	48.4	49.4	49.0	50.2	.
Harrington *	49.8*	46.9*	48.5*	48.2*	49.3*	48.8*
Steptoe	46.6	43.8	44.8	44.5	45.9	45.6
Average	49.2	47.2	48.3	47.9	49.1	48.3
# Locations	16	40	65	91	131	165

* - # of observations is one less than shown

Table 7. 1995 spring barley on-farm variety testing protein performance summarized among production zones.

	Production Zone (lbs/acre)			
Variety	<3000	3000-4000	>4000	Average
	Grain protein (%)			
Baronesse	11.5bc	10.7b	10.6b	11.0bc
Camelot	12.3a	11.6a	10.9ab	11.7a
Colter	10.6d	10.1c	9.8c	10.2d
Crest	12.0ab	10.6bc	10.7b	11.2b
Harrington *	12.0ab	11.3a	11.4a	11.6a
Steptoe	11.1cd	10.5bc	10.6b	10.8c
Average	11.5	10.8	10.6	11.1
LSD(10%)	0.8	0.4	0.5	0.4
CV	7.0%	3.7%	4.1%	5.6%
# Locations	7	5	4	16

* - # of locations is one less than shown

Table 8. Protein Percent Summary for the Spring Barley On-Farm Variety Testing Program.

Variety	1995	1994-95	1993-95	1992-95
	Grain protein (%)			
			.	.
Baronesse	11.0	12.9*	.	.
Camelot	11.7	13.6	12.6	12.8*
Colter	10.2	.	.	.
Crest	11.2	13.0	12.2	12.5*
Harrington *	11.6*	13.6*	12.4*	12.6*
Steptoe	10.8*	11.9	10.9	11.1
Average	11.1	13	12.0	12.3
# Locations	16	40	64	88

* - # of observations is one less than shown

Table 9. 1994 and 1995 Washington State barley variety on-farm testing residue sampling summary.

1994 & 1995 Washington State Spring Barley Variety On-Farm Testing Results** (2/10/96)

Variety	Large Plot					Subsample							
	Grain Yield	Test Weight	Protein	Plump	Thin	Grain Yield	Spikes	000 Kernel Weight	Seeds	Seeds	Straw Yield	Harvest Index	Residue: Grain
	lbs/acre	lbs/bu	%	%	%	lbs/acre	per ft2	g	per spike	per lb	lbs/acre	ratio	ratio
Baronesse	2636	47.9	12.9	57.5	17.2	3248	49.0	34.2	19.8	13813	4016	0.43	1.37
Camelot	2464	48.9	13.6	60.4	16.1	2918	40.7	34.3	21.5	13715	3776	0.43	1.40
Crest	2375	48.4	13.0	60.7	17.3	2855	42.5	33.8	20.3	14043	3856	0.42	1.45
Harrington	2350	47.0	13.6	57.7	17.8	2855	44.2	32.9	20.5	14297	3925	0.41	1.52
Steptoe	2541	43.9	11.8	64.9	13.5	3218	26.4	36.5	34.6	12960	3386	0.48	1.13
Average	2473	47.2	13.0	60.2	16.4	3019	40.6	34.4	23.3	13765	3792	0.44	1.37
LSD (.10)	76	0.4	0.3	2.7	1.8	120	2.1	0.6	1.0	280	138	0.01	0.07
CV (%)	8.3	2.2	5.6	12.1	28.8	10.7	14.0	4.9	11.9	5.5	9.8	4.7	13.1
Number	200	200	200	200	200	200	200	200	200	200	200	200	200

** Based on the common dataset from the residue samples

1994 Washington State Spring Barley Variety On-Farm Testing Results** (2/10/96)

Variety	Large Plot					Subsample							
	Grain Yield	Test Weight	Protein	Plump	Thin	Grain Yield	Spikes	000 Kernel Weight	Seeds	Seeds	Straw Yield	Harvest Index	Residue: Grain
	lbs/acre	lbs/bu	%	%	%	lbs/acre	per ft2	g	per spike	per lb	lbs/acre	ratio	ratio
Baronesse	2049	46.5	14.3	36.6	28.7	2523	44.1	31.5	44.1	14934	3675	0.40	1.57
Camelot	1934	47.6	14.9	40.8	26.5	2297	37.0	31.4	37.0	14893	3473	0.40	1.59
Crest	1838	46.9	14.3	41.7	28.4	2280	37.5	31.0	37.5	15301	3481	0.39	1.61
Harrington	1748	45.2	14.9	38.5	28.4	2226	39.5	30.0	39.5	15603	3587	0.38	1.74
Steptoe	1990	42.0	12.6	47.3	22.0	2617	24.0	33.1	24.0	14226	3231	0.45	1.30
Average	1912	45.6	14.2	41.0	26.8	2389	36.4	31.4	22.7	14991	3489	0.40	1.56
LSD (.10)	88	0.6	0.4	4.2	3.0	130	2.5	0.7	1.3	397	151	0.01	0.11
CV (%)	9.6	2.5	5.7	21.1	22.6	11.3	14.1	4.9	11.5	5.5	9.0	5.4	14.2
Number	120	120	120	120	120	120	120	120	120	120	120	120	120

** Based on the common dataset from the residue samples

1995 Washington State Spring Barley Variety On-Farm Testing Results** (2/10/96)

Variety	Large Plot					Subsample							
	Grain Yield	Test Weight	Protein	Plump	Thin	Grain Yield	Spikes	000 Kernel Weight	Seeds	Seeds	Straw Yield	Harvest Index	Residue: Grain
	lbs/acre	lbs/bu	%	%	%	lbs/acre	per ft2	g	per spike	per lb	lbs/acre	ratio	ratio
Baronesse	3516	49.8	11.0	86.3	1.3	4337	56.5	38.2	21.0	12133	4528	0.49	1.06
Camelot	3259	50.8	11.7	88.5	1.0	3849	46.2	38.6	22.6	11946	4229	0.48	1.11
Colter	3370	47.7	10.2	83.4	2.1	4056	33.4	35.6	35.8	12898	3697	0.52	0.93
Crest	3181	50.7	11.2	88.0	1.4	3717	50.0	38.1	20.3	12155	4419	0.46	1.20
Harrington	3254	49.8	11.6	87.0	1.4	3799	51.3	37.4	22.0	12339	4432	0.46	1.18
Steptoe	3367	46.6	10.8	90.1	1.4	4119	30.0	41.7	35.2	11060	3617	0.53	0.89
Average	3324	49.2	11.1	87.2	1.4	3979	44.6	38.3	26.2	12089	4154	0.49	1.06
LSD (.10)	138	0.6	0.4	3.0	0.6	234	3.5	1.1	1.8	374	250	0.01	0.05
CV (%)	7.1	2.1	5.6	5.9	66.3	10.0	13.5	5.0	11.3	5.3	10.2	3.8	7.4
Number	96	96	96	96	96	96	96	96	96	96	96	96	96

** Based on the common dataset from the residue samples

BREEDING DIMENSIONS OF PALOUSE GRAIN LEGUME CROPS

F. J. Muehlbauer, W. J. Kaiser, J. L. Coker and R. W. Short

The USDA-ARS Grain Legume Breeding Program is developing varieties of dry pea, lentil, chickpea and Austrian winter pea that are high yielding, disease resistant and market acceptable. The breeding efforts directed at each of these crops are described below.

Dry Peas

Dry peas are attacked by a number of diseases including root rots, wilts, viruses and powdery mildew, some of which can be epidemic. Principal quality factors for green dry peas are good color retention and resistance to seed bleaching. Besides color quality, progress is being made in developing dry pea lines with multiple disease resistance, particularly to root rot, wilt, powdery mildew and viruses.

An improved yellow pea variety is needed to replace Umatilla because of the problems that have developed with seedcoat cracking. Selections of yellow peas with good seed size and color and with resistance to diseases, including powdery mildew, Fusarium wilt and viruses are being tested. During the recent market assessment visit to the Orient sponsored by the USA Dry Pea and Lentil Council, it was determined that there is an increasing demand for large seeded yellow peas for making extruded snack items. Also, there appears to be a growing demand for marrowfat varieties of dry peas. The marrowfat type is typified by large green flattened seeds that weigh at or above 30 grams per 100 seeds compared ti about 20 grams for Columbian. Marrowfats are used extensively in the orient to make popular snack items. Marrowfats are also used widely for canning and for sprouting. The potential in Indonesia for marrowfats could greatly expand with the increasing population and the growing demand for snack items. As a result of these findings, we have placed high priority on development of marrowfat type varieties adapted to the Palouse region.

A brief summary of work underway on the various types of dry peas is as follows:

<u>Green Peas:</u>
In evaluation trials, PS110028 has had high yields and excellent seed quality traits when compared to the checks. PS110028 has resistance to powdery mildew and Fusarium wilt race 1. PS110028 is large seeded (100 seeds weigh 23.6 g compared to 19.7 g for Columbian) and is fast cooking with good color. It is anticipated that PS110028 will be proposed for release next fall.

Selections in preliminary trials are being evaluated for yield, seed quality, resistance to powdery mildew and Fusarium wilt race 1. All advanced selections are also being evaluated for resistance to Pea Enation Mosaic Virus at Corvallis, Oregon and for Bean Leaf Roll Virus resistance at Kimberly, Idaho. Evaluations for resistance to root rot are underway at Prosser, Washington.

<u>Yellow Peas:</u>
In evaluation trials, PS210387 was significancy higher yielding over three locations when compared to the checks in 1995. PS210387 has a semi-leafless semi-dwarf plant habit that

proved to be very resistant to lodging. The selection is resistant to powdery mildew and Fusarium wilt race 1. PS210387 has large seeds with a 100 seed weight of 25.8 g compared to 22.8 for Umatilla. PS210387 is fast cooking and has excellent color when compared to the checks.

Marrowfat Peas:

Marrowfat parental lines were used in crosses to adapted material to develop selections specifically adapted to Palouse conditions. The two selections, PS310148 and PS310150, were significantly higher yielding in 1995 when compared to the two checks; however, seed size, shape and color was poor. Two other selections, PS210332 and PS210333, had acceptable seed size and shape but had lower yields when compared to the checks. Early generation breeding materials for development of a marrowfat variety were advanced in the field and greenhouse in 1995/96, and are being further advanced in the field this season.

Possible Variety Releases:

Line PS110028 is a candidate for release of an improved green dry pea with multiple disease resistance, excellent seed quality, dark green color and significantly higher yields. Line PS210387 is a candidate for release of an improved yellow dry pea with multiple disease resistance, excellent seed quality, semi-leafless, semi-dwarf plant habit, large yellow seeds and significantly higher yields. Line PS010603 may be suitable as an immediate replacement for Umatilla. Line PS010603 has multiple disease resistance, good seed quality, normal pod type and comparable yields to Umatilla. All three selections are being increased.

Lentils

The lentil industry needs varieties that produce acceptable quality for various international and domestic markets. Until very recently, the Palouse region produced only one type of lentil, the so-called Chilean type ('Brewer') with large yellow cotyledons. However, several other types can be produced and are in demand in various markets both domestically and world-wide. The industry needs an exceptionally large yellow seeded lentil with uniformly green seedcoats to compete with the Laird lentil from Canada. In addition to a large yellow lentil variety, the industry would benefit from a small typically Turkish red type of lentil. A brief summary of the work on lentil variety development is as follows:

Large Yellow Lentils:

LC960254 is promising because it has consistently out yielded Brewer and Palouse over the past four seasons. LC960254 has clear non-mottled seed coats, a rounded seed edge to avoid damage during processing and excellent seed quality. LC960254 has 100 seed weight of 7.2 g compared to 5.8 g for Brewer and 7.4 for Palouse. Cooking times of LC960254 compare favorably to Brewer and Palouse. LC960254 is currently being increased to produce pre-breeder seed.

Selections in preliminary trials are being evaluated for tall upright plant habit, tolerance to viruses, biomass production, large uniform seed size with little or no mottling and blunt seed edges.

Turkish Red Lentils:

Turkish red types have been used in crosses with germplasm adapted to the Palouse region. The progenies have been selected for Turkish red quality traits and are currently being evaluated in the field.

Variety Release:
LC960254 will be released as soon as sufficient quantities of seed are available. LC960254 is an improved large yellow lentil with excellent yield potential, seed quality and an upright and bushy growth habit. LC960254 is being considered as a replacement for Palouse.

Chickpeas (Garbanzo Beans)

Ascochyta blight is a devastating disease of chickpea in the Palouse area and has caused serious problems with production. Recent success in the development of blight resistant varieties such as 'Sanford' and 'Dwelley' have made it possible for producers to grow the crop with some assurance that the disease will not be devastating. These two varieties are the only large seeded kabuli types with resistance to blight that are available for production. Recent market information indicates that there is an increasing demand for the so-called 'Spanish White' type which is characterized by exceptionally large white seeds. We have initiated a program to incorporate Ascochyta blight resistance into the Spanish White type. In addition to the work on the Spanish White type, there is a need to improve on the resistance to blight in Sanford and Dwelley. Those varieties need to have better resistance to the pod infection phase of the disease. Germplasm was identified in 1993, in the blight nursery, as having good resistance to pod infection. Resistance to pod infection in the regular cream colored varieties and a blight resistant Spanish White variety are needed for future long-term control of the disease.

Advanced generation Spanish White types with good seed quality traits have been selected and are being screened in the blight nursery. Additional crosses designed to transfer Ascochyta blight resistance to large seeded Spanish White types were made in the greenhouse and field in 1994 and 1995. The hybrids have been increased and selected for size, shape and color of the seeds. The resulting F_3 and F_4 lines are currently being evaluated in the Ascochyta blight nursery.

Besides the work on resistance to blight, we have begun to identify earlier flowering and maturing germplasm lines which have now been crossed to our blight resistant material. The delayed maturity of available chickpea varieties is due to late flowering and a high degree of abortion of the first flowers. This appears to be related to cold temperature sensitivity and that pod setting begins only when mean daily temperatures rise above a critical low temperature point. However, pod setting ceases when mean daily temperatures rise above a critical high temperature point. Because of these observations, we are now attempting to widen this temperature range so that podding can begin at lower temperatures and continue at higher temperatures. The widening of the temperature range for podding should increase yields and also advance maturity.

An earlier flowering and maturing blight resistant chickpea has been selected. CA188163 is about 7 days earlier to flower and also sets pods and matures earlier when compared to Sanford and Dwelley. CA188163 is equal to Sanford and Dwelley for resistance to blight and also for yield. Seed size is similar to Dwelley and color is very good. This particular selection could be a replacement for Sanford which seems to be borderline for seed size.

The Ascochyta blight nursery continues to be excellent for screening for resistance. Nearly 1000 lines from the breeding program and other sources are screened each year. Inoculation is by infected chickpea debris from the previous crop season and sprinkler irrigation to ensure good spread of the disease and to promote the pod infection phase.

Variety Release:
CA188163 is in the process of being released as a replacement for Sanford. CA188163 was increased at Yuma, this past winter to about 1500 pounds of seed. This new variety is currently being increased at the Plant Science Farm at the University of Idaho.

Austrian Winter Peas

Austrian winter peas are an alternative legume crop on the Camas Prairie of northern Idaho and to a limited extent in southeastern Washington and eastern Oregon. The crop is important in these areas as an alternative to cereals and it fits well into the rotation. Fall planting is important because wet soil conditions often make planting difficult in the spring. In the past, Austrian winter peas have been exported to the Orient where they are used as a filler in the production of An-paste, a confection made mostly from usually very expensive Azuki beans. Other uses include green manure crop in the southeastern U.S., inexpensive split yellow peas, and bird seed. Production of the crop has declined over the past 10 years due to a serious problem with Aphanomyces root rot and infestations of Ascochyta blight and Sclerotinia white mold. These foliar disease problems appear to be solvable through the use of plant types that keep the canopy upright during most of the growing season increasing air movement and thereby reducing the humidity in the lower canopy. The root disease problem is somewhat more difficult. However, we have established root disease screening nurseries to identify genetic material with tolerance. Multiple disease resistant varieties are needed if this crop is to continue as an integral part of the cropping system used on the Camas prairie. The most urgent need is to develop varieties with resistance to these diseases and with sufficient winter hardiness to be grown over a wide area.

Granger, the recently released Austrian Winter pea variety, was significantly higher yielding when compared to Melrose, Fenn, and Common and had a nearly 900kg/ha (800lbs/acre) yield advantage in 1995. Granger is a semi-leafless type that is taller than Melrose, Fenn or Glacier. Even though Granger is tall, the increased tendril number brought about by the semi-leafless trait provides good resistance to lodging along with increased air movement through the canopy and should provide an escape mechanism from Ascochyta blight and Sclerotinia white mold.

About 30 new crosses were made in 1995 to add powdery mildew resistance, Aphanomyces resistance and virus resistance to Austrian winter pea types. These crosses have been increased in the greenhouse and are being increased in the field in 1996. To improve the vine strength and standing ability of Austrian winter peas, we have used 'Bohatyr' in the crossing program. Bohatyr, for Czechoslovakia, has exceptionally strong and woody stems that improve standing ability. The woody stem trait if combined with the semi-leafless trait should greatly improve standing ability and help avoid foliar diseases such as Sclerotinia white mold and Ascochyta blight while improving yields and crop quality. In addition, we have utilized sources of virus resistance in the crossing program in order to incorporate resistance to Pea Enation Mosaic Virus and Bean Leaf Roll Virus.

RETURNING CRP TO CROP PRODUCTION
A Preliminary Management Resource Guide and Review of Research in 1996

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A Washington State University research project was initiated in 1994 to evaluate management strategies for returning Conservation Reserve Program (CRP) land to crop production. A preliminary research summary was published in March 1996 as WSU Cooperative Extension Crop and Soil Sciences Dept. Technical Report 96-2. It provides an in depth description of the field trials and results available to that time. The trials will be completed in 1996 and results published in early fall.

The project goal is to identify management strategies that optimize agronomic performance and profitability of the first crops following CRP take-out, while providing effective soil erosion control, and preservation of soil improvements gained during CRP. There are two primary research thrusts in this statewide project: 1) evaluate management strategies for returning CRP land to winter wheat production following a summer fallow period; and 2) evaluate management strategies for returning CRP land to spring crop production. Additional research efforts focus on fertility management in CRP take-out, herbicide application rates and timings for killing CRP grass, changes in soil quality under different take-out systems, and economics of management options.

Planning and management of the trials with field scale equipment directly involve 13 grower cooperators, as well as more than 20 other scientists and Ag support personnel in the region. This research project is funded in part by two grant programs from the USDA Cooperative States Research, Education and Extension Service (CSREES): STEEP II (Solutions To Environmental and Economic Problems) and the Columbia Plateau Wind Erosion/Air Quality Project.

CRP Background

The Pacific Northwest has more than 2.5 million acres of cropland in CRP. In Washington State there is over 1.045 million acres. This represents nearly 14% of the 7.6 million acres in a 20 county area of eastern Washington. More than 70% of the CRP acres under contract are scheduled to expire by the fall of 1997. In addition, growers now have an early release option on CRP contracts underway for at least 5 years, allowing them to participate in the 7-year Farm Bill payment program on crop base acreage in the CRP contract.

A majority of the CRP land in Washington and the Northwest is in the low rainfall, winter wheat-summer fallow regions. These regions typically receives from 7 to 14 inches annual precipitation and are commonly vulnerable to wind erosion. Crested wheatgrass is the predominant CRP grass. Serious soil erosion problems could result if intensive tillage and residue removal practices are used in returning CRP land to crop production. Prior to this project, only limited research has been conducted on converting perennial grass cover to crop production in these dryland regions. Conservation tillage technologies have also changed dramatically over the last 20 years. A research knowledge base is needed to evaluate the profitability of different management strategies for returning CRP land to crop production, and their effectiveness of erosion control and preserving soil benefits gained during CRP.

Overview of Field Trials Established in 1994 and 1995

Seven large-scale on-farm trials for evaluating CRP take-out were established in 1994 and 1995, but only three with spring crops have been harvested. Most trials include 4-5 tillage and residue management systems or "treatments" that result in a range in surface residue and roughness levels.

This field research project uses large, replicated experiments with farm-scale equipment operated by growers. This approach increases grower confidence in the research results and facilitates rapid grower adaptation of research results. Treatment area for each plot is generally 30 to 50 feet wide and 800 to 1,000 feet long, depending on the implements used and field size. Each treatment is replicated four times. Trials are generally 15 to 35 acres in size.

In cooperation with other university and industry researchers, satellite experiments are also being conducted to evaluate alternative spring crop choices, fertilizer application options, nonselective herbicide rates and timings and other management questions.

Three trials in Franklin, Adams and Lincoln Counties are evaluating different tillage and residue management systems of fall and spring take-out with summer fallow and soft white winter wheat to be harvested in 1996. A 1995 spring take-out trial in Garfield County is evaluating four management systems with soft white winter wheat after summer fallow. It also includes soft white spring wheat under two spring take-out systems in 1996.

Spring take-out trials with soft white spring wheat were completed in Columbia County in 1994 and 1995. A small plot satellite study to compare soft white spring wheat, hard red spring wheat, spring barley and spring oats under high and low residue systems was also conducted near the large trial in 1995. The second crop on both large trials will be harvested in 1996; winter wheat after summer fallow on the 1994 site and recrop spring wheat on the 1995 site. A direct seeding trial with spring barley compared two preplant application rates of Roundup in Columbia County in 1995.

Overview of New CRP Take-out Trials in 1996

Four new trials on spring CRP take-out with spring cereals were established in 1996 in Adams, Lincoln and Douglas Counties. The following are brief descriptions of the research trials:

Direct Seeding Strategies for Hard Red Spring Wheat - Adams County:
The trial is located on the Wellsandt Road 2.5 miles east of Ritzville on the Dale and Gary Galbreath farm in a 10- to 12-inch annual rainfall zone. The field has been in crested wheatgrass

for 9 years. Several direct seeding systems with a Yielder drill are being compared with a "reduced" tillage system and seeding with a John Deere double disc drill. All treatments were sprayed with 3 pints/acre of Roundup RT. Five tillage and residue management treatments are included in the trial: 1) direct seed in undisturbed grass; 2) direct seed with a fertilizer/starch blend in undisturbed grass; 3) spring flail - direct seed; 4) spring burn - direct seed; and 5) a minimum tillage take-out system consisting of one discing, fertilizer injection, coil-packing and seeding with convention IH double disc drills.

Drill Comparison for Direct Seeding Hard Red Spring Wheat In CRP and Recrop Spring Wheat - Douglas County:
This trial is being conducted in collaboration with the June 18, 1996 "Fields of Tomorrow" program sponsored by Monsanto in cooperation with WSU, UI and a number of area grower groups, and Ag support agencies and industries. The trial is located east of Waterville (2 miles west of Farmer) on the Tony Viebrock farm in an 11-inch annual rainfall zone. The field is in its 9th year of crested wheatgrass. The grass residue was cut and chopped with a combine in fall 1995. Hard red spring wheat was planted with a number of direct seeding drills and air seeders, and under a conventional tillage system. Direct seeding implements include: Concord airseeder; Flexicoil 5000 and 1330 airseeders; John Deere 750 disc drill; and John Deere HZ deep furrow drill. The conventional tillage operations included a discing, conventional fertilizer injection, second discing, and seeding with the John Deere HZ drill. The trial is repeated in undisturbed CRP grass and in spring wheat stubble.

Drill Comparison for Direct Seeding Hard Red Spring Wheat - Adams County:
This trial is being conducted in collaboration with the June 20, 1996 "Fields of Tomorrow" program sponsored by Monsanto in cooperation with WSU, UI and a number of area grower groups, and Ag support agencies and industries. The trial is located west of Ritzville (Rosenoff and Dewald Roads) on the Ron Jirava farm in a 10- to 12-inch annual rainfall zone. The field is in its 10th year of crested wheatgrass. Hard red spring wheat will be planted with a number of direct seeding drills and air seeders, and under a minimum tillage system. Direct seeding implements tentatively include: Concord airseeder; Flexicoil 5000 and 1330 airseeders; John Deere 750 drill; John Deere 9400 hoe drill on 15" spacing; John Deere 9400 drill hoe drill on 9" spacing with deep fertilizer banding; John Deere HZ deep furrow drill with deep fertilizer banding. The minimum tillage system included one pass with a sweep and attached single gang of skewtreaders, conventional fertilizer injector, coil-packer and seeding with a John Deere double disc drill.

Tall Wheatgrass Tillage and Residue Management Options for Spring Barley - Lincoln County:
The trial is north of Sprague on the Andy and John Rustemeyer farm in a 13-inch annual rainfall zone. The field is in its 10th year of CRP and is predominantly tall wheatgrass. Four different tillage and residue management combinations are compared. Prior to the initial field operations, Roundup RT was applied at 0, 16, 24 and 32 oz/acre in a split plot experiment across all the main tillage plots. Primary treatments included: 1) flail-2X sweep/tine harrow; 2) 2X disc-cultivate/tine harrow; 3) burn-2X sweep/tine harrow and 4) light disc-burn-2X sweep/tine harrow. After the above primary tillage and residue management treatments have been

established, the trial was managed as one field with a conventional fertilizer injector, cultivator/tine harrow and seeding with conventional IH hoe drills on 9" spacings.

Cooperative Research Efforts

Nitrogen Fertility Management in CRP Take-out:
Nitrogen fertilizer rate trials were established across the main plots of large-scale trials with winter wheat after summer fallow in Franklin and Adams Counties. Application were made in June of 1995 in the fallow year. A similar study was established in the Lincoln County spring take-out trial with spring barley. Four nitrogen rates and a non-fertilized check are being compared at each of the sites.

Economic Analyses of the CRP Take-out Systems in the Large-Scale Trials:
Doug Young, WSU agricultural economist, and Kate Painter, WSU economics research associate, are conducting the economic analyses of the CRP take-out systems for this project. The economic comparisons are underway and will be completed after harvest of the trials in 1996.

Soil Quality Changes with Different CRP Take-out Systems:
Ann Kennedy, ARS soil microbiologist in Pullman, is cooperating in the evaluation of soil quality changes as the CRP land is returned to crop production under different tillage and residue management systems. Soil samples will continue to be collected and analyzed for several years after CRP take-out to document longer term impacts of management practices.

Additional Report Copies and More Information on CRP Take-out

Additional copies of the preliminary research report on CRP take-out (WSU Technical Rpt. 96-2) are available at Washington State county offices of WSU Cooperative Extension, Conservation Districts, USDA-Natural Resources Conservation Service and USDA-Farm Service Agency. Copies can also be requested from the WSU Crop and Soil Sciences Dept. office at 509-335-2915.

For more information on the WSU CRP take-out research project contact the project leaders:

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ECONOMICS OF CRP TAKE-OUT: EXPERIMENTAL PLOT RESULTS

Kathleen Painter

This report presents economic results for experimental trials conducted at sites in four eastern Washington counties to determine best management practices for returning Conservation Reserve Program (CRP) land to production. The goal of these on-farm trials was to identify management strategies that optimize agronomic and economic performance while providing effective erosion control. Criteria used to measure performance for each system included soil water storage efficiency; seed zone soil water content in fallow systems; crop establishment and development; soil erosion potential based on surface residue, roughness, and soil aggregation; pest incidence; crop yield and quality; and economic performance. Data collected at each site included grass biomass, soil water content in the spring and fall, soil fertility, surface residue and roughness, pest incidence, plant stands, and crop yield.

Complete crop enterprise budgets were developed for each trial and site using customized representative farm data. For example, different machinery complements are used for each site based on information provided by interviews with farmers and Cooperative Extension personnel. This information will be published in an Extension Bulletin at a later date.

At the Columbia County site near Starbuck, different spring tillage treatments for removing sod prior to planting spring wheat were compared (Table 1). Yields for spring wheat following spring CRP takeout in 1995 were more than double the yields achieved in the 1994 trials due to weather variance. The average yields over 1994-1995 are more typical of this region. Using a wheat

Table 1. Estimated annual costs of production, revenue, and net returns for spring wheat following CRP takeout, by tillage treatment for removing CRP sod, Starbuck, Columbia County site

Spring Tillage Treatment For Removing CRP Sod[1]	Variable Cost ($/acre)	Total Cost[2] ($/acre)	1994-95 Average Yield (bu/acre)	Est. Revenue[3] ($/acre)	Returns Over Var. Costs ($/acre)	Returns Over Tot. Costs ($/acre)	Land Cost[4] ($/acre)
Burn, sweep	88.54	114.38	29.74	148.70	60.16	34.32	42.26
Sweep, disc	90.59	119.25	26.16	130.80	40.21	11.55	36.35
Disc, disc	90.90	121.02	26.84	134.20	43.30	13.18	37.47
Plow, disc	93.73	125.30	30.57	152.85	59.12	27.55	43.63

NOTE: Agronomic data supplied by Dept. of Crop and Soil Sciences Technical Reports 95-1 and 96-1, *1994 Pacific Northwest On-Farm Test Results* and *1995 Pacific Northwest On-Farm Test Results.*

[1]Remain tillage operations are the same for each treatment: fertilize, skewtread, and plant.

[2]Total cost does not include land cost. Machinery fixed costs and land taxes are included.

[3]Wheat price estimate $5.00/bu.

[4]Assumes landlord's crop-share rent is calculated as one-third crop revenue less one-third of fertilizer expenses and land taxes.

price of $5 per bushel and the two-year yield averages, returns over variable costs ranged from approximately $40 to $60 over the four spring tillage treatments. The two more traditional treatments, *plow, disc* and *burn, sweep,* had statistically significantly higher yields but left little residue for erosion protection (Veseth et al.). The two less intensive tillage treatments, *disc, disc* and *sweep, disc*, left over three times as much surface residue as the plow and burn treatments. *Burn, sweep* was the least costly of the three treatments with a total cost of $114.38 acre, while *plow, disc* was the most costly with a total cost of $125.30 per acre. Assuming traditional cost-share arrangements for land costs, none of the systems in this trial would have positive net returns to total production costs including land costs, despite the high wheat price.

On-farm trials at the remaining three sites compare management strategies for returning CRP land to a rotation of summer fallow - winter wheat. Different fall and spring tillage treatments were tested at these sites. Winter wheat yield data will not be available to compute net revenue by treatment and site until fall of 1996.

Table 2: Costs of production for summer fallow, Adams County site, north of Lind

Treatment[1]	Var. Cost ($/acre)	Total Costs[2] ($/acre)
Spring sweep, disc[3]	41.79	59.16
Spring disc	44.03	63.31
Fall disc	44.20	63.48
Fall flail, spring sweep[4]	47.46	69.31
Fall 2X harrow, chisel	52.08	72.10

[1]Remaining tillage operations are the same except where indicated. They include spring cultivate, skewtread, rodweed, rotary harrow, fertilize/cultivate, summer fallow, rodweed 3X.

[2]Land costs are not included. Includes machinery fixed costs and land taxes.

[3]No spring cultivate or skewtread operation for this treatment.

[4]No spring cultivate operation for this treatment.

For the Adams County site north of Lind, variable production costs ranged from $42 to $52 per acre while total production costs excluding land costs ranged from $59 to $72 (Table 2). Significant agronomic results for this trial included a reduction in overwinter water storage for the fall tillage treatments, particularly the fall disc treatment. This treatment also had the lowest plant stand of all treatments at 5.4 plants per square foot compared to 6.0 to 6.6 plants per square foot in the other treatments. Surface residue levels were relatively low for all treatments, ranging from 11.5% cover for fall disc to 15% cover for fall flail (Veseth et al.).

At the Franklin County site north of Connell, variable costs of production for summer fallow following CRP take-out ranged from approximately $39 to $46 per acre while total production costs ranged from about $50 to $63. The *spring burn, spring sweep* treatment was least costly while the *fall disc, spring sweep* was most costly. The fall treatments resulted in significantly lower overwinter water storage, particularly the fall disc treatment, as was also observed in the Adams County trial. This treatment also had the lowest plant stand, about half the population of the other trials. In terms of surface cover, the *fall flail, spring sweep* treatment had the highest residue cover at about 9%,

Table 3: Costs of production for summer fallow after CRP takeout, Franklin County site, north of Connell, 1995

Treatment[1]	Variable Cost ($/acre)	Total Cost[2] ($/acre)
Spring burn, spring sweep	39.11	50.13
Fall 2Xharrow, spring disc	40.72	54.46
Spring disc, disc	41.72	57.23
Fall flail, spring sweep	43.55	61.18
Fall disc, spring disc, sweep	46.14	63.01

NOTE: Agronomic data supplied by Dept. of Crop and Soil Sciences Technical Report 96-1, *1995 Pacific Northwest On-Farm Test Results.*

[1]Remaining tillage operations are the same: fertilize, summer fallow, and plant.

[2]Fixed costs include machinery fixed costs and land taxes. Land costs are not included.

Table 4: Costs of production for summer fallow after CRP takeout, Lincoln County site, east of Lamona, 1995

Treatment[1]	Variable Cost	Total Cost[2]
Spring disc & harrow	45.76	58.55
Fall harrow, spring disc & harrow	46.84	59.98
Spring burn, spring sweep & harrow	47.59	58.82
Fall disc & harrow, spring sweep & harrow	50.15	64.31
Spring flail, disc & harrow	52.15	71.56

NOTE: Agronomic data supplied by Dept. of Crop and Soil Sciences Technical Report 96-1, *1995 Pacific Northwest On-Farm Test Results.*

[1]Remaining tillage operations are the same: fertilize, summer fallow, and plant.

[2]Fixed costs include machinery fixed costs and land taxes. Land costs are not included.

while the *spring burn, sweep* was lowest at about 2% (Veseth et al.).

For the Lincoln County site east of Lamona, variable production costs ranged from approximately $46 to $52 per acre while total production costs ranged from about $58 to $72. *Fall harrow, spring disc, harrow* was least costly in terms of variable production costs while *spring flail, disc, harrow* was most costly. Unlike the Adams and Franklin County trials, there was no significant difference in overwinter soil water storage between fall and spring take-out treatments. The spring burn treatment had the lowest residue cover at 14%. The remaining treatments had surface residue cover ranging from approximately 40% to 51%. There was no significant difference in plant stands for the various treatments (Veseth et al.).

REFERENCES:

Veseth, Roger, Baird Miller, Tim Fiez, Tim Walters, and Harry Schafer. *Management Considerations for Returning CRP Land to Crop Production,* Wash. State University Department of Crop and Soil Sciences Technical Report 96-2.

PLANTING OPTIONS FOR LOW RAINFALL WINTER WHEAT PRODUCTION

Edwin Donaldson

The varieties and seeding rate of winter wheat planted in the low rainfall areas are determined by the producer. However, the time of seeding is often determined by the weather or by available seedzone moisture. A study was initiated in the fall of 1994 at Lind to determine the effect of seeding date and seeding rate on grain and straw production. Seeding conditions in the fall of 1994 were very dry and stands from early seeding were hard to obtain. Fall rains did not start till into October.

Four varieties (Moro, Lewjain, Hatton, and Buchanan) three seeding rates (15, 30, and 60 pounds per acre) and three seeding dates (August 15, September 12, and October 10) were used. Each variety was seeded at each rate, each date. Seeding was conducted with a deep furrow plot seeder having hoe openers on 16 in. centers. Seedzone moisture for the first two seedings was poor. Consequently, the seeds were covered with 6 - 7 in. of soil. The last seeding was planted shallow and covered with 1 - 2 in. of soil. A split plot design with four replications was used.

After maturity plant samples were pulled, counted, and cut off at ground level. The number of fertile tillers (heads) was counted. The above ground portion of the plants was weighed. After thrashing, the grain was weighed and test weights were taken. Residue weight is the difference between total sample weight and grain weight. The results of two samples from each plot were averaged before analysis.

RESULTS

Early (August 15) seeding produced the most residue (chaff, leaves, and stems), Table 1. Profuse tillering was able to compensate for reduced stands. Plants seeded on September 12 were not able to tiller sufficiently to compensate for the reduced stands. This is also true for grain yield. Seeding September 12 into poor moisture resulted in stands equal to those of the August 15 seeding and tillering (tillers/plant) no better than the October 10 seeding. The September 12 seeding had slightly larger heads but this was not sufficient to compensate for the lack of tillers. In this trial, the later the seeding the more grain was produced compared to residue.

Seeding rate had no effect on the amount of residue produced (Table 2). The lowest grain yield and highest test weight were obtained by the highest seeding rate (60 lb/a). As expected, tillers/plant and head size decreased with an increased seeding rate. Protein content, also, decreased as the seeding rate increased.

TABLE 1. Influence of seeding date on variety characteristics for four varieties and three seeding rates planted at Lind.

SEEDING DATE	August 15	September 12	October 10
PLANTS/ft row	5.58 A	6.04 A	7.77 B
TILLERS/ft row	40.0 C	26.9 A	32.0 B
TILLERS/PLANT	7.18 B	4.46 A	4.12 A
RESIDUE tons/a	2.82 B	1.66 A	1.73 A
KERNELS/HEAD	32.2 A	33.8 A	37.1 B
GRAIN bu/a	56.8 C	44.2 A	49.0 B
TEST WT lb/bu	62.5 C	62.2 B	62.0 A
PROTEIN %	12.3 A	12.8 B	12.7 AB

values, in the same row, followed by the same letter are not statistically different.

TABLE 2. Influence of seeding rate on plant characteristics averaged over four varieties and three seeding dates planted at Lind.

Seeding Rate (lb/a)	15	30	60
PLANTS/ ft row	4.46 A	6.00 B	8.93 C
TILLERS/ft row	30.6 A	33.1 B	35.3 B
TILLERS/PLANT	6.87 C	5.51 B	3.95 A
RESIDUE tons/a	2.01 A	2.15 A	2.07 A
KERNELS/HEAD	37.4 C	35.2 B	30.6 A
GRAIN bu/a	51.4 B	51.7 B	46.9 A
TEST WT lb/bu	62.1 A	62.3 AB	62.4 B
PROTEIN %	12.9 B	12.6 A	12.4 A

values, in the same row, followed by the same letter are not statistically different.

Of the varieties used, Moro was the exception, having the fewest tillers per unit area and per plant and the largest heads (Table 3). Buchanan had the smallest heads and the most tillering. Stands (plants/yd^2) and grain yield were equal among cultivars. The residue produced by the semidwarf, Lewjain, was equal to that of Buchanan and Hatton.

For the traits measured there was no interaction between variety and seeding rate, i.e. varieties responded similarly to an increase in seeding rate. Increasing seeding rate enhanced the stand and tillers per unit area, reduced the tillers/plant and head size, but exhibited little change in residue yield.

Seeding rate vs. seeding date and seeding rate vs. variety showed no interaction for residue yield. For grain yield, the response to seeding rate is greater for early seeding, August 15, than for later seedings. The trend was for fewer tillers/plant with later seeding, however, Buchanan tillered more from the October 10 seeding than from the September 12 seeding. Grain yield response to seeding date was the least for Hatton and the most for Lewjain. Lewjain exhibited the greatest drop in test weight with late seeding. Moro was the only variety to indicate an increase in test weight with later seeding.

TABLE 3. Characteristics of four winter wheat varieties planted on three dates and three seeding rates at Lind

VARIETY	Buchanan	Lewjain	Hatton	Moro
PLANTS/ft row	6.10 A	6.57 A	6.69 A	6.49 A
TILLERS/ft row	38.0 C	35.2 CB	32.8 B	26.0 A
TILLERS/PLANT	6.23 C	5.36 BC	4.90 AB	4.00 A
RESIDUE tons/a	2.19 B	2.17 B	2.13 B	1.80 A
KERNELS/HEAD	27.0 A	35.2 C	30.8 B	44.5 D
GRAIN bu/a	51.1A	51.7 A	49.9 A	47.2 A
TEST Wt lb/bu	62.4 B	62.1 B	63.4 C	61.1 A
PROTEIN %	12.4 A	12.7 B	13.2 C	12.2 D

values, in the same row, followed by the same letter are not statistically different.

CONCLUSIONS

Based on the results of one very abnormal year:

(1) Variety selection makes a difference in residue yield without effecting grain yield. Lewjain (semidwarf) produced as much residue as Hatton and Buchanan.

(2) Early seeding produced the highest yield, the best test weight, and the lowest protein content.

(3) Early seeding produces more residue. The observation that an October 10 seeding produced as much residue as a September 12 seeding will probably not be true under better seeding conditions.

(4) All varieties responded the same to seeding dates, for residue yield.

(5) All seeding rates respond the same to seeding dates, for residue yield.

(6) A low seeding rate should be used with early seeding. Seeding rate had little effect on later seeding.

LATE FALL SEEDED COVER CROP TRIALS

Mark Stannard, Edward Branchaw
USDA PLANT MATERIALS CENTER

Low residue crops which are harvested late in the fall provide little soil protection during winter and early spring. Fall seeded cover crops can dramatically reduce wind erosion if they develop adequate growth in the fall and early spring to protect the soil. One hundred small grain cultivars were initially screened for cold tolerance in 1994-1995 at Pullman. All the cultivars were selected from northern origins in the hope that they would exhibit cold tolerance. Some of the cultivars came from as far away as Alaska and Finland. Plots were seeded September 15 and October 1, 1994, and emergence and growth were rated through mid-April, 1995. This initial screening enabled us to narrow our focus on types with cover crop potential. A more refined study was established in the fall of 1995

Study Description

Two sites were selected for the 1995-1996 study. The first site was located near George on a Quincy sand soil. The previous crop, potatoes, was harvested a few days prior to planting the cover crop study. The second site was located at the Lind Dryland Experiment Station on a Shano silt loam soil. The previous crop was barley. Sixteen cultivars were seeded at the George site on October 11, 1995 using a Hege 90 plot drill. The same 16 cultivars plus 'Moro' winter wheat were seeded at Lind on October 12, 1995 using the same drill. Each cultivar plot was 6'x 20' and replicated three times at each site. Growth data were collected during the fall and spring.

Cultivars Seeded at George and Lind, WA

'Celia'	Winter Triticale	**'Grey'**	Winter Oats
'Centurk'	Winter Wheat	**'Hoody'**	Winter Barley
'Common'	Austrian Winter Pea	**'Stephens'**	Winter Wheat
'Alpowa'	Spring Wheat	**'Norstar'**	Winter Wheat
'Breaker'	Winter Triticale	**'Nugaines'**	Winter Wheat
'Dusty'	Winter Wheat	**'Penawawa'**	Winter Wheat
'Granger'	Austrian Winter Pea	**'Tyfon'**	Turnip
'Parma'	Winter Triticale	**'Yamhill'**	Winter Wheat
'Moro'	Winter Wheat		

Results

Excellent stands were obtained within two weeks after planting. None of the cultivars developed more than two leaves prior to the onset of winter. Since leaf numbers were minimal going into the winter, stand density, winter-hardiness, leaf length, and rapid spring recovery were critical factors for protecting the soil.

'Stephens' winter wheat was used as our standard for comparisons. Very few cultivars demonstrated significantly better soil protection attributes than 'Stephens'. Its upright, narrow canopy was characteristic of all the winter wheats evaluated in this trial. The upright growth form (stature) protects the soil by keeping the wind energy above the soil surface. However, narrow canopies offer little wind energy reduction when winds are moving parallel to the rows.

Several older winter wheat cultivars were evaluated in this trial. We hypothesized that the older, tall statured winter wheats would produce more leaf material in the fall and early spring. No significant differences in leaf production were noticed in this trial between the older winter wheats and 'Stephens' winter wheat. 'Nugaines' seed failed to emerge and was later found to be totally nonviable.

The two hard red winter wheats, 'Centurk' and 'Norstar', exhibited very thick stands but the plants were noticeably shorter than the white winter wheats. Because of their short stature, these two cultivars do not appear to be good candidates for wind erosion protection during the fall and winter months. Spring growth on 'Centurk' and 'Norstar' was excellent, and they offered excellent early-mid spring cover.

'Tyfon' turnip was seeded quite heavy (80 seeds per foot of row) and a solid stand was obtained. It failed to survive the winter and the dead tissue offered minimal soil. Neither of the two Austrian winter peas provided consistent stands. Soil crusting severely inhibited at the Lind site. Neither provided adequate ground cover to protect the soil.

'Alpowa' spring wheat exhibited excellent emergence, growth, and winter-hardiness. Although it did not persist through the winter following fall grazing in a separate study. 'Grey' oats and 'Hoody' winter barley exhibited chlorotic spots in the fall at George which might be attributed to residual Sencor/Lexone injury. 'Hoody' winter barley outgrew the injury and provided very good early spring cover. 'Grey' winter oats still exhibited some chlorosis in the spring and spring growth was much slower than the other winter grains.

The triticales tended to be less upright than the winter wheats but leaf lengths were comparable. Ground cover percentages were generally high which can be attributed to the characteristic decumbant growth of triticales. 'Breaker' winter triticale, a new Oregon State University release, exhibited outstanding vigor and ground cover. Its leaves were approximately 50% wider than the other triticales tested. 'Breaker' is said to reach 7-feet in height when mature.

The triticales offered slightly better ground cover during the wind erosion periods of the Columbia Basin than the winter wheats. However, higher seed costs associated with the triticales might make these materials less acceptable to producers. If the triticales are to be accepted by producers, this species will need to provide benefits beyond protecting the soil from wind erosion. Additional research is scheduled to evaluate the forage value and excess nitrate uptake potential of the triticales.

Cooperators -
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LATE FALL SEEDED COVER CROP TRIAL RESULTS PLANTED OCT. 11 AND 12 AT GEORGE AND LIND, WA, RESPECTIVELY.

CULTIVAR		FALL STAND COUNTS *		SPR GROUND COVER **	
		GEORGE	LIND	GEORGE	LIND
		(no/3ft of row)		(%)	
'Stephens'	Winter Wheat	30	26	81	83
'Celia'	W Triticale	37	27	88	82
'Centurk'	W Wheat	40	16	88	87
'Common'	Aust W Pea	13	5	27	37
'Alpowa'	S Wheat	33	27	86	88
'Breaker'	W Triticale	26	28	93	93
'Dusty'	W Wheat	27	8	72	75
'Granger'	Aust W Pea	17	6	23	45
'Parma'	W Triticale	27	21	87	87
'Grey'	Winter Oats	33	6	23	28
'Hoody'	Winter Barley	32	33	73	80
'Norstar'	Winter Wheat	44	31	78	83
'Nugaines'	Winter Wheat	00	00	00	00
'Penawawa'	Winter Wheat	31	25	38	65
'Tyfon'	Turnip	91	56	00	00
'Yamhill'	Winter Wheat	27	11	78	80
'Moro'	W Wheat	--	30	--	88
LSD .05		14.7	8.8	13.4	8.8

* Rated 11-8-95

** Rated 4-3-96 at Lind, 4-8-96 at George

NO-TILLAGE SPRING BARLEY IN DRY AREAS

Bill Schillinger, Don and Doug Wellsandt, Jim Cook, Bob Papendick,
Harry Schafer, Hal Johnson, Roger Veseth, Jon Newkirk, and Gayle Willett

Introduction: Winter wheat-summer fallow is the traditional cropping pattern in the 10-to 12-inch annual precipitation zone in eastern Washington. Some growers in these dry areas are increasing cropping intensity by undertaking a winter wheat - spring barley - fallow rotation. This rotation: 1) reduces the duration of the non-productive fallow period; 2) decreases diseases in the subsequent wheat crop and; 3) holds potential for increasing residue production, which benefits soil quality compared to the traditional wheat-fallow rotation. Adoption of this 3-year rotation in low-precipitation areas, however, has been limited because grain yield of recropped spring barley is highly variable.

Results for no-tillage seeding of spring cereals in the intermediate and high rainfall areas of eastern Washington show that: 1) yield potential is high, probably higher than when conventional tillage is used to prepare a seedbed, and; 2) achieving higher yield potential depends on equipment to loosen the soil and place fertilizer in the seed row and below the seed. We are testing this principle for low-rainfall dryland areas in this research project.

Study Description and Results: We are comparing conventional land preparation and planting methods with "one-pass" planting for recropping spring barley. The study site is the Don Wellsandt farm near Ritzville. Our objectives are:

1. To develop one-pass methods of seeding spring barley into standing winter wheat stubble which are equal to, or superior to, conventional land preparation methods.
2. To better determine the agronomic and economic potential of a winter wheat - spring barley - fallow rotation in 10-to 12-inch rainfall areas.
3. To document that, with no-tillage methods, adequate barley and remnant wheat residue can be maintained during the fallow cycle to reduce the risk of erosion and meet government farm program requirements.

In 1995, conventional land preparation and planting with 7" disk drills was compared to one-pass seeding with the Ag Pro drill and Morris air seeder. Both the Ag Pro and air seeder delivered fertilizer 1.5" below the seed. The best stand was achieved, and most dry matter produced, with the traditional planting method. Barley yield was 1.95 tons/acre for the traditional method, 1.73 tons/acre for the Ag Pro, and 1.52 tons/acre for the Morris air seeder.

In 1996, traditional practices were similar to the preceding year. One-pass seeding was conducted into both standing wheat stubble and standing barley stubble with a John Deere 750 disk drill, Flexicoil air seeder, and John Deere HZ fitted with special points. Fertilizer was delivered between the rows of the JD 750 drill (7.5" rows), and below the seed with the Flexicoil (9" paired rows) and HZ drill (16" rows). The John Deere HZ was included because it is the standard drill for deep-furrow planting of winter wheat in dry areas. We want to see how, with relatively inexpensive modifications, the HZ compares to one-pass drills now on the market.

In the spring of 1996, we collected data on soil temperature, surface soil moisture, stand establishment, dry matter production, and root disease severity amongst the four planting methods. We will collect yield data this summer. In addition, a cost/benefit analysis of each of the planting methods will be conducted. We plan to publish the results from the first two years of this study in *Wheat Life* in the fall.

MULCH DEPTH EFFECTS DURING FALLOW ON WHEAT ESTABLISHMENT AND EROSION CONTROL

Bill Schillinger, Curtis Hennings, Bob Papendick, and Harry Schafer

Introduction: A winter wheat - summer fallow rotation is practiced on about 3 million acres in the low-rainfall (< 12 inch annual) dryland regions of eastern Washington and north-central Oregon. Early establishment of winter wheat on summer fallow, which protects the soil from erosion and increases yield potential, is frequently limited by insufficient seed zone moisture. During the dry summer months, seed zone moisture loss occurs across a dry surface mulch layer. Seed zone moisture is best conserved using a soil mulch of maximum resistance to vapor and liquid water flow, and maximum thermal insulation, overlying a seed zone having good capillary continuity with deeper soil layers.
More information is needed concerning both the agronomic feasibility and environmental friendliness of conservation tillage practices during fallow.

Study Description: A 3-year study was conducted on the Curtis Hennings farm near Ralston (11.2 inch average rainfall) to measure effects of soil mulch depth during fallow on wheat emergence and control of wind erosion. Mulch depth combinations were created by primary spring tillage with V-shaped sweeps operated at 4-or 6-inch depth, and with subsequent rodweeding operations conducted at 2-or 4-inch depth.

Soil mulch depth did not affect wheat emergence after two wet fallow cycles. But in a dry year, when dry soil extended beneath the rodweeder layer, deep mulching increased stand establishment two-fold, grain yield 19%, and residue production 32%, compared to the shallowest mulch treatment. Surface soil cloddiness, desirable for wind erosion control, increased with depth of mulching, but so did subsurface clods within the 0-to 4-inch mulch, ranging from 41-to 79-tons per acre. Larger clods within the mulch do not retard moisture loss as effectively as more finely divided soil particles. Surface residue retention was not affected by mulch depth.

Conclusions: Results show that surface clod structure and roughness during fallow can be maintained to protect the soil from erosion without adversely affecting, and sometimes benefiting, wheat production potential. In this study, deep tillage combinations created the cloddiest surface for wind erosion control and, in a dry fallow cycle, produced the most desirable seedbed for wheat stand establishment and subsequent grain yield compared to the shallower soil mulch combinations.

Disadvantages of the deep tillage mulches were (*1*) increased clod mass within the 0-to 4-inch subsurface soil layer, which likely reduced moisture retention efficiency, and (*2*) the need to reduce speed when planting with deep-furrow drills to avoid pushing soil in front of the packer wheels. In addition, the angle of the drill openers may need to be adjusted to keep the points horizontal (i.e. kept from tilting back) when seeding through deep mulches.

Results from this study suggest that growers will benefit from deep mulching when winter precipitation is less then average because the drying front can be expected to penetrate below rodweeding depth by late August. Under these conditions deep primary tillage may provide a more friable soil condition, allowing grain drill openers to penetrate deeper into wetter soil. Seed zone moisture adequate for seedling emergence can generally be retained throughout the summer regardless of mulch depth after wet winters.

We feel the ideal summer fallow mulch for wind erosion problem areas of the PNW would maximize surface residue, clods, and roughness for erosion control but contain finely divided soil particles beneath the soil surface to optimize seed zone moisture conservation.

PACKING SUMMER FALLOW BEFORE PLANTING WINTER WHEAT

Bill Schillinger, Harry Schafer, Grant Miller, and Ron Jirava

Introduction: In dry years, winter wheat is sown as deep as 8 inches below the summer fallow soil surface to reach adequate moisture for germination, and seedlings emerge through as much as 6 inches of soil cover. Many growers pack the summer fallow mulch in late August before seeding winter wheat to improve stand establishment. Growers in low-rainfall areas have mixed attitudes towards packing summer fallow before seeding winter wheat. Advocates report packing enhances wheat seedling emergence and allows them to obtain stands in dry years where it would otherwise not be possible. This is achieved by: (*I*) reducing the thickness of the dry surface mulch, allowing deeper penetration of grain drill openers into wetter soil; (*ii*) providing improved seed-soil contact through increased soil bulk density and; (*iii*) rendering a thinner layer of soil covering the seed. Opponents feel packing often creates an unacceptable wind erosion hazard through excessive pulverization of soil clods and residue burial.

Study Description: We conducted a 2-year on-farm study on two silt loam soil types near Ritzville and southeast of Lind to determine the agronomic benefits and potential wind erosion hazards associated with packing. Packing a loose, thick surface mulch increased soil bulk density between the 2-to 5-inch depth. This significantly benefited wheat seedling emergence and stand establishment, which subsequently increased grain yield 9% over non-packed plots. But packing a soil with a thin mulch layer overlying a tillage pan had no effect on soil bulk density, wheat seedling emergence, or grain yield. Packing rendered the soil more vulnerable to wind erosion at both locations by reducing soil clod mass 55% and surface residue 38% compared to not packing.

Conclusions: Packing summer fallow just before seeding winter wheat may be a viable option for improving stand establishment and increasing grain yield in low-rainfall areas. Packing, however, reduces soil clod mass and buries residue. Surface residue and soil cloddiness are the primary factors affecting wind erosion that growers can control to some degree.

On finer-textured soils and under higher annual precipitation, growers using conservation tillage can generally maintain adequate surface residue and soil cloddiness to minimize wind erosion throughout the fallow cycle. Packing may provide agronomic benefits without undue risk of soil loss under these circumstances. In the drier (less than 10 inch annual precipitation) wheat-fallow areas, soils are generally coarse-textured and residue production potential is low. Surface roughness and clods are difficult to retain throughout the fallow cycle on these soils, often leaving residue as the only defense against wind erosion. Packing summer fallow should be considered only when ample surface residue is present under these conditions.

NEW STEEP III CROPPING SYSTEMS RESEARCH PROGRAM

Roger Veseth, WSU/UI Conservation Tillage Specialist
Don Wysocki, OSU Soil Scientist
Donn Thill, UI Weed Scientist
Dwane Miller, WSU Crop Scientist

Crop production systems in the Northwest are undergoing major changes in response to increased cropping flexibility and other opportunities in the new Farm Bill. Also contributing to this change are the need to improve production efficiency and profitability in an increasingly global market, and to increase protection of natural resources. A Pacific Northwest research and education program offers growers new technologies to help them make a successful transition to more efficient and resource conserving crop production systems.

The STEEP III (Solutions To Environmental and Economic Problems) program on technologies for conservation farming is getting underway in 1996. Four new STEEP III research projects selected for funding focus on developing conservation farming systems technologies to improve farm profitability and solve critical soil and water conservation problems in the region.

STEEP and STEEP II Background

STEEP has been a national model for multi-state, multi-disciplinary efforts among land grant universities, USDA-agencies, conservation districts, grower commodity organizations and Ag advisers to work collectively to solve regional environmental and economic problems. STEEP and STEEP II grants were cost effective investments of federal funds. Project operating funds (no faculty salary funding) has effectively leveraged state and local funding for conservation farming research and education projects in the region at a ratio of about 1 to 10.

STEEP was initiated in 1976 as a 15-year program. Funding was provided annually as special grants to Washington, Idaho and Oregon Agricultural Experiment Stations and as an increase in base funds for the USDA Agricultural Research Service. The original STEEP program generally provided about $200,000 per year for each of the three agricultural experiment stations. About $440,000 was added to the base funds of USDA-ARS in 1976 to support STEEP research.

The program was renewed as STEEP II in 1991 as a 5-year program. Funding was provided to the three state experiment stations as special grants through USDA. The funding level varied from $980,000 in 1991 to $829,000 in 1995. In addition, there was a $200,000 increase to ARS base funds beginning in 1992. During each year of the STEEP II program about 55 university and ARS scientists in the Pacific Northwest cooperated on 30 to 35 projects per year.

STEEP and STEEP II programs have made significant contributions in improving the profitability, effectiveness and adoption of conservation farming systems in the Northwest. Some examples of research accomplishments are:

- Documenting the importance of deep banding of fertilizer near the seed row to improve crop yield potential and reduce competition from weeds and diseases -- technology that is guiding the design of conservation tillage equipment.

- Adapting soil erosion prediction models to Northwest conditions and determining the effectiveness of surface residue, surface roughness, green cover and field strips in soil erosion control.
- Discovering the "Green Bridge" impact of volunteer grain and weeds on root disease potential in no-till and minimum tillage systems, and the importance of early green bridge control.
- Developing integrated management strategies to improve control of several major weed, disease and insect problems in conservation tillage.
- Developing Hessian-fly resistant spring wheat and supporting registration of Goucho seed treatment for Hessian fly.
- Developing varieties and management technologies for alternate crops such as rapeseed, Canola and mustard, for diversifying rotations to improve pest control, crop yields and profitability.
- Developing management practices for returning CRP land to crop production.
- Documenting the economic impacts of soil erosion and the economic risks and profitability of conservation systems.

STEEP III Funding and Projects

STEEP III was funded in 1996 at a total of only $469,000 for the tri-state region, a level far below previous years and the requested annual budget of $1.3 million. Although written as a 5-year project, STEEP III funding needs Congressional approval each year. Strong support from Northwest producer groups and conservation districts will be needed to continue funding for STEEP III.

Cropping systems research should be conducted for a minimum of 3 years, and preferably 5 to 7 years or more, before much confidence can be placed in the results because of the high variability of weather and growing conditions from year to year, and slow biological adjustment to changes in management practices. Because of the budget reduction and uncertainty of future funding, the STEEP III Grower Advisory, Technical Coordinating and Administrative Committees jointly selected five multi-disciplinary team projects for funding with the initial $469,000 grant over a 3-year period.

This provides a coordinated systems approach to solving production problems. Each project consist of multi-disciplinary teams of scientists from the PNW land-grant universities and ARS, growers, and agricultural support industry and agency personnel working to develop solutions to the critical conservation problems. More than 45 scientists from WSU, OSU, UI and USDA-ARS are involved in the projects. A STEEP III integrated cropping systems technology transfer project also has been developed for the Northwest.

In the fall of 1995, a questionnaire was sent to conservation districts, county grain producer organizations and other grower groups in the three states. The purpose of the questionnaire was to identify critical conservation farming problems and prospective solutions on which to focus STEEP III research. Priorities were identified for each of the three major wheat cropping systems in the Inland Northwest. These systems include: (1) low-intermediate rainfall areas with summer fallow, (2) annual cropping areas under high rainfall, and (3) irrigated areas. The results of the questionnaire provided the basis for developing and selecting STEEP III research projects.

The following are titles and brief descriptions of the four STEEP III cropping systems team research projects and the technology transfer project:

1) Development of Conservation Farming Systems for Protecting Soil and Water Quality in Downy Brome Infested Dryland Farming Areas. This project continues a STEEP II project initiated in 1992. Dan Ball, OSU weed scientist, is coordinating the project with a team of eight investigators and cooperators, and a 6-member grower advisory group. The goal is to develop integrated methods of downy brome control in winter wheat cropping systems. The project is investigating combinations of crop rotations, herbicides, fallow management and timing of cultural operations to control downy brome in 10- to 14-inch rainfall, shallow soil areas. Continuous and flex cropping systems utilizing spring and winter cereals, and non-cereal crops are also part of the study that includes seven different cropping systems. Trials located near Pilot Rock, Oregon are managed in cooperation with growers using field scale equipment. Disease control, fertility management, and economic assessment are integral project components.

2) Integrated Conservation Spring Cropping Systems for the Arid and Semiarid Wheat-Fallow Region of the PNW. Spring cropping in the traditional winter wheat-fallow region would largely eliminate the wind and water erosion associated with summer fallow and the subsequent winter wheat crop. Frank Young, USDA-ARS research agronomist, leads a 14-member team with scientists from 10 disciplines. Cooperators also include a 12-member grower advisory group, Monsanto and The McGregor Company. This research project is similar to a 9-year, large-scale, integrated pest management project on conservation cropping systems conducted earlier in the Palouse region near Pullman, WA. The main emphasis of this 5-year project is to examine the economic and environmental feasibility of annual cropping systems under reduced-tillage and direct seeding to replace or supplement the traditional winter wheat-fallow system. The 20-acre primary research site is near Ralston, south of Ritzville, WA. Several satellite trials around the region address additional fertility, weed management, and other agronomic considerations.

3) Residue Production and Retention in Small Grain Cereal and Legume Rotations with Different Tillage Practices. This cooperative Idaho/Washington project is lead by Stephen Guy, UI crop management specialist, and involves an interdisciplinary team of eight scientists. Soil erosion in winter wheat after dry pea, lentil and chickpea has been difficult to control in the Inland Northwest because of limited legume residue production and intensive tillage practices traditionally used to establish both the legumes and winter wheat. The project has two objectives: 1) evaluate the production and durability of residue from different legume cultivars under a range of tillage practices for winter wheat establishment; 2) develop integrated management systems for minimum tillage and direct seeding of legumes after spring cereals that retain adequate surface residue, surface roughness, and water infiltration and storage potential to effectively control runoff and erosion during legume establishment and in the following winter wheat crop. Agronomic performance, weed and disease control, fertility management, erosion control effectiveness, and economics are important aspects of the project.

4) Modified Wheat-Potato Rotations to Reduce Wind Erosion. Wind erosion can be severe on sandy irrigated soils after harvest of low residue crops such as potatoes. A 6-member interdisciplinary team project lead by Charlotte Eberlein, UI potato weed specialist, is underway to help develop solutions to the problem. The project is an extension and expansion of a 3-year STEEP II project being conducted near Aberdeen, ID. Project objectives include: 1) evaluation of winter wheat, and dormant-seeded spring wheat planted after potato harvest for stand, winter and spring soil cover, weed suppression and yield; 2) evaluation of reduced-till planting of Brassica crops (rapeseed) for stand establishment, ground cover biomass production, and winter survival; 3) examination of the effects of alternative Brassica species on ground cover, and weed control and disease suppression in potatoes; 4) assessment of the effects of alternative wheat/tillage/Brassica systems on the economics of wheat and potato production.

5) PNW STEEP III Integrated Cropping Systems Technology Transfer. The project is a tri-state cooperative effort by the extension cropping systems specialist team of Roger Veseth (WSU/UI), Don Wysocki (OSU), Baird Miller (WSU), Russ Karow (OSU), Stephen Guy (UI) and Tim Fiez (WSU). The project will help provide growers and Ag support personnel with increased access to STEEP III and related research technologies as integrated components of conservation tillage systems for specific agronomic regions. The project will have two educational thrusts: 1) printed and electronic versions of the PNW STEEP III Conservation Farming Update newsletter and new PNW Extension Conservation Tillage Handbook Series publications; and 2) a World Wide Web (WWW) Home Page on PNW STEEP Conservation Farming Systems Technology (http://www.cahe.wsu.edu/~pnwsteep/) with links to related home pages. The WWW is rapidly becoming a major source of new agricultural technology and information.

Future Needs

Although substantial progress should be made over the next three years through the STEEP III projects, the initial $469,000 grant is not adequate to effectively address conservation problems affecting agricultural profitability and resource sustainability in the region. Continuation of funding for the 5-year STEEP III program is important so that these and other research and educational projects can more effectively address the scope and complexity of developing new conservation cropping systems for the different production areas.

Northwest grower input through conservation districts and grain producer organizations has been vital in identifying critical conservation problems and prospective solutions to be addressed through team efforts of scientists, growers and Ag support personnel in the STEEP III program. Grower support for continued funding will determine the future and effectiveness of STEEP III.

THE EFFECT OF PRECIPITATION ON THE YIELD OF SMALL GRAINS AND PEA IN THE EASTERN PALOUSE

Michael J. Hall, Douglas L. Young, and Frank L. Young

It has been reported that in Eastern Washington wheat needs four inches of moisture to grow, and, on average, that each additional inch of precipitation will produce seven additional bushels (Cooperative Extension Service, 1975). Research conducted in the eastern Palouse in the late 1950's indicated that rainfall received during the growing season contributed seven bu/ac/inch to wheat yield (Legget, 1959). Of course, factors such as initial soil moisture, timing of precipitation, infiltration, evaporation, transpiration, and pests will cause annual deviations from this average relationship.

The objectives of this paper are: (1) to estimate the simple linear relationship between precipitation and crop yield for winter wheat, spring barley, spring pea, and spring wheat using recent data from the eastern Palouse of southeastern Washington, (2) to provide measures of the statistical reliability of the estimated relationships, and (3) to estimate separate relationships for conservation and conventional tillage for each crop to illustrate the effect of tillage on yield response to precipitation. This analysis will provide producers, agronomists, and other interested parties with information on the reliability of commonly quoted "rules of thumb" for marginal yield boosts from precipitation.

Crop yield and weather data are from the USDA/ARS Integrated Pest Management (IPM) experiment located near Pullman, WA from 1986-94 (Boerboom, Young, Kwon, and Feldick 1993; USDA Ag. Research Service). Individual plots received the same rotations and tillage treatments throughout the experiment. Yields were adjusted to the typical levels of moisture and foreign material for marketed crops in the region: 5%, 7.5%, and 10% for pea, barley, and wheat, respectively.

Two linear regression relationships were estimated for each crop/tillage combination. One used crop year (Sept.-Aug.) precipitation to explain variation in crop yields, the other used growing season (April-June) precipitation. The slope of the regression lines represent the expected increase in crop yield for each additional inch of precipitation for the time period. Tables 1 and 2 provide predictions over the range of both crop year and growing season precipitation included in the data set. Mean absolute percent errors (MAPE's) are included in the tables to assess the accuracy of the predictions. MAPE is the average percentage difference between the predicted yield and the actual yield (Pindyck and Rubinfeld, 1991). The higher the MAPE, the further the predicted yields were from the observed yields.

Results

The results support the hypothesis that a positive relationship exists between yield and crop year precipitation. However, the reliability and precision of this relationship varies by crop, length of precipitation period, tillage, and, for winter wheat, the preceding crop. For winter wheat, the estimated increase in yield per inch of precipitation ranges from 1.6 to 14.6 bu/ac/in (Table 1).

TABLE 1. Winter Wheat Yield Response Per Inch of Crop Year (Sept.-Aug.) and Growing Season (April-June) Precipitation by Rotational Position and Tillage, IPM Experiment, Pullman, WA

Preceding Crop	Crop Year Precipitation															Growing Season Precipitation						
	Add. Yield	Mean Absolute	Effective Predicting Range (in)													Additional Yield	Mean Absolute	Effective Predicting Range (in)				
Tillage	(bu/ac/in)	Percent Error	11.1	12	13	14	15	16	17	18	19	20	21	22	23	(bu/ac/in)	Percent Error	3	4	5	6	6.7
Following peas (1986-94)			---predicted yields (bu/ac)---															---predicted yields (bu/ac)---				
Conventional	5.5	11.6	48.3	53.3	58.8	64.3	69.8	75.3	80.8	86.3	91.8	97.3	102.8	108.3	113.8	6.8	20.0	75	81.8	88.6	95.4	100.2
Conservation	4.6	11.6	67.5	71.6	76.2	80.8	85.4	90.0	94.6	99.2	103.8	108.4	113.0	117.6	122.2	5.7	15.6	89.8	95.5	101.2	106.9	110.9
Following spring wheat (1986-91)																						
Conventional	6.5	14.6	----	----	----	----	----	53.7	60.2	66.7	73.2	79.7	86.2	92.7	99.2	4.8	23.3	63.3	68.1	72.9	77.7	81.1
Conservation	3.9	9.3	----	----	----	----	----	74.0	77.9	81.8	85.7	89.6	93.5	97.4	101.3	1.3	12.6	85.7	87.0	88.3	89.6	90.5
Following winter wheat (1986-91)																						
Conventional	7.5	13.2	----	----	----	----	----	44.1	51.6	59.1	66.6	74.1	81.6	89.1	96.6	3.6	24.6	64.6	68.2	71.8	75.4	77.9
Conservation	3.2	8.7	----	----	----	----	----	60.4	63.6	66.8	70.0	73.2	76.4	79.6	82.8	1.6	12.5	69.1	70.7	72.3	73.9	75.0

TABLE 2. Spring Crop Yield Response Per Inch of Crop Year (Sept.-Aug.) and Growing Season (April-June) Precipitation by Rotational Position and Tillage, IPM Experiment, Pullman, WA

Crop	Crop Year Precipitation															Growing Season Precipitation						
	Add. Yield	Mean Absolute	Effective Predicting Range (in)													Additional Yield	Mean Absolute	Effective Predicting Range (in)				
Tillage	(bu/ac/in)	Percent Error	11.1	12	13	14	15	16	17	18	19	20	21	22	23	(bu/ac/in)	Percent Error	3	4	5	6	6.7
Spring Barley (1986-94)			---predicted yields (bu/ac)---															---predicted yields (bu/ac)---				
Conventional	6.3	14.5	39.2	44.9	51.2	57.5	63.8	70.1	76.4	82.7	89.0	95.3	101.6	107.9	114.2	10.4	23.7	64.3	73.7	84.1	94.5	104.9
Conservation	6.1	22.0	46.8	52.3	58.4	64.5	70.6	76.7	82.8	88.9	95.0	101.1	107.2	113.3	119.4	11.3	22.0	68.5	78.7	90.0	101.3	112.6
Spring Pea (1986-94)[1]																						
Conventional	1.2	29.6	8.7	9.8	11.0	12.2	13.4	14.6	15.8	17.0	18.2	19.4	20.6	21.8	23.0	0.3	38.8	16.7	17	17.3	17.6	17.9
Conservation	0.8	27.8	12.8	13.5	14.3	15.1	15.9	16.7	17.5	18.3	19.1	19.9	20.7	21.5	22.3	0.4	32.3	17.7	18.1	18.5	18.9	19.3
Spring Wheat (1986-91)																						
Conventional	4.0	12.2	----	----	----	----	----	44.8	48.8	52.8	56.8	60.8	64.8	68.8	72.8	5.3	14.2	49.1	53.9	59.2	64.5	69.8
Conservation	3.5	17.0	----	----	----	----	----	43.7	47.2	50.7	54.2	57.7	61.2	64.7	68.2	0.4	14.1	43.2	43.6	44.0	44.4	44.8

Note: [1]Peas are reported at cwt/ac.

To estimate crop yield, locate the preceding crop and tillage combination in the table that most closely corresponds to that being predicted. Then choose the amount of precipitation that has been received or is expected to be received during that time period.

These responses vary widely around the seven bu/ac per inch rule of thumb (Cooperative Extension Service 1974). The average MAPE for winter wheat over both annual and growing season precipitation was 14.8%. Spring crop yield predictions were less accurate, on average, than winter wheat yield predictions with an average MAPE = 22.4% for spring crops.

Across all crops, precipitation received over April-June performed poorly as a predictor of yield, probably due to sizeable annual variations in stored soil moisture at the beginning of the growing season. In winter wheat, the average MAPE was 34% lower for the annual precipitation models (11.5% vs. 18.1%, as calculated from Table 1). The slope of the regression lines for annual precipitation averaged 1.2 bu/ac/inch greater than for April-June precipitation (5.2 bu/ac/inch vs. 4.0 bu/ac/inch). In spring crops, the divergence between growing season and crop year precipitation models was reduced. The average difference in MAPE between annual and growing season prediction equations was 20.5% vs. 24.2%. Both spring barley and spring wheat displayed considerably higher yield responses to April-June rainfall than to annual precipitation. These results support beliefs that spring planted grains do not utilize winter precipitation as well as winter wheat and are more dependent upon spring rainfall.

As expected, most crops experienced a higher yield response to crop year rainfall under conventional than conservation tillage, probably due to increased moisture storage in conservation tillage. In winter wheat, yield response to annual precipitation averaged 2.6 bu/ac/in higher for conventional tillage compared to conservation tillage (calculated from Table 1). However, because of the substantial yield advantage for conservation tillage at low precipitation levels, yields remained higher for conservation tillage over the entire range of precipitation for winter wheat following pea and winter wheat following winter wheat (Table 1). In contrast to winter wheat, the yield response for spring crops to April-June precipitation in conservation tillage was slightly higher than in conventional tillage (Table 2).

Conclusions

Mid-year yield predictions are useful in determining marketing strategies, storage requirements, and cash flow planning. Results from this analysis of six to nine years of experimental data suggest that farmers and others should apply rule of thumb relationships between precipitation and expected crop yields as only rough guides. The predicted yields were always within 25% of the actual yield for winter wheat and averaged 14.8%. Predictive accuracy was better for conservation tillage winter wheat, where the Mean Average Percent Error (MAPE) averaged 10%. For spring crops the MAPE ranged from 15% to 39%, reflecting poor predictive accuracy. Given the modest predictive reliability of these simple linear yield-precipitation relationships, farmers making important decisions based on mid-season yield predictions should consider more sophisticated (and costly) approaches. These include models based on seasonal evapo-transpiration moisture deficits and computerized plant growth models which use a spectrum of soil nutrient, water availability, pest incidence, and crop status information.

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NEW FRONTIERS

Tim Fiez
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How will the Palouse farm look in the year 2000, 2010, or 2020? Two recent developments, precision farming technology and the new farm bill, have the potential to greatly change crop production management as we move into the next century. Below are summaries of two ongoing projects which address future issues.

Precision Farming: Can we put technology to work?

Last summer, we worked with growers Dale Dietrich and Dave Fletcher and Jim Benson from Cenex to produce our first yield maps. Yield maps show how yields vary within fields. Getting our first yield map was definitely a learning experience. The popular press magazines make using the technology look easy; it took us several tries to get the global positioning receiver (GPS) which tells the combine where it is in the field to interface with the yield monitor in the combine. However, once we started getting maps, we were able to see a fascinating degree of yield variability in our test fields.

Our next step is to go beyond producing maps and try to determine what the yield data mean in terms of optimizing crop production. We are currently developing techniques to look for patterns in the yield maps so that we can 1) identify causal factors and 2) provide precision management recommendations. We will be posting our progress on our World Wide Web site. Go to http://www.cahe.wsu.edu/~drycrops/siteman.html. For more information about precision farming, see the articles "Dryland Precision Farming" and "Winter Wheat Seeding Rates: A Precision Farming Approach" located elsewhere in this publication.

Searching For Alternatives: Dryland Corn

With the advent of the new farm bill, growers have much greater flexibility to experiment with new crops and rotations. Crop rotations break disease cycles, allow for different weed control strategies, and improve risk management. Success in growing dryland corn in South Dakota was spurred interest in growing corn in the dryland areas of Washington. To investigate this possibility, Pioneer Hybrids, Monsanto, and Tumac Machinery have worked with interested growers to place over 10 small variety testing strips throughout eastern Washington.

To improve our understanding of the potential for successful corn production, we will be intensively monitoring corn growth, weather, and soil conditions at two of these locations. People involved in this project include Claudio Stockle, Gaylon Campbell, and myself from WSU-Pullman, Roland Schirman from WSU-Columbia County, Brian Lewis and Roger Willis from Pioneer, and growers Pat Barker, Russ Zehner, and Dave Carlton. Our goal is to use the data from this year to predict how corn will perform at different sites in future years using a crop model. While the crop model will not replace actual field trials, it can help us understand the potential tradeoffs between increasing growing degree days and decreasing precipitation as you go from Pullman to Walla Walla or Lind for example.

DRYLAND PRECISION FARMING

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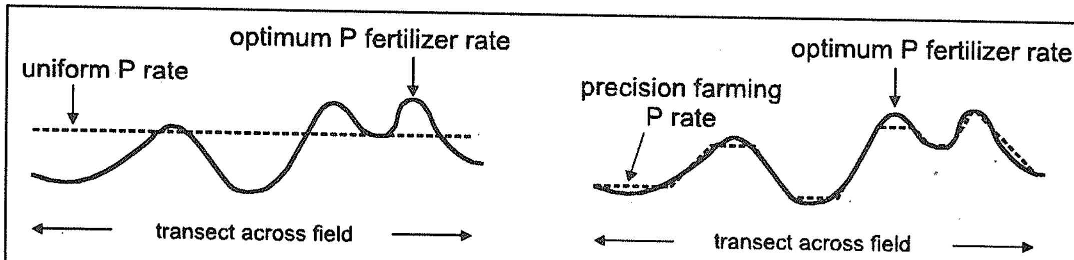
Precision farming, site-specific farming, and variable rate technology are among the terms used to describe a "new" approach to growing crops. In comparison to a typical crop production system where production practices are kept constant over a fairly large acreage, precision farming systems vary practices within fields or land units. The basic concept behind precision ag is that fields are not uniform, and production practices will have to vary accordingly to optimize results. Precision farming optimizes crop production by matching crop management to crop needs.

To illustrate the precision farming principle, let's consider an example that might be faced when applying P fertilizer. Due to soil differences across a field, the optimum level of P fertilizer varies. Using conventional uniform P fertilizer application will always result in areas of under- and/or over-application. If the uniform rate is set to meet the needs of the poorest area in the field (highest fertilizer need), many other areas will be over-fertilized. Conversely, if the uniform rate is set for the lowest requirement in the field, many areas will be under-fertilized. No single fertilizer rate will be optimum for all areas. The goal of precision farming in this instance is to adjust P fertilizer rates so that applications match needs.



Uniform Farming Versus Precision Farming

Increased profitability is the primary driving force behind precision farming. At the same time, precision farming provides the opportunity to improve environmental stewardship by reducing areas of over-application. This could be too much N, P or herbicide, for example. Not only is this over-application expensive, but it places additional product on the field that can be lost through surface runoff or leaching.

Components of a Precision Farming System

A precision farming system is a three part process.

- Assessment of field variability.
- Determination of optimal production practices in response to variability.
- Implementation of variable management practices.

Assessing field variability

Many methods are available to document variability within a field. These include aerial photography, satellite imagery, soil survey maps, yield maps, intensive soil sampling, and insect and weed scouting. How to best measure field variability is an area of ongoing research throughout the country. For example, researchers and fertilizer dealers are using intensive soil sampling on 100 to 300 foot grids to measure soil nutrient variability in other areas of the country. A 200' by 200' grid is equal to approximately one sample per acre, and the cost of sampling and analysis using this approach may eliminate the potential profit from precision fertilizer application in the dryland areas of Washington.

While soil test levels surely vary within fields in the dryland areas, we may need to develop methods to divide fields into units of similar slope and aspect or organic matter concentration and then sample soil within these units. Recent WSU research in Columbia County has shown that in Athena soils, field areas with high surface organic matter levels have the highest levels of inorganic soil N.

Yield mapping is a new tool for measuring field variability. To make a yield map, you need a combine equipped with a factory installed or after-market yield monitor and a Global Position System (GPS) receiver. The yield monitor software will record yield and field location every one to two seconds while the field is harvested. The resulting map can be used in several ways. First, you can relate yield differences to the site characteristics to try to determine what is causing the yield variation. You might view this as post-harvest detective work. As an example, WSU research in the high rainfall areas of the Palouse has shown that some of the lowest winter wheat yields occurred on steep north-facing slopes and that low tiller production was the cause of these low yields. Because of these findings, we double seeded north slopes and found that the double seeding increased yields by about ten percent.

Second, you can use a yield map as a basis for modifying production practices and monitoring profitability within a field. A yield map can easily be converted to a net return map by map by multiplying yield by price and subtracting the production costs. It is possible that the high yielding areas in the field may benefit from additional production inputs and that the low yielding areas could produce similar yields with reduced input levels.

How to determine optimal production practices in response to field variability

The biggest challenge in precision farming is interpreting field variability and modifying management practices so that crop production is optimized over all field areas. In the past, universities and others have often developed general recommendations that apply to an entire region, soil series, or precipitation zone. However, with precision farming, you need to know how small scale differences affect crop production. For example, what is best for a south slope and what is best for a north slope, or are different varieties, seeding rates, and fertilizer levels needed to maximize production on a Shano silt loam than for a Burke silt loam?

Those involved in precision farming are taking various approaches to determine optimal production practices for each area in a field. One approach is to conduct site-specific research;

this involves repeating the same study on multiple areas in a field to learn how field characteristics influence crop response. WSU has used this approach to determine if optimum seeding rates and N application rates vary in fields.

Another approach is to use knowledge of basic principles to predict the best practice for each area of a field. For example, disease pressure will probably be more severe in the wetter portions of a field so one recommendation could be to plant the variety with highest disease resistance in these wetter areas. A third approach is to use existing general recommendations for site-specific practices. This approach is commonly used for site-specific fertilizer applications. For elements such as P and K, the critical values found in fertilizer guides can be compared to site-specific soil test values to determine if and how much fertilizer is needed.

For N, site-specific soil test and yield goal information could be combined with average values for the N requirement per bushel and N mineralization. However, WSU research has shown that using the regional value for the N requirement per bushel (2.7 lb N/bu wheat) is inadequate for developing site-specific N recommendations for winter wheat. Recommendations based on the 2.7 lb N/bu requirement for all field areas were no better in terms of profitability than applying fertilizer N uniformly at one rate to all field areas. Thus, we may not have the knowledge to determine optimal production practices for every area of a field at this time.

Implementation of variable management practices

The application of variable management practices ranges from high to low tech. On the high tech end, you can use fertilizer spreaders equipped with GPS and computers which adjust fertilizer rates on-the-go in accordance to a computerized application map. Similar devices are available or are in development to vary liquid products, such as herbicide solutions, and to control planters.

The prevalence of high tech and high cost applicators in many popular press magazines should not discourage you from implementing a precision farming system on your farm. The key is to vary your farming practices according to your knowledge of field variability. This knowledge could be based on your memory of what has happened in the past. You might be able to sketch management zones on a soil survey map for the equipment operator to use.

While machines that change operations automatically might simplify precision farming, precision management can be implemented with standard equipment. For example, varying tillage within fields only requires switching implements. Varieties can be changed by planting a field in sections such as planting a cold hardy variety on the ridgetops and upper slopes and then switching varieties and planting the lower field areas.

Farmers have been able to modify standard dryland fertilizer applicators to apply several rates which can be selected with the tractor's hydraulic system. These growers can switch to a low application rate on ridgetops and knobs, an intermediate rate for midslopes, and a high rate for the flats. Precision farming does not necessarily require a "Star Wars" approach to farming, and there are many ways to apply precision farming principles.

Does Precision Farming Have a Place in Dryland Agriculture?

There is tremendous potential for precision farming in the dryland areas of the Pacific Northwest. Every step in growing a crop can be managed using the precision farming concept of adjusting management within a field to match site-specific conditions. Soil fertility, tillage and residue management, diseases, weeds, variety selection, seeding rates and crop rotations are just some of the areas where growers can apply precision farming. However, to increase profits and improve environmental stewardship, the entire precision farming system must be employed. Assessing variability can increase your knowledge differences within a field, but this will not result in greater profits unless you can determine what the variability means in terms of crop production. Similarly, the high-tech fertilizer applicator will not result in increased profits unless you can correctly instruct the machine to vary fertilizer rates as it crosses the field. In many cases, growers, industry, and the university are still developing the expertise to measure variability, determine optimal practices, and apply variable management.

WINTER WHEAT SEEDING RATES: A PRECISION FARMING APPROACH

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The goal of precision farming is to optimize crop production practices for all field areas. Recent research in the 21-23" precipitation area of the Palouse indicates that it may be beneficial to increase seeding rates on steep north-facing slopes. This investigation into whether current seeding rates are adequate for all field areas is a good example of how to develop precision farming practices. As discussed in the article "Dryland Precision Farming", precision farming is a three step process of 1) assessing field variability, 2) developing management recommendations to adjust for the variability, and 3) applying variable management practices.

Assessment of Field Variability and The Possible Benefit of Increased Seeding Rates

For precision farming, field variability is opportunity. Research during the 1990 and 1991 growing seasons found that some of the lowest winter wheat yields within fields often occurred on north-facing backslopes. Although yields were low, it seemed that these north-facing slopes had the potential to produce greater yields. There was adequate soil water left at harvest and the plant stands were so thin that not all of the incoming sunlight was being captured. We speculated that poor tillering due to cold and wet conditions in late winter and early spring was one of the factors limiting yield on these north slopes. Although wheat plants can compensate for poor tillering by producing bigger heads or heavier seed, tiller number seems to be the most important component in determining yields in the wetter parts of the Palouse. High yielding field locations tend to have the greatest number of heads per area while low head numbers usually result in low yields. If we were correct that tiller number was limiting north slope yields, increased seeding rates could result in greater yields as there would be more plants per area to make up for the low tiller production per plant.

Developing Precision Farming Management Recommendations: an On-Farm Test of Seeding Rates

Seeding rates of 1.0, 1.5, and 2.0 times the growers standard seeding rate (1.0X, 1.5X, and 2.0X treatments) were evaluated at Farmington and Pullman, WA during 1992 and 1993 using on-farm testing protocols. The treatments were laid out as long replicated strips which ran up and over a ridge to give seeding rate comparisons on footslope, south-facing, north-facing, and ridgetop landscape positions. The 1.5X and 2.0X seeding rate treatments were established by cross drilling. A drill pass at a 0.5X or 1.0X rate was made perpendicular to a pass at the 1.0X standard rate.

Doubling the seeding rate increased yields on the north slopes by an average of 10.3% (7.5 bu/acre). The 1.5X treatment increased north-slope yields by 5%. In both cases, the yield increases were associated with an increase in the number of heads per area. On the footslope, south slope and ridgetop landscape positions, doubling the seeding rates did not increase yields indicating that the standard seeding rates were adequate to maximize yields.

Application of Variable Seeding Recommendations: a Low-Tech Approach

So far we have identified field areas (north-slopes) which might need differential management and have demonstrated that doubled seeding rates can increase yields on these sites. The final step is to apply the differential management in real field situations. We implemented our variable seeding rate management using a low tech approach. We identified north slopes visually and used a second pass with the drill and the tractor to double seeding rates. Alternatively, the technology exists to double seeding rates on-the-go using a tractor equipped with GPS and a computer and a drill equipped with a variable rate controller.

The Bottom Line

To realize our goal of optimizing crop production practices across all field areas, the double seeding of north-facing backslopes must provide additional benefit such as greater profit. Below is a partial budget for double seeding. This budget compares the additional costs of double seeding to the additional income. The economic results based on the average yield response from the four experimental locations are encouraging. Growers can easily experiment with double seeding on their own farms using the low tech approach. We used a double disk drill in our experiments and the number of plants in the double seeded treatments was 1.84 times that of the single seeded treatment, indicating only a slight reduction in emergence as the result of the second drill pass. Promising areas for double seeding are north facing slopes where head densities are low enough that you can easily see the ground between the rows after heading. The double seeding experiments were conducted in the 21 to 23" annual precipitation area and the yield increases might not occur in drier areas where moisture is more critical in determining yield.

Additional income and cost from doubling soft white winter wheat seeding rates on north-facing backslopes.

	Price of wheat		
	$3.50/bu	$4.50/bu	$5.50/bu
	---------------	$/acre	--------------
Additional income from 7.5 bu/acre yield increase	26.25	33.75	41.25
Additional variable cost due to the 2.0X seeding rate treatment*	15.88	15.88	15.88
Net change in profit	10.37	17.87	25.37

*Total additional variable costs included $11.20 for seed (80 lb/acre @ 0.14/lb), $0.67 to haul seed, and $4.01 for the second seeding operation (1995 Crop Rotation Budgets for Eastern Whitman County, Washington; WSU Cooperative Extension Farm Business Management Report EB 1437).

STRIPE RUST, LEAF RUST AND STEM RUST OF WHEAT, 1996

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General Characteristics. Three rusts (stripe rust, leaf rust, and stem rust) occur on wheat in the Pacific Northwest. Stripe rust appears as golden-yellow, long, narrow stripes on the leaf surface and glumes; leaf rust appears as small, red pustules on the leaf surface and leaf sheath; and stem rust appears on the stems and as large, red-brown, diamond-shaped pustules on the leaf surface. Stripe rust and stem rust can also occur on the heads. Stripe rust and leaf rust overwinter on wheat and rapidly increase during the spring. Stripe rust develops during the cool temperatures of early spring. Leaf rust develops at warmer temperatures later in the spring. The stem rust pathogen does not usually survive on living plants during the winter. It survives as dormant spores on straw and depends upon the common barberry for completion of its life cycle. In the spring, the dormant spores germinate and produce another type of spore that infects barberry leaves but not wheat. Spores produced on the barberry are the source of inoculum for the wheat in the spring. Therefore, elimination of the barberry would eliminate or reduce stem rust.

Historical Importance. In the late 1950's and early 1960's stripe rust caused losses in excess of 70 percent. Since then, destructive epidemics of stripe rust that cause losses of more than 20% have occurred in fields of susceptible cultivars in three out of four years and every year in western Washington. Stripe rust reduced yields in the Pacific Northwest by more than 20 percent in 1981 and more than 15 percent in several other years. Without development of resistant cultivars and emergency registration of a fungicide (Bayleton) for rust control, losses caused by stripe rust in Washington would have exceeded 50 percent in 1981. Omar, was completely destroyed in 1981. A new form of *Puccinia striiformis* that attacks barley (barley stripe rust) is now present in the Pacific Northwest. Barley stripe rust looks like wheat stripe rust but is a different pathogen that is more severe on barley and is not a destructive disease of wheat. We expect barley stripe rust to damage barley in the same manner that wheat stripe rust has damaged wheat in the past.

As we develop wheat cultivars with better stripe rust resistance, leaf rust becomes more important because tissue not damaged by stripe rust is damaged by the later developing leaf rust. Consequently, leaf rust has become increasingly more important since 1962. Losses caused by leaf rust in susceptible varieties have exceeded 50 percent in some years. When not controlled, leaf rust has reduced yields by more than 20% in one out of two years since 1974. When not controlled in irrigated fields, leaf rust can cause severe losses almost every year. Those losses have exceeded 60 percent in some fields.

Stem rust is less frequently severe, but when present, it can cause major damage to both wheat and barley in specific areas. In 1980 to 1984, stem rust significantly damaged both wheat and barley in eastern Washington and Oregon and northern Idaho, especially in late maturing fields. In 1993, because of late planting of spring wheat and barley and unusually favorable weather, stem rust was very severe in those same regions. Spring crops were again planted late in 1996. Severity of the disease will depend upon weather in late spring and early summer.

Monitoring Rust. Races of *Puccinia striiformis*, the pathogen that causes stripe rust, are identified by the cultivars that they attack, and new races of the pathogen frequently evolve to attack cultivars that were previously resistant. Figure 1 lists the races of *Puccinia striiformis* that have been detected in North America and their virulence on differential cultivars. Fifty-six stripe rust races have been identified of which 45 have been detected in eastern Washington.

In 1995, the most prevalent races in the Pacific Northwest were those virulent on Hatton, Tres, Tyee, Moro, Jacmar, Weston, Paha, Yamhill, Fielder, Owens, and seedlings of Hyak, Madsen, Stephens, and Daws (Races CDL-5, CDL-20, CDL-22, CDL-25, CDL-26, CDL-27, CDL-29, CDL-33, CDL-38, CDL-41, CDL-42, CDL-43, and CDL45 to CDL-55). In addition to the wheat stripe rust races, at least 14 barley stripe rust races were identified in the United States in 1994, and more than 35 races have been identified since then. All major barley cultivars are susceptible to the barley stripe rust.

Most winter wheat varieties currently grown in the region are very susceptible to leaf rust. Since the current races can attack most winter wheat varieties and the resistance in spring wheat is now race specific, there is no major selective pressure for new races of leaf rust. Consequently, no significant new races of *Puccinia recondita*, the pathogen causing leaf rust, were detected in 1995.

Stem rust attacks both barley and wheat. We have more races of stem rust in the Pacific Northwest than in all of the other regions of North America, and races of *Puccinia graminis*, the pathogen causing stem rust, are uniquely different from races in the other regions. This is because new races more easily arise from the stage of rust that occurs on the common barberry. All barley cultivars and some wheat cultivars are susceptible to stem rust .

Effect of Weather. The rusts are obligate parasites and must have a living host to grow on. The continual presence of living plants (wheat, barley, and some grasses depending upon the rust) throughout the year provides hosts for the rusts and adequate inoculum for initiation of new stripe rust and leaf rust epidemics. Therefore, the factor that is most limiting for rust development is often the weather. When used in combination with monitoring data, a model for predicting stripe rust, based on temperature and precipitation, has proved to be reliable since 1979. When that information is used with precipitation data in the late spring, it has also enabled prediction of leaf rust and stem rust. Severe stripe rust epidemics and leaf rust have been predicted for 1996. As of early May 1996, stripe rust and leaf rust epidemics were already developing in fields of hard red and club wheats in central Washington.

Resistance. High-temperature, adult-plant resistance to stripe rust, which has now been incorporated into all major soft white winter wheats and most spring wheats (see Figure 2), has continued to be durable against all races in the Pacific Northwest. In contrast, the high resistance that is expressed in both seedling and adult plant stages at all temperatures has been effective for three years or less.

Figure 1. Virulence of Cereal Disease Laboratory races of the wheat stripe rust fungus on differentials.

DIFFERENTIAL	
NO.	NAME
1	Lemhi
2	Chinese 166
3	Heines VII
4	Moro
5	Paha
6	Druchamp
7	Riebesel 47-51
8	Produra
9	Yamhill
10	Stephens
11	Lee
12	Fielder
13	Tyee
14	Tres
15	Hyak

RACES OF PUCCINIA STRIIFORMIS TRITICI, WHEAT STRIPE RUST					
CDL RACE	VIRULENCE ON DIFFERENTIALS	CDL RACE	VIRULENCE ON DIFFERENTIALS	CDL RACE	VIRULENCE ON DIFFERENTIALS
1	1,2	20	1,6,8,10,12	39	1,2,4
2	1,2,5	21	2	40	1,4,14
3	1,3	22	1,3,12	41	1,3,4,14
4	1,3,?	23	1,3,6,9,10	42	1,3,11,12
5	1,3,4	24	1,3,5,12	43	1,3,4,5,12,14
6	1,6,8,12	25	1,3,6,8,9,10,12	44	1,4,5
7	1,3,5	26	1,3,9,12	45	1,3,12,13,15
8	1,3,9	27	1,3,12,13	46	1,3,6,9,10,11
9	1,3,6,8,12	28	1,3,4,12	47	1,6,8,12,13
10	1,2,3,9	29	1,3,4,5	48	1,6,8,12,13,14
11	1	30	1,4,6,8,12	49	1,3,11,14
12	1,5,6,12	31	1,3,5,11	50	1,3,4,5,14
13	1,5,6,8,12	32	1,4	51	1,3,4,12,14
14	1,8,12	33	1,3,9,12,13	52	1,4,8,12,14
15	1,3,6,8,10	34	1,3,4,5,12	53	1,6,10
16	1,3,9,11	35	1,10	54	1,3,4,6,8,9,10,12
17	1,2,3,9,11	36	1,3,4,9,12	55	1,6,10,11
18	1,3,4,9	37	1,3,6,8,9,10,11,12	56	1,4,6,8,12,14
19	1,3,6,8,10,12	38	1,3,11		

Information on the characteristics and inheritance of high-temperature, adult-plant resistance has been obtained, and that resistance has been or is being used in development of new resistant cultivars. New information on the inheritance of race-specific resistance and location of genes for resistance has been obtained, and that information and material should be useful in developing new disease control programs, identifying races, and understanding how resistance works.

We are currently evaluating the national germplasm collection for resistance to stripe rust in the field at Mt. Vernon and Pullman, WA and for specific resistance to the five most virulent stripe rust races in the greenhouse. The five races include all of the identified virulences in North America. As of this date more than 40,000 germplasm entries for regions throughout the world have been evaluated in the field and most of those have been evaluated for resistance to the stripe rust races.

Studies of the inheritance of slow rusting resistance to leaf rust, have resulted in new information and germplasm for resistance to leaf rust. That germplasm has been useful in developing more durable leaf rust resistant wheats.

We annually evaluate commercial cultivars, advanced breeding lines from breeders in the Pacific Northwest, and differential cultivars for resistance to stripe rust, leaf rust and stem rust. The information on resistance of germplasm and advanced lines has made possible the development and release of rust resistant cultivars and has provided breeders with new sources of resistance, lead to a better understanding of how to use rust resistance, and improved the resistance of wheat cultivars.

Use of Fungicides. Resistance to all disease problems may be difficult or impossible to incorporate into a single cultivar, and new races of the pathogens are a frequent problem. Therefore, additional control measures are necessary. We have an ongoing program to study the use of fungicides for control of the diseases as part of an integrated disease control program. Results of those studies show that foliar applications of Bayleton, Tilt, Folicur, Spotless, Punch, ASC-66811, SAN-619 (Alto), RH-7592 (Govern), LS86263, and BRC-519 (Quadris) control stripe rust, leaf rust and stem rust, especially when applied at jointing to heading stages of growth, and they have effectively prevented major wheat losses. Some of the chemicals also control leaf spotting fungi such as septoria. Baytan, Raxil, and several new experimental fungicides applied as seed treatments control early rust and mildew development, and if they are, manage to prevent a delay in emergence, their use significantly improves yields. Bayleton has been used as a foliar spray since 1981 to control stripe rust and leaf rust when existing cultivars become susceptible to new races and in combination with various types of resistance. Tilt was registered for rust control in 1988 and has also been highly effective as a control for the diseases. Baytan was registered as a seed treatment in 1989. The remaining chemicals are still in the experimental stage and are not yet cleared for use on a commercial basis. However, several are expected to be registered in the near future. Guidelines for the use of the chemical seed treatments and sprays have been developed based on type of rust, type of resistance, intensity of rust, stage of growth, potential yield, and economic return. A new expert system, MoreCrop, has been developed for managing wheat diseases and is explained in another section.

Figure 2. Seedling and adult plant resistance to stripe rust.

SOFT WHITE WINTER		
CULTIVAR	SEEDLING	ADULT
ROD	S	R
KMOR	S	R
ELTAN	S	R
MADSEN	S	R
STEPHENS	S	R
LUKE	S	R
LEWJAIN	S	R
DUSTY	S	R
DAWS	S	MR
HILL 81	S	MR
MALCOLM	S	MR
HYSLOP	S	MR
MCDERMOD	S	MR
NUGAINES	S	MR-MS
GAINES	S	MR-MS
WALLADAY	S	MS-S
YAMHILL	S	S

CLUB WINTER		
CULTIVAR	SEEDLING	ADULT
WA7692	S	R
ROHDE	S	MR
HILLER	S	MR
RELY	R+S	R+S
CREW	R+S	R+S
HYAK	S	MS
TRES	S	S
MORO	S	S
JACMAR	S	S
BARBEE	S	S
PAHA	S	S
TYEE	S	S

HARD RED WINTER		
CULTIVAR	SEEDLING	ADULT
BUCHANAN	S	R
BLIZZARD	S	MR-MS
BATUM	S	MR-MS
WANSER	S	MR-MS
MCCALL	S	MR-MS
CENTURY	S	S
HATTON	S	S
WESTON	S	S

SOFTWHITE SPRING		
CULTIVAR	SEEDLING	ADULT
PENAWAWA	S	R-MR
EDWALL	S	R-MR
WAVERLY	S	R-MR
WADUAL	S	R-MR
WAKANZ	S	MR-MS
URQUIE	S	MR-MS
WALLADAY	S	MS-S
FIELDER	S	S
FIELDWIN	S	S
TWIN	S	S
DIRKWIN	S	S
OWENS	S	S

BARLEY STRIPE RUST AND STEM RUST IN THE PACIFIC NORTHWEST, 1996

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A new barley disease, barley stripe rust, is now in the Pacific Northwest and could cause wide-spread damage to barley in Washington and adjacent states. The disease can cause losses as severe as the losses that occurred in wheat during the early 1960's when there were no resistant cultivars and no other available methods of control. A research program aimed at preventing such a disaster was started in 1993.

Barley stripe rust is one of the many fungal diseases of cereals and grasses that are referred to as rusts. They get their names by the characteristic rust-like spores that are produced on the foliage of the plants. Stripe rust appears as golden-yellow, long, narrow stripes on the leaf surface and glumes. The stripes generally appear between the leaf veins but can sometimes cover the entire leaf. The spores produced on a leaf are carried by the wind to other leaves on the same plant, to other plants, and to plants in other fields. When the leaves are moist, the spores germinate, infect the leaves, and produce new spores. The cycle can be repeated many times in a growing season. Thus, the disease can start from a few infections and increase to completely cover the plant. The fungus can only infect and grow on living plants. Therefore, the presence of susceptible barley plants throughout the year contributes to the survival and spread of the pathogen. Barley stripe rust is similar to the well known wheat stripe rust; however, they are two different diseases. Wheat stripe rust (*Puccinia striiformis tritici*) can attack cultivars of barley as well as wheat, but it has never been observed to cause severe damage to fields of barley in the Pacific Northwest. In contrast, barley stripe rust (*Puccinia striiformis hordei*) is known to reduce barley yields by 30 to 90 percent and to greatly reduce the quality of the grain. Barley stripe rust is not known to damage wheat.

Barley stripe rust is a new disease in the United States. It was not known to be present in the United States until 1991. The disease is well known in Europe, and like wheat stripe rust, several races of the barley pathogen occur in that part of the world. Barley stripe rust was reported to be present in South America near Bogota, Columbia in 1975. It was postulated that the barley rust was introduced by people traveling from Europe, since the race that was detected in Columbia was the same as a race that was common in Europe. The rust soon spread to other South American countries and eventually to Mexico. It caused wide-spread devastating losses in each of the regions where it occurred. The disease was first detected in Texas in 1991. It appeared in Oklahoma, New Mexico, and Colorado in 1992, and in Arizona in the spring of 1993 where it again caused major yield losses and greatly reduced malting quality. By August 1993, it was detected in southern Idaho and Montana. There were reports of barley stripe rust in California in 1993, which were confirmed during the spring of 1994. Barley stripe rust also appeared in Utah in 1994 and 1995, and caused severe damage. By the spring of 1995 the disease had appeared in western Washington and Oregon, and by July in the same year, it appeared in eastern Washington. Also by July, it developed to severe disease intensities in southwestern Oregon and northern California. As of early May 1996, barley stripe rust has been widely destructive in California (causing almost total losses to some cultivars) and has been detected in both eastern and western

Washington and Oregon. When the weather is favorable for the disease, we expect it to be as destructive as it has been in other regions of the world and as destructive as wheat stripe rust has been in fields of susceptible cultivars in the Pacific Northwest.

Based on what we know about wheat stripe rust in this region, barley stripe rust in other regions, and controlled temperature studies in the greenhouse, we have determined that the environment in the Pacific Northwest will be highly favorable for the disease. Now that barley stripe rust has appeared in Oregon, Washington, and northern Idaho, it will remain in the region and spread throughout the Pacific Northwest. Field research in the Pacific Northwest was not appropriate until the disease became widespread in the region. Now that the disease is in the region, both field and controlled environmental research will be needed to clearly understand how weather and management contribute to severe epidemics of the rust.

Monitoring the pathogen is important. To forewarn growers and breeders, we must determine the prevalence, distribution, and severity of the disease; identify the races; determine how those races evolve; and determine the vulnerability of cultivars to the races. At this time, barley stripe rust and wheat stripe rust cannot be differentiated without extensive, detailed tests in the greenhouse. These include testing the cultures of the pathogen on a series of wheat and barley differential cultivars. To add to the difficulties, we determined in 1994 that at least 14 races of the barley stripe rust pathogen exists in North America. Since then, more than twice that number of races have been identified. Therefore, barley stripe rust is an extremely variable pathogen. Until 1994, we did not know how similar or different barley stripe rust and wheat stripe rust are or if they can cross with one another and make races that could be severe on both crops. We have shown that new molecular techniques, such as Random Amplified Polymorphic DNA (RAPD) analyses, can differentiate barley stripe rust from wheat stripe rust as well as other rusts of wheat and barley and stripe rust of bluegrass. These techniques as well as studies on pathogen virulence are useful to differentiate the wheat and barley pathogens from one another.

Resistant cultivars are the preferred control. There is already a significant effort in searching for resistance to barley stripe rust. Barley germplasm is being evaluated in South America, Mexico, Texas, Colorado, Oregon, and Washington for resistance to the disease. We have identified sources of resistances and are conducting studies to determine what genes provide resistance. The current barley cultivars grown in the United States are susceptible, and it will take a few years to incorporate the resistance into locally adapted cultivars. Also, new races may circumvent some types of rust resistance. We know little about what type of resistance to barley stripe rust exist and how durable the resistance may be. There appear to be types such as the high-temperature, adult-plant resistance that is so effective in wheat. Therefore, various types of resistance must be identified and germplasm must be evaluated more thoroughly in order to be used to develop locally adapted, resistant cultivars.

Fungicides have been useful for control of the wheat rusts and have potential for control of barley stripe rust. They might be used when resistance is ineffective or in combination with certain types of resistance. However, the use of fungicides must be economical and non-hazardous to the environment. Therefore, seed treatments and foliar fungicides must be evaluated under various integrated management systems to determine what fungicides are effective and how they may be used. This field research was initiated in 1996.

Some barley cultivars are also susceptible to stem rust. Stem rust is characterized by red pustules on stems and leaves. Stem rust was severe in 1993 in fields that were planted late because it appears later in the growing season. The cool, wet weather of 1993 was highly favorable for stem rust. This year, 1996, was also wet and barley was planted late in some fields. If the crop matures late in the season and precipitation is high in June and July, stem rust could be a problem in 1996. Resistant cultivars and foliar sprays are possible controls for stem rust.

What can we do to prevent a barley stripe rust epidemic?

Monitor your crop. Being forewarned is half of the battle against the disease. Timely control is important. Fields should be examined frequently throughout the growing season. Wheat stripe rust and barley stripe rust should develop under similar conditions. If wheat stripe rust appears, barley stripe rust will probably also appear. Look for small golden-yellow stripes on the leaves, contact your county agent, and verify that it is stripe rust. Barley and wheat stripe rust look alike. If it is stripe rust, send a sample to Roland F. Line, 361 Johnson Hall, WSU, Pullman, WA 99164-6430, to determine if it is barley stripe rust or wheat stripe rust on barley. Continue to monitor the field. If it begins to spread and become more severe, it is probably barley stripe rust.

Consider treatment of the barley seed with Baytan. Baytan controls early stripe rust development but will not control the disease throughout the season. Also, Baytan is more expensive the other seed treatments. Be sure to use Baytan at the rate indicated on the label. Higher rates may delay emergence when seed is planted deep. Baytan will be an even more important control measure now that the disease is widespread in the region.

Consider using foliar fungicides if the disease starts to spread and increase rapidly. Foliar sprays are not necessary unless severe rust is expected. Best control should be before the rust develops on the upper leaves. Bayleton and Tilt are systemic fungicides that control stripe rust on wheat, but Bayleton is no longer labeled for barley. Tilt cannot be used beyond the late jointing stage. Several new fungicides have potential for control of the disease and may be registered in the near future. Determine your economical benefits before using the foliar fungicide.

THE SMUTS AND BUNTS OF WHEAT, 1996

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Common Bunt. Common bunt (stinking smut), caused by the fungus *Tilletia tritici*, is a disease characterized by replacement of the normal wheat kernel with bunt balls containing a black, powdery mass of spores. For the first half of the twentieth century, common bunt was considered to be the most important disease of wheat in the Pacific Northwest. Massive clouds of sooty black spores released during harvest were a common sight in the region. When severe, the disease totally destroyed the wheat crop. When less severe, grain harvested from fields with bunt was contaminated with the spores and had a fishy odor and a darkened appearance. When that grain was milled, it produces off-white flour, which affected its market value. Wheat graded as smutty received a lower price because of the cost of cleaning the grain. During the mid 1940's, more than 40% of the grain brought to the local elevators was graded as smutty.

The large masses of spores released during harvest were easily ignited by sparks and frequently caused explosions and fires in threshing machines, combines, and grain storage facilities. Such fires destroyed machinery and crops and were a danger to people working in the area. In addition to the destruction of a major food crop and the detrimental effect of the disease on the economy of the region, the air-borne spores released into the atmosphere caused respiratory problems for people who were allergic to the spores. The disease was so important that the Pacific Northwest became known by agriculturist and plant scientists as the smut capital of the world.

In most regions of the world, spores on the seed are the major source of inoculum. Under the right environment, the spores germinate and infect the plant before the wheat seedlings emerge. The fungus grows within the plant and replaces the normal wheat kernel with bunt balls containing a black, powdery mass of spores. The Pacific Northwest, however, has a unique environment that allows the pathogen to survive in the soil as well as on the seed. Thus, many of the methods used to control the disease in other regions were not adequate for control of the disease in the Pacific Northwest. Use of seed protectants did not prevent infection by the fungus in the soil, and adjusting planting dates and other management practices only reduced disease severity. Use of resistant varieties was at best short-lived. Within a few years after the release of new resistant varieties, new races of the pathogen that could circumvent that resistance evolve.

The discovery that polychlorobenzenes, such as hexachlorobenzene (HCB) and pentachloronitrobenzene (PCNB), would control soilborne common bunt was a major break-through in the 1950's. Use of those seed treatments has reduced common bunt from the most important disease of wheat in the region to a disease of minor importance. The treatments not only controlled common bunt but also extended the life of resistant varieties by delaying the appearance of new races. More recently, new fungicides that also control common bunt have effectively controlled the disease.

Flag Smut. Flag smut caused by the fungus *Urocystis tritici* was first detected on wheat in the Pacific Northwest in 1940. During the following 20 years, the disease spread to additional counties of eastern Washington and Oregon, but little was done to control the disease primarily because other diseases were more important, especially common bunt.

By 1968 when I arrived in the Pacific Northwest, flag smut had become the most important disease in Klickitat County, WA and Wasco County, OR and had spread to several other counties of the two states. Like common bunt, clouds of flag smut spores were often observed during harvest. It was common for flag smut to cause annual losses of 10% or greater. Many of the commercial varieties grown in the region were susceptible and several new varieties being considered for release were also susceptible; the seed treatments that were so highly effective for control of soilborne common bunt did not control flag smut; information on the epidemiology and control of the disease was inconsistent, often contradictory, or unavailable; and the distribution and potential destructiveness of the disease was not clear. To add to the problem, there was concern about the possible effect of the disease on the export market, since some countries have quarantines against importing grain contaminated with flag smut.

Like common bunt, flag smut survives in the soil as well as on the seed and infects the plant before emergence. However, the disease does not appear in the heads. Flag smut appears as gray-black stripes between the veins of leaf blades and sheaths. Infected plants are usually dwarfed with distorted and twisted leaves. When severe, heads never develop.

Research on control of flag smut was initiated in 1968. By 1972, the environmental and managerial factors that contributed to severe flag smut were determined and the disease was controlled. The major break-through was the discovery that two, new systemic seed treatments, oxycarboxin (Plantvax) and carboxin (Vitavax), would provide complete control of flag smut. Carboxin became the registered treatment, because it was also effective against common bunt. Because of the use of carboxin, flag has become an insignificant disease of wheat in North America and is no longer a threat to the marketing of wheat in the Pacific Northwest. More recently, newer seed treatments have been developed that control flag smut at lower rates.

Loose Smut. Loose smut, caused by the fungus *Ustilago tritici*, is most obvious when new heads emerge. The disease first appears as deformed spikelets filled with a dry, dusty, powdery mass of black spores enclosed by a fine membrane. The membrane quickly disintegrates, and within a few days, only the bare spike with a few black spores remains. The exposed spores are dispersed by wind to newly emerging healthy heads where they germinate and infection the plant when the spikelets open for pollination. The fungus develops in the embryo as the seed develops and becomes dormant as the seeds ripens. The pathogen remains dormant within the seed until the seed germinates. Then it grows along with the plant and ultimately occupies the developing spike.

Loose smut has been difficult to control for centuries primarily because it is dormant within the seed embryo. Applications of protectants to the seed surface were ineffective, and other treatments that penetrated the seed were difficult to use. The break through in the control of loose smut was also seed treatment with the systemic fungicide, carboxin.

Dwarf Bunt. Dwarf bunt, caused by the fungus *Tilletia controversa* and also called dwarf smut or TCK smut, is similar to common bunt, except that it infects tillers of wheat plants in the winter under snow at temperatures near freezing, and it can survive in the soil for many years. Because of those characteristics, the disease was not controlled by the seed treatments that were effective in controlling common bunt, flag smut, and loose smut. Planting very early or very late in the fall and combining several genes for resistance into one variety reduces losses in yield caused by dwarf bunt but does not provide complete control and does not prevent contamination of the grain. Furthermore, the People's Republic of China has a quarantine to prevent the import of grain contaminated with dwarf bunt spores. Thus, a few spores in a grain sample can affect international marketing of wheat from a region, even when the disease does not significantly reducing yield in that region or reduce flour quality . Such restrictions have had the effect of eliminating a major world market. Results of our recent research show that a new systemic seed treatment called difenoconazole (Dividend) provided complete control of dwarf bunt under a wide range of environmental and managerial conditions. The new treatment was registered in the summer of 1994 and was used extensively to treat fall planted wheat in 1994 and 1995. Hopefully, difenoconazole will be as effective in controlling dwarf bunt as the other treatments were in controlling common bunt, flag smut, and loose smut and will alleviate the problems related to marketing wheat in China.

Karnal Bunt. Karnal bunt (partial bunt), caused by *Tilletia indica,* is a new smut disease of wheat in the United States. Karnal bunt is a disease occurs under the environmental conditions that occur in India, Pakistan Nepal, and Mexico and is seldom severe and seldom affects grain quality even in those countries. The disease was detected in Arizona and California in regions adjacent to Mexico in March 1996. The smut spores survive in the soil and germinate when wet to produce a type of spore that is carried to wheat heads where infection occurs. Because of its environmental requirements for survival, germination, and infection, Karnal bunt is not expected to become a production problem in the Pacific Northwest or in regions of northern United States. It should not affect yield or quality in those regions. However, because of national and international quarantine regulations, the disease has an impact on the marketing of wheat. It is to the southwestern United States what dwarf bunt is to the Pacific Northwest. Some seed treatments reduce the spread of Karnal bunt, but none of the currently registered seed treatments provide 100% control of the bunt. Future control of Karnal bunt on seed will depend upon the ability of the seed treatments to kill all spores in and on the wheat seed or in the soil or to kill all germination spores. Some systemic foliar fungicides show great possibilities for preventing infection of the heads or for preventing disease development in the field. There is a need for research aimed at elucidating the epidemiological factors affecting the disease in order to understand its importance to the wheat industry and implement control methods.

General Comments Regarding Control of Smuts and Bunts. Quarantine regulations have proven to be ineffective and unnecessary for control of the smuts and bunts. Whereas, use of resistant cultivars, and management, has controlled the diseases. The use of seed treatments for the control of smuts and bunts is the best example of the effectiveness, value, usefulness, and importance of chemicals for control of cereal diseases. Seed treatments have provided outstanding control of common bunt, flag smut, and loose smut with essentially no adverse environmental impact and a minimum cost to the grower. There is strong evidence that difenoconazole will provide similar control of dwarf bunt. Seed treatments and foliar fungicides have possibilities for control of Karnal bunt. Use of chemical seed treatments has prevented world-wide crop losses and saved the economy of the Pacific Northwest while preventing pollution of the environment with bunt and smut spores. The newest systemic fungicides control the diseases at rates lower than 0.5 ounces per acre, rates that have essentially no affect on the environment. If the seed treatments were not available, those diseases would return to their former importance, and the economy of the Pacific Northwest would be drastically affected.

EXPERT SYSTEM FOR INTEGRATED MANAGEMENT OF WHEAT DISEASES AND SUSTAINABLE WHEAT PRODUCTION

Roland F. Line
USDA-ARS, WSU

An expert system for managing wheat diseases referred to by the acronym MoreCrop (Managerial Options for Reasonable Economical Control of Rusts and Other Pathogens) was developed for the U.S. Pacific Northwest. The purpose of MoreCrop is to present outcomes that may happen and options for control. The user evaluates the provided information and by a process of reasoning determines the most economical control. MoreCrop was developed using the enormous knowledge base on wheat diseases together with tools from recent technological advances in the computer industry. It provides information, options, and suggestions to help the user make decisions regarding management of wheat diseases. MoreCrop predicts what diseases are more likely to occur based on selected geographical regions, agronomic zones, crop managerial practices, cultivar characteristics, prevailing weather, crop history, and disease history and provides the reasons for the disease outcome. The classical disease triangle is used as the overriding principle in predicting the diseases; i.e. a susceptible host, a virulent pathogen, and a favorable environment must exist for the disease to develop. It considers the diseases that are likely to occur and evaluates integrated disease management (IDM) options. It can suggest an IDM program or provide an opportunity to develop a customized IDM program. It evaluates the IDM program, provides a list of diseases that can and can not be controlled, and the rationale for control or absence of control. MoreCrop can use past decisions to reconstruct disease conditions, assist in reasoning which control option to select, and provide disease-related as well as cultivar-related information for teaching, research and extension. The concepts of MoreCrop can be extended to include fertility management and management of other pests. Thus, MoreCrop can serve as a prototype in developing a total wheat management program. Its programming structure, the visual controls, and the principles should be easily adapted for use in IDM of other crops or in other regions of the world. For details about MoreCrop, contact Roland F. Line, Agricultural Research Service, U.S. Dept. of Agriculture, 361 Johnson Hall, Washington State University, Pullman, WA 99164-6430, Telephone: 509/335-3755. To purchase MCP22 MoreCrop, contact Washington Cooperative Extension Bulletin Office, Cooper Publication Building, WSU, Pullman, WA 99164-5912, Telephone: 509/335-2857.

DEVELOPMENT OF MOLECULAR MARKERS ASSOCIATED WITH QUANTITATIVE TRAIT LOCI IN WHEAT FOR DURABLE RESISTANCE TO STRIPE RUST

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A RAPD marker associated with quantitative trait loci for durable, high-temperature, adult-plant resistance to *Puccinia striiformis* f. sp. *tritici* was identified using bulked segregant analysis of F3 families. Genomic DNAs of the five most resistant and five most susceptible F3 families of a cross between Stephens (resistant) and Michigan Amber (susceptible) were bulked based on disease severity ratings from field data. A 1.1 kb DNA fragment amplified by primer OPF-14 was present in the resistant bulked samples and Stephens, but not in the susceptible bulked samples and Michigan Amber. Sequence characterized amplified region (SCAR) primers developed from the RAPD marker were used to analyze the F5 families. The specific PCR band was present in six of the top resistant F5 families but not in the susceptible families. RFLP and nulli-tetrasomic analyses show that the marker is located on the short arm of chromosome 3B. Probes flanking the 1.1 kb DNA fragment will be used to identify markers that are more closely linked to the resistance gene(s).

WHEAT AND BARLEY ROOT DISEASE RESEARCH

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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*, occur in various mixtures in wheat and barley field soils of the Inland Northwest and collectively cause major damage to these crops. Research over the past 20 years using soil fumigation as a tool gives some idea of the importance of these root diseases: the average increase in yield of winter wheat in response to soil fumigation has been 70, 22, and 7%, respectively, in commercial fields cropped every year, every other year, and every third year to wheat. Besides showing the importance of root diseases, the results with soil fumigation also show the value of the 3-year crop rotation, which can be almost as effective as fumigation for root disease control. Soil fumigation is not an option, but neither is the 3-year rotation always acceptable in this region where the climate and soils are so very suitable for wheat and barley at least every other year or two years in three.

The poor performance of wheat and barley planted into wheat or barley residue, typical of "one-pass" (direct drilled) planting systems, is also the result of root diseases, favored by: a) the moist conditions, typical of soil covered with straw; and b) better survival of the root pathogens, owing to slower decomposition of infested residue and more volunteer hosts. Yet one-pass (or two-pass) planting systems, where the field is tilled, fertilized, and planted into standing stubble with one (or two) passes, offer one of the few if not only emerging technologies with the potential to reduce costs (because of fewer trips over the fields), increase yield (because of more water available for the crop), and save or even improve the soil (because of less erosion and more soil organic matter). Root diseases must be controlled to achieve both the high yields and the fertilizer-use efficiency possible with conservation farming and frequent cropping to small grains.

The practices developed thus far to manage root diseases of wheat and barley planted without tillage (other than at the time of fertilizing and/or planting) are as follows:

1) Use a crop rotation such as spring barley/spring peas or lentils/winter wheat in the high rainfall areas; spring barley/fallow/winter wheat in the intermediate rainfall areas; and winter wheat/fallow/winter wheat or continuous spring grain rotations in the low-rainfall areas, to reduce the inoculum load of pathogens in the soil;

2) Clean up the volunteer at least 7-10 days (or preferably 2-3 weeks before planting or already in the fall) before planting spring cereals into cereal stubble, and keep fallow clean, to reduce the inoculum load of pathogens in the soil; and

3) Fertilize at the time of planting, including, place the fertilizer band within easy access of the primary root system of young wheat or barley plants so as to make nutrients more accessible to diseased roots. Soil disturbance at the time of planting and

within the seed row can also be beneficial in cases of seeding directly into stubble where Rhizoctonia root rot is important.

It is important to recognize that the root disease pressure on wheat and barley results from several strains and species of at least three groups of soilborne fungi. The group responsible for take-all is represented by a diversity of strains known by one name - *Gaeumannomyces graminis* var. *tritici*. The group responsible for Rhizoctonia root rot is represented by at least three very different species-- *Rhizoctonia solani* AG8, *R. oryzae* and *R. cerealis*. *R. solani* AG8 causes mainly root pruning and hence stunting of seedlings, whereas *R. oryzae* can cause seed rot and hence stand failure. *R. cerealis* causes root pruning and also infects the lower stems. Strains of *Rhizoctonia oryzae* can now be detected and distinguished in plant tissues by molecular techniques based on their unique DNA. The group responsible for Pythium root rot is represented by several species, of which *P. irregulare* and *P. ultimum* may be most important.

While mixtures of pathogens 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 *Rhizoctonia*, especially *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*, possibly *R. cerealis*. A treatment designed to control just one component can sometimes favor another member 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 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 Apron + Terrachlor controls both pathogens on seeds and very young seedlings but the plants are still vulnerable to take-all. Thiram and Captan control seed-infecting pathogens only, although neither of these fungicides are 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*. Dividend + Apron is now available commercially to broaden the spectrum of effectiveness to include *Rhizoctonia* and *Pythium* infection of seeds and seedlings and possibly also provides some protection against take-all.

Our greatest effort is in development of biological controls for these root diseases. We have identified a great diversity of microorganisms naturally associated with roots of wheat and that have the ability to produce antibiotics inhibitory to one or more of these wheat root pathogens. Most of our research on these beneficial root-associated microorganisms has been aimed at understanding how they control take-all, the root disease that seems to be most amenable to this kind of biological control. We have obtained some of the best results against the combination of all three root diseases using select strains of microorganisms combined with Dividend and applied as a seed treatment. Some strains have also shown activity against Pythium root rot, and one strain has shown activity against all strains of the take-all fungus, *Rhizoctonia*, and *Pythium*. The reservoir of potentially useful microbial germplasm in some soils seems virtually unlimited.

At least two kinds of antibiotics produced by these microorganisms have been identified. The genes for production of two of these antibiotics have been cloned and expressed in other bacteria that normally do not produce them. This accomplishment shows that microorganisms can be "genetically engineered" to express a desirable trait such as ability to inhibit one or more root pathogens. The other important attribute of effective strains is their ability to establish competitively in the root zone of wheat or barley following their introduction as a seed treatment. We have learned a great deal about this process as well, including, not surprisingly, that different strains seem to do better in different soils. We may need to select strains for adaptation to local conditions and then genetically introduce or combine traits for ability to control the local mixtures of root pathogens.

Field trials are currently in progress in eastern Washington and northern Idaho with these bacteria. In 1993 near Almota, winter wheat planted directly into stubble of winter wheat averaged 25 bu/A greater yield (100 bu/A vs. 75 bu/A) in response to seed treatment with one of our most widely effective strains. In 1995, also near Almota, winter wheat planted directly into spring wheat stubble averaged 17 and 21% higher yields in response to seed treatments with Dividend plus two select strains of microorganisms, respectively, while Dividend alone and each strain alone gave no yield response. We have conducted nearly two dozen performance trails with microbial seed treatments in growers' fields with spring and winter wheat and spring barley planted directly into cereal stubble, and continue to see progress towards more consistent and significant responses. We are very encouraged by these field trials. We have also had success with *Pythium* control; one strain tested in field plots near Pullman where Pythium root rot was the dominant root disease gave an average yield increase of 25%.

Most recently, in greenhouse tests conducted in cooperation with Steve Jones, we have discovered a high degree of resistance to both take-all and Rhizoctonia root rot in the wheat relative *Dasapyrum villosum*. This could be the first breakthrough ever in finding a source of genes for use in wheat to help manage the root disease complex. We also have trials in cooperation with Steve Ullrich to find useful sources of resistance in barley to Rhizoctonia root rot and are beginning cooperative work with Kim Kidwell on comparisons of spring wheats for resistance/tolerance to root diseases.

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. We have begun the steps to scale-up and eventual commercial use of our seed treatments. 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 is 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 grower and agribusiness cooperators.

DRYLAND SOIL FERTILITY

Tim Fiez
Extension Soil Fertility Specialist

Below are summaries of ongoing research projects at Washington State University in Dryland Soil Fertility. Several of these trials are new and have been started this year. If you need information beyond what is in the summaries, or if you have suggestions for new soil fertility projects, please contact me at 509-335-2997.

Chloride Fertilization of Winter Wheat

Researchers in Montana, Oregon, Washington, and the Great Plains have been finding that the application of chloride can increase wheat yields. While chloride is essential for general plant biochemistry, many of the studies showing economic benefit from chloride application have associated chloride with disease suppression or a reduction in physiological leaf spot.

We have placed an experiment at Spillman Farm to compare fall application of $CaCl_2$, KCl, and K_2SO_4 to no K or Cl fertilization on winter wheat. This experiment allows for a comparison between K and Cl. It is possible that previous reports of yield responses to KCl has been due to the Cl and not the K. These treatments duplicate (with the exception of the fungicide treatments) an ongoing experiment which is being conducted in eastern Oregon. We currently do not address Cl in our dryland wheat fertility guides, and as we learn more about Cl, we may need to direct resources into building a recommendation database.

N Fertility for CRP Takeout

The Dryland Cropping System Team—Baird Miller, Roger Veseth, and Tim Fiez-- has been investigating management considerations for returning CRP ground to crop production. As part of a systems approach for taking CRP out, we have established several N rate by tillage system trials. The purpose of these trials is to determine the degree of N immobilization, the conversion of N from mineral to organic forms, as the CRP grass starts to break down after takeout and to determine if the degree of immobilization varies by tillage system. Tillage implements or burning can make huge differences in the amount of CRP biomass that is soil incorportated.

We will be combining data from a 1995 experiment on George Young's farm in Columbia County in cooperation with Roland Schirman, and three 1996 experiments in place on the Lenard Roth farm in Adams County, the George O'Neal and Remie DeRuwe farm in Franklin County, and the Andy and John Rustemeyer farm in Lincoln County. Look for a complete data summary in late summer/early fall. If you need immediate information, please contact me (Tim Fiez, 509-335-2997) or Roger Veseth (208-885-6386).

Fertilizer Management in No- till Barley: a Matter of Inches?

Research by Dr. Jim Cook has shown that proper fertilizer management is a matter of inches. Root accessibility to fertilizer is of great importance when root diseases occur such as in cereal after cereal rotations under no-till. Fertilizer should be banded in no-till systems. It is key to place the fertilizer so the seminal roots can access the fertilizer band. Placement below or below and 2-3" to the side of the seed is best for seminal root access. In addition to giving good root access to the fertilizer, under-seed soil disturbance by a fertilizer shank can improve yields, apparently by disturbing the disease organisms.

Usually the position of the fertilizer band is determined by the brand/model of drill. Even though the differences in band placement might be measured in inches, yields can be affected if seminal roots cannot reach the fertilizer. No-till drills are major investments. While we cannot test every drill, we are continuing research in fertilizer placement to determine which inches matter .

Palouse Conservation Farm No-till Barley Experiment

We have started a no-till barley experiment this year at the Palouse Conservation Farm. This project is a joint effort between Alex Ogg, Roger Veseth, Jim Cook, and me. The experiment will investigate the following for no-till barley after barley:

- Fertilizer placement
  - -below or below and 3-1/2" to the side of the seed using the Cook research drill.
  - -placement to the side at seed depth using the USDA cross-slot drill.
- Green bridge control
  - -spray-out of volunteer and weeds three weeks or more or three days before seeding.
- P fertility
  - -Is there a benefit from starter P application, and does the benefit vary with how the P is placed?
- Seed treatment
  - -There is a Dividend and Apron treatment.

To learn more about this exciting experiment and to actually see the treatments, please come to the Palouse Conservation Farm Field Day.

Spring N Management and Topdress Options for Winter Wheat

Is there an alternative to aerial topdressing of winter wheat after winters such as 95-96, when large amounts of N were leached out of soil profiles? The Columbia County Farm Bureau has been using a spoke wheel injector to ground-apply N on winter wheat fields for the last two years. A spoke wheel injector is as it sounds: it is a wheel of spokes. Each spoke has a hole in the end which, when the wheel rolls over the ground, will inject fertilizer 4-5" deep into the soil with very little disturbance.

Working with Dave Sutherland of the Farm Bureau, growers Dave Fletcher and Randy James, Roland Schirman of WSU-Columbia County, and Craig Walters of PACER Consulting, we have set up two trials in Columbia County to compare spoke wheel injection of solution 32 and aqua ammonia to topdress applications of ammonium nitrate and urea. As the spoke wheel method requires that the ground be dry enough to support a tractor, we are comparing two application timings for the spoke wheel. The first timing will be as soon as the ground is dry enough. The second timing will be at the 5.5-6.5 Haun leaf stage before significant jointing occurs. The aerial topdress treatments will coincide with typical grower application dates.

The ability of the spoke wheel to apply N below the soil surface and at rates that might not be feasible with an airplane can make it an important tool for N management in winter wheat. In the high rainfall areas, growers could apply a moderate N application in the fall and supply the rest of the crop's N needs in the spring using the spoke wheel. Please keep an eye out for the results of this experiment as we have a good visual response to the N treatments at the time I am writing this (May 20).

Fertilizer Management for Continuous Spring Cropping in Traditional Wheat-Fallow Areas

Dr. Bill Pan, as part of Frank Young's Ralston experiment, is in the second year of a study to investigate fertilizer rates and placement for hard red and soft white spring wheat. Last year, there was a yield response to P and the two researchers were able to place a surprising amount of fertilizer directly with the seed, without causing injury. A summary of the first year results will be presented during tours of the Ralston trial this summer.

SOIL QUALITY PERCEPTIONS OF EASTERN WASHINGTON CRP CONTRACT HOLDERS

Mary L. Staben, Douglas L. Young, and David F. Bezdicek

The assessment of soil quality on Conservation Reserve Program (CRP) lands is important in determining the program's overall value. The field portion of this study included 20 paired fields of CRP and wheat-fallow (W-F) fields that were compared to determine possible soil quality differences. In 1994, soil samples were analyzed for chemical and biological soil properties. The data show that there were soil quality differences between the CRP and W-F soils. After four to seven years in grass, the total organic carbon and microbial biomass contents of the CRP fields were not significantly different from the W-F soil; however, total nitrogen and enzyme activities had increased. Soil pH had increased 0.7 units and nitrate levels had decreased under CRP. The data indicated that soil quality in the CRP was improving after four to seven years compared to its previous function as a W-F cropland.

It is also important to consider growers' perspectives on soil quality and the CRP. The objective of the survey reported in this paper was to gather information on how the growers in this study evaluated soil quality and the CRP. In March 1994, nine CRP contract holders in Adams County, Washington responded to a three-page questionnaire to help in evaluating their perceptions of soil quality and the CRP. These growers were also participants in the physical assessment study. Because the survey was based on a small ($n = 9$) nonrandom sample, no statistical analyses were performed on the results.

All nine respondents in this study indicated that erodibility and crop yield potential were the most important attributes of soil quality (Table 1). Moisture absorption and storage were almost as important as yield and erodibility. Workability, look, and pest and weed resistance were fairly important to these growers, with about half the respondents ranking each attribute as very important and the other half ranking them as moderately important. The growers placed soil feel and smell as least important for determining soil quality.

Six out of eight growers indicated that reducing erosion on their farm was a moderately to very important reason for enrolling land in CRP (Table 2). The ability of CRP to provide income was moderately to very important to all respondents. A 1989 Soil and Water Conservation Society survey showed that CRP contract holders in the Pacific region, including California, Oregon, and Washington, placed economic factors for enrolling in the CRP higher than these factors were placed by any other region in the nation.

Six of the eight growers felt that letting their soil rest/regenerate was a moderately to very important reason to enroll their land in the CRP. Environmental reasons, such as reducing erosion and soil regeneration, were ranked almost as highly by these growers as economic motivations. Three write-in responses were received to the question on reasons for enrolling land in CRP. These write-in reasons included "land not profitable to farm at current prices," "landlord's instructions," and "soil not appropriate for cultivation."

Table 1. Frequency distribution of growers' views on attributes of soil quality ($n = 9$).

	Response			
Attribute	Very Important	Moderately Important	Of Little Importance	Not Important
Look	4	5	0	0
Smell	0	5	2	2
Feel	2	5	2	0
Workability	5	4	0	0
Erodibility	9	0	0	0
Pest and weed resistance (n = 8)	4	3	1	0
Moisture absorption and storage	8	1	0	0
Crop yield potential	9	0	0	0

Table 2. Relative importance of reasons why growers enrolled land in CRP ($n = 8$).

	Response			
Reasons	Very Important	Moderately Important	Of Little Importance	Not Important
CRP provides income	6	2	0	0
Reduce erosion on your farm	4	2	1	1
To let your soil rest or regenerate	2	4	1	1

Eight of the nine growers agreed or strongly agreed that CRP had improved soil quality on their farm (Table 3). Results from the field portion of this study indicated that there had been a slight shift towards improved soil quality on the CRP sites compared to the wheat-fallow sites. The growers appear to have slightly more conviction on the improvement in soil quality by CRP than the field data show. This may be the result of information the growers have received on how grass improves soil quality. Most have little personal experience with grass systems.

Analysis of the results showed there was a slight correlation between erosion as a very important reason for enrolling in CRP and perceived air quality improvements. It is possible that growers concerned with erosion on their farm might be more aware of environmental changes, such as improved air quality.

Summary and Conclusions

The results from this study indicated that growers rely mainly on aspects of soil and plant health to determine soil quality. Growers indicated that economics was the greatest factor in choosing to enroll in the CRP, although environmental reasons were almost as important. There appeared to be some connection between erosion as a reason for enrolling in CRP and perceived air quality improvements from CRP.

The results from this survey indicated that the growers felt that CRP had improved soil quality on their farms, which agreed with the physical measurements of soil quality taken on their CRP fields. The growers expressed a relatively high level of confidence in the soil quality improvements on their CRP land. This may encourage them to convert CRP land to crop production when contracts expire in order to capture the benefits from the perceived increase in soil productivity. This and other studies documenting improvements in soil quality from CRP could also influence Congress to continue the program as exemplified by the CRP extension in the 1996 Farm Bill.

Table 3. Other grower perceptions of CRP (*n* = 9).

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Do you feel that soil quality or health were improved by CRP on your farm?	2	6	1	0	0
Has CRP improved air quality in Adams County?	1	4	3	0	1

SOIL QUALITY AND SOIL MICROBIOLOGY

A.C. Kennedy, C.R. Peterson (USDA-ARS, Pullman, WA),
T.L. Stubbs, P.S. Frohne (Crop & Soil Sciences, WSU),
V.L. Gewin (Environmental Science Program, WSU)

Soil quality is a term used to describe the essence or natural characteristics of a soil. Soil can be thought of as a savings account, where the crop is the interest. The greater the amount of savings, the greater the amount of interest earned; the better the quality of the soil, the greater the potential for high crop yields. In the case of soil, spending too much of the savings can lead to financial ruin. The better the soil quality, the better this natural resource will be able to provide for us. Over the past year, we have worked on a number of projects in an effort to maintain or improve soil quality for maximum production.

TILLAGE AND BURNING EFFECTS ON SOIL QUALITY

Burning is one of many residue management tools that eliminates the excessive seedbed tillage operations normally required to reduce residues and control weeds and diseases in continuous winter wheat production. Burning followed by intensive tillage can result in excessive soil erosion, loss of organic matter, and degradation of soil quality. Burn/low-till represents a possible management scheme for growers with high post-harvest residue. Currently, there is a very small research knowledge base for determining soil quality differences between burn/low-till and conventional tillage and for developing management practices to retain or enhance soil quality benefits. Assessing the differences in soil quality between these systems is a unique opportunity to compare these management practices. We have monitored changes in soil biological and chemical parameters. Soil pH, electrical conductivity, organic matter, microbial biomass, readily-mineralized carbon, and fatty acid analysis (to determine community structure) were conducted. While these soil quality parameters were similar between the two treatments, the data indicated a tendency for greater carbon sequestration in the burn/low-till than the no-burn, tilled comparisons. Changes in microbial community structure were evident between the two management strategies. This research will provide growers with greater management options for cereal production, while reducing soil erosion and enhancing soil quality on highly erodible lands.

MICROBIAL CHANGES OF SOIL QUALITY IN CONSERVATION RESERVE PROGRAM TAKE-OUT

The Conservation Reserve Program (CRP) has impacted soil, air and water quality by reducing soil loss from highly erodible lands. As the ten year contracts expire, and these lands are placed back into production, our CRP takeout study offers a novel approach to assess changes which have occurred in the grassland system. The objective of our research was to determine changes in soil quality parameters with different tillage intensity levels. Soil physical, chemical, and biological parameters of both CRP and the tillage practices used in this study, including plowing, discing, burning, sweeping, harrowing, mowing and no-till were monitored. Our portion of the study focused on biological parameters since they respond rapidly to perturbations. Soil pH, electrical conductivity, dehydrogenase, biomass, readily-mineralized carbon, nitrifier populations, substrate utilization, and fatty acids were analyzed. The most intensive tillage practices had the greatest and most variable response. Monitoring the biological parameters will help us assess the best management practices for the system.

BIOSOLIDS EFFECTS ON SOIL QUALITY

One way that soil quality can be enhanced is by the addition of organic matter to the soil. Practices such as adding biosolids to fields can help accomplish this by leading to increased grain and straw yields. By maintaining this additional crop residue, wind and water erosion will be reduced. Soil aggregation may improve with the addition of biosolids, which may also reduce wind erosion potential. Biosolids appear to provide essential nutrients to the crop which may have been mined from the soil. Biosolids add nitrogen to the soil as well as some micronutrients which might be lacking. Excess biosolids, as with anything, may not necessarily be a good thing. It is important to take soil tests to monitor pH and nutrient levels. Soil microbial activity doesn't appear to be enhanced, so further studies are needed to see what is happening with biosolids application. The soil is a resource which must be maintained for plant and human health in future generations. Biosolids have the potential to be a management practice that improves soil quality.

BIOLOGICAL CONTROL OF WEEDS IN CEREALS

Weed management is one factor limiting yield in cereal grain production, and can affect soil quality. We are researching biological control as an alternative means of suppressing weed growth and establishment. We have worked specifically on utilizing soil bacteria to control the weeds downy brome (*Bromus tectorum* L.) and jointed goatgrass (*Aegilops cylindrica* L.). Suppression of downy brome and jointed goatgrass has been shown in field plot studies. The downy brome inhibitory bacteria suppressed downy brome aboveground growth by up to 50%. Jointed goatgrass aboveground growth was inhibited by up to 75% with the application of jointed goatgrass inhibitory bacteria. When suppression of either weed by the bacteria was greater than 40%, an increase in crop yield was generally seen.

We are investigating formulations to protect these microorganisms, and enhance their growth and survival in soil to aid in delivering viable and active biocontrol agents. Strains of our bacteria have been incorporated into a clay encapsulation prepared by the Lipha Tech Company of Milwaukee, WI. By increasing the length of time the bacteria are able to survive in the soil under sub-optimal conditions, we hope to increase the window of time the bacteria survive under the warm, dry conditions which are often present in eastern Washington during the fall.

Combinations of biocontrol agents and reduced rates of chemical herbicides may improve and broaden the spectra of weed control. In greenhouse studies, we found that by combining strains of bacteria with sub-lethal rates of herbicide we could achieve a greater degree of weed root and shoot inhibition than by using either the bacteria or the reduced rate of herbicide alone. One particular strain of bacteria in combination with the herbicide diclofop (Hoelon) was successful in reducing jointed goatgrass shoot dry weight 36% more than with Hoelon alone.

Weed-suppressive soils can be an important component of weed control by enhancing weed suppression. The number of weed suppressive bacteria in soil varies with management, which may influence the competitive ability of the weed, and thus may be a useful consideration in developing biological control agents. Microbial activity of indigenous organisms can be managed for weed seed decay, and could contribute to the depletion of the weed seed bank. The horizonation of residue and microbial activity in some systems, such as no-till, establishes areas of increased seed decay potential within the residue zone, thereby exhibiting increased weed suppression potential relative to other microsites.