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Department of Crop and Soil Sciences

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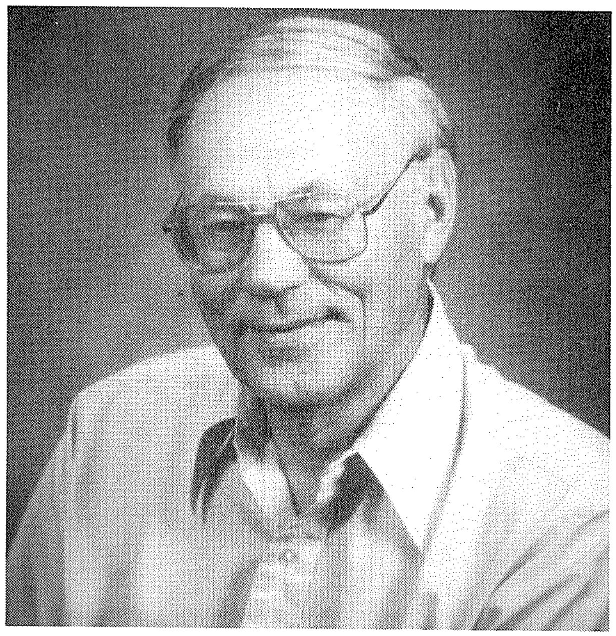

1994 Field Day Proceedings: Highlights of Research Progress

Dryland Research Unit, Lind
June 16, 1994

Integrated Pest Management, Pullman
June 23, 1994

Spillman Farm, Pullman
July 7, 1994

Baird Miller, Editor

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

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DEDICATION TO CALVIN F. KONZAK

Dr. Calvin Konzak retired from Crop and Soil Sciences Department of Washington State University (WSU) in December 1993 after an exemplary career of 37 years as professor, agronomist and spring wheat breeder. A native of North Dakota, he obtained his B.S. in Agriculture from North Dakota State University (1948) and his Ph.D. in Plant Breeding and Genetics from Cornell University (1952). Prior to coming to WSU he was an Associate Geneticist at the Brookhaven National Laboratory from 1951 to 1957.

The scope and impact of his scientific discoveries, plant breeding accomplishments, teaching, and advising graduate students have been extraordinary. He developed 24 cultivars including spring oats, durum wheats, soft white spring wheats and hard red spring wheats. His variety Penawawa is currently the most widely grown spring wheat in the Pacific Northwest. He advised 14 Ph.D. and 14 M.S. students in their graduate studies in genetics and agronomy. He taught several genetics and agronomy courses and had numerous post doctorates and visiting scientists who collaborated with him on research. Many of his former students have gone on to become nationally and internationally recognized scientists, educators and CEO's.

Throughout his career C.F. Konzak has directed his genius and energy toward facilitating plant breeding. To that end, his efforts include: contributing over 300 scholarly papers on cereal genetics research; conceiving innovative germplasm evaluation procedures; designing standardized ways for data collection, processing, and analysis; outlining methods to enhance genetic variability and reduce genetic vulnerability; and writing in depth reviews of important topics in cereal breeding and genetics. Dr. Konzak and his coworkers have contributed valuable landmark publications on the genetic diversity for semidwarfism, wheat quality and mutation breeding strategy. More recently he and his students have focused on double haploids in wheat, and on wheat transformation.

Among the most notable accomplishments for which he was instrumental include developing a standardized - computer friendly pedigree system; a one-person plot combine/data acquisition system; the first procedure for embryo rescue via tissue culture (1951); a decimal code for cereal growth stages; a staining procedure to detect aluminum toxicity; and developing dual-purpose pastry and bread wheat varieties. He pioneered modern mutation breeding and conducted exhaustive studies to improve the efficiency of mutagenesis and to identify effective mutagens. His strategies for exploiting mutation breeding to augment conventional breeding have been adopted worldwide. Because of his broad expertise he served as consultant to numerous organizations including FAO, the National Research Council, International Atomic Energy Agency and several private companies. He has received many honors including U.S. Public Health Senior Scientist Fellow, the O.A. Vogel Plant Breeding Award and Fellow in AAAS, ASA and CSSA.

Cal remains actively involved in research. He began a private mutation and plant breeding program in 1982, focusing mainly on oats and durum wheats. This program has produced a wide range of semidwarf and other mutants in oats and several valuable semidwarf durums. He and his wife, Margaret, will continue to make their home in Pullman.

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Reggie Waldher	Pomeroy
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Curt/Gil/Dave White	Lamont
Bob Wigen	Dusty
Kirk Wigen	Lacrosse
Fred Wilkins	Klickitat Co.
Lyle Wiltse	Spokane Co.
Jon/Mike Whitman	Pullman
Pat Wolf	Asotin Co.
Eric/Russell Zakarison	Pullman

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 78th 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.

D. A. Deerkop was appointed farm manager in 1991.

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)			
	1993		30 YEAR AVE					
MONTH	MAX	MIN	MAX	MIN	30 YR AVE.	MONTHLY 1993	ACCUM 1993	DEVIATION
JANUARY	28	17	35	22	1.11	0.80	0.80	-0.31
FEBRUARY	34	20	44	28	0.83	0.51	1.31	-0.32
MARCH	49	31	53	30	0.71	1.27	2.58	0.56
APRIL	58	39	62	34	0.68	1.72	4.30	1.04
MAY	77	49	72	41	0.81	0.84	5.14	0.03
JUNE	75	48	81	47	0.65	0.87	6.01	0.22
JULY	78	50	90	53	0.27	2.07	8.08	1.80
AUGUST	83	51	88	52	0.42	0.39	8.47	-0.03
SEPTEMBER	79	44	79	45	0.49	0.00	8.47	-0.49
OCTOBER	67	38	65	37	0.75	0.57	9.04	-0.18
NOVEMBER	43	21	46	30	1.18	0.24	9.28	0.94
DECEMBER	37	29	38	25	1.31	1.28	10.56	-0.03
		1994				1994		
JANUARY	45	31	35	22	1.11	1.29	1.29	0.18
FEBRUARY	40	26	44	28	0.83	0.33	1.62	-0.50
MARCH	58	31	53	30	0.91	0.20	1.82	-0.51
APRIL	66	39	62	34	0.68	1.02	2.84	0.34

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, 1993-94**

Month	Monthly Avg. Temperature(F)		Precipitation (in)				
	Max.	Min.	30-Yr Avg.*	Monthly	Total Accum.	Deviation from Avg. Monthly	Deviation from Avg. Accum.
1993							
January	30.0	17.9	2.89	1.93	1.93	- .96	- .96
February	36.2	20.9	2.09	.78	2.71	-1.31	-2.27
March	49.2	32.2	1.96	1.80	4.51	- .16	-2.43
April	54.8	37.3	1.58	3.75	8.26	+2.17	- .26
May	70.5	46.3	1.52	1.85	10.11	+ .33	+ .07
June	71.5	47.0	1.49	1.09	11.20	- .40	- .33
July	72.3	48.4	.53	1.41	12.61	+ .88	+ .55
August	80.8	46.7	.95	.30	12.91	- .65	- .10
September	77.1	42.0	.99	.04	12.95	- .95	-1.05
October	64.5	38.5	1.61	.44	13.39	-1.17	-2.22
November	41.6	22.7	2.64	1.10	14.49	-1.54	-3.76
December	37.2	28.8	3.07	2.19	16.68	- .88	-4.64
TOTAL	57.1	35.7	21.32		16.68		-4.64
1993 CROP YEAR Sept. 1992 thru June 30, 1993			19.84		17.63		-2.21

*Thirty year average for precipitation, 1951-1980

SOFT WHITE WINTER WHEAT

C.J. Peterson, Jr., R.E. Allan, B.C. Miller, J.A. Pritchett,
P.E. Reisenauer, D.F. Moser, V.L. DeMacon, and L.D. Weller.

Washington wheat growers harvested 163 million bushels of winter wheat in 1993 for an average yield per acre of 65 bushels. The growers harvested 15.6 million bushels of spring wheat for a 52 bushel per acre average. The 1992/93 winter was quite cold, but the wheat was covered with snow during the cold weather. The snow remained on the ground for a long period of time and therefore snow mold caused considerable amount of damage in some regions. Eltan (released in 1990) came through snow mold infection in Douglas county in good condition and produced record grain yields. Most of the wheat in the rest of the state came through the winter in good condition.

The spring and early summer was quite cold and wet and planting of the spring crops was delayed. The cereal pathogens stripe rust, dry land foot rot, strawbreaker foot rot, Cephalosporium stripe and dwarf bunt reduced grain yields. The crop matured late and in the eastern region stem rust and leaf rust were severe.

New Lines:

Two lines (WA007686, WA007729) that were entered in the Western Regional nursery were among the best lines in the 1992/93 Washington nurseries. WA0077529 is a club wheat with good yield potential. We have been given permission to increase WA007729 for possible release in 1996. Two new lines (WA007768, and WA007769) were entered in the 1993/94 Western Regional Nursery. A number of the new hard white lines obtain from crosses with Sentry appear to have good yield potential and resistance to Cephalosporium stripe. Green plant development has improved in the anther culture program by crossing adapted lines with lines that have good green plant development. The Hard white cultivar "Arlin" is being used intensively in the anther culture program because it produces's a high percentage of green plants. Grain production of the double haploid lines that were tested in 1992/93 was encouraging as some of the lines equalled the grain production of Stephens.

Nurseries:

The performance of the commercial soft white winter wheat varieties grown in the Cooperative Washington State University/USDA-Agricultural Research Service nurseries during the last six years is shown in tables 1 through 9. The past data from Coulee City is also included, however we lost the 1992/93 nursery. Table 10 provides additional information on the varieties. Unfortunately Rely was left out of the 1992/93 nurseries.

The soft white winter wheat nurseries were grown at Pullman (early and late), Pomeroy, Walla Walla, Ritzville, Cunningham, and Cavendish, Idaho. Rod and Madsen (86 bu/a) were the best commercial cultivars when the grain yields were averaged across all locations and years (table 1). Rohde (85 bu/a) was the best commercial club wheat. There was only 4 bushels per acre separating the top six varieties.

When the 1992/93 grain yields (table 1) were averaged over the nurseries grown at Pullman, Pomeroy, Walla Walla, Ritzville, Cunningham, and Cavendish Madsen (95 bu/a), produced the most grain and Rod (94 bu/a) was second. The highest yielding club wheats were Rohde, Hyak, and Tres (85 bu/a).

The Pullman Early nursery (table 2) was sown during the first week of September. One half of each plot was inoculated with Cercosporella foot rot fungus in the fall and the other half was sprayed with a fungicide early in the spring to control the disease. Grain production (table 2) was reduced over the years by both strawbreaker foot rot and Cephalosporium stripe. Madsen (86, 89 bu/a) was the highest yielding cultivar in both treatments and Kmor (77, 80 bu/a) was second. Hyak (79, 81 bu/a) was the highest yielding club wheat under both treatments.

The Pullman late (table 3) nursery (seeded 1st week of October) was sown in a field following two years of red clover that was plowed under the second year. There was still some yield reduction caused by Cephalosporium stripe. The nursery also showed evidence of being short of moisture. Eltan (93 bu/a) and Daws (92 bu/a) produced the most grain in 1992/93. Eltan (104 bu/a) had the highest average over the past six years. Eltan needs to be seeded late because it will lodge if seeded early. Crew was the highest yielding club variety.

The stands were very good at Pomeroy (table 4) in 1992/93. The nursery did show evidence of being under an early moisture stress, the yields however were very good. MacVicar (94 bu/a) and Kmor (93 bu/a) had the highest grain yield at Pomeroy in 1992/93. When the yields were averaged over the past six years Rod (78 bu/a) and Malcolm (73 bu/a) produced the most grain. Hyak was the highest yielding club wheat over the past six years.

Grain yields were reduced in the Walla Walla (table 5) nursery by powdery mildew, Strawbreaker foot rot, leaf rust, and stripe rust. The powdery mildew and the strawbreaker foot rot caused extensive lodging. W301 (131 bu/a) had the highest grain yield in 1992/93 and Gene was second (122 bu/a). When the yields were averaged over the past six years the top two varieties were W301 (101 bu/a) and Malcolm (101 bu/a). The best club was Rohde.

The Ritzville (table 6) nursery was sown too deep and the stands were very poor. The resulting stands were related to the emergence capability of the variety. Most of the varieties tillered extensively and made up for much of the poor stand. The percent of the area covered in each plot was estimated before harvest and this estimate appears to have been low, therefore accounting for the excellent yields. Rod (95 bu/a) was the top variety in 1992/93 and Daws (94 bu/a) was second. When the yields were averaged over 4 years Rod (68 bu/a) produced the most grain. Rod is similar to Stephens in winter hardiness and therefore not a very good choice for the Ritzville area. Lewjain, Daws, Kmor, and Eltan were very similar in their performance over the 4 year period. The grain yields were reduced in the irrigated nursery at Cunningham (table 7) because of lodging. Rod (149 bu/a) and MacVicar (149 bu/a) produced the most grain in 1992/93.

MacVicar (137 bu/a) has the highest average production over the past 4 nurseries. Rod has weaker straw that Stephens and MacVicar and it will lodge under high production.

The Cavendish nursery (table 8) is sown about the 1st week of October. Dwarf bunt infection was very high and reduced grain yields. The nursery also showed evidence of being short of moisture. Lewjain and Rod (63 bu/a) produced the most grain in 1992/93. Rod (68 bu/a) had the highest average grain yield over the past six years. Hyak was the highest yielding club variety.

The Coulee City nursery (table 3)is sown the last week of August. The 1992/93 nursery was lost because of poor emergence and high winds that buried the nursery. Eltan (49 bu/a) had the highest average grain production over the past five years. Hyak was the highest yielding club variety.

The above discussion does not take into consideration if the yields are actually different based on statistical significance. Therefore the yields of the top producing cultivars are probably not different.

Table 1. Average yield data (bu/a) on soft white winter wheats grown at 6 locations (Pullman, Pomeroy, Walla Walla, Ritzville, Cunningham, and Cavendish, Idaho) and for the past 6 years (4 years at Ritzville and Cunningham).

		AVG 88	AVG 89	AVG 90	AVG 91	AVG 92	AVG 93	AVG 88/93
Nugaines	CI013968	56	79	76	72	81	74	71
Daws	CI017419	66	93	81	75	89	93	81
Stephens	CI017596	58	85	91	44	90	87	76
Lewjain	CI017909	71	92	80	69	89	83	79
HIll-81	CI017954	67	93	88	74	92	88	82
W301	ORFW0301	60	89	94	37	89	93	79
MacVicar	ORF75336	65	96	88	59	93	92	83
Gene	OR830801	-	88	73	56	84	87	-
Malcolm	PI497672	66	88	89	63	91	90	82
Madsen	PI511673	72	92	95	68	95	95	86
Eltan	PI536994	68	99	75	83	86	85	79
Kmor	PI536995	73	98	83	77	87	81	81
Rod	PI558510	73	100	89	64	95	94	86
Tres	CI017917	64	92	76	68	85	85	77
Crew	CI017951	60	84	83	68	84	82	75
Rohde	OR000855	68	87	81	61	85	85	85
Hyak	PI511694	64	86	86	79	84	85	80
Rely	PI542401	68	-	81	53	83	-	-

Table 2. Yield data (bu/a) on winter wheat varieties gown at Pullman (early), WA for six years. Inoculated with the Strawbreaker foot rot organism (moderate infection).

		88	89	90	91	92	93	Avg
Nugaines	CI013968	66	82	37	54	91	42	58
Daws	CI017419	84	101	42	37	115	70	70
Stephens	CI017596	65	96	61	26	121	70	71
Lewjain	CI017909	69	106	53	59	108	51	71
Hill-81	CI017954	81	108	47	52	117	53	72
W301	ORFW0301	56	94	62	2	91	87	64
MacVicar	ORF75336	61	10	84	73	115	86	75
Gene	OR830801	-	94	66	16	103	102	-
Malcolm	PI497672	55	90	67	35	112	79	70
Madsen	PI511673	78	102	92	39	130	93	86
Eltan	PI536994	58	103	42	57	105	80	68
Kmor	PI536995	93	105	53	74	100	53	77
Rod	PI558510	59	104	48	45	117	69	72
Tres	CI017917	53	109	41	54	108	90	71
Crew	CI017951	70	94	53	56	116	74	70
Rohde	OR000855	-	92	44	30	92	65	-
Hyak	PI511674	63	94	69	69	111	84	79
Rely	PI542401	65	-	35	54	115	-	-

Treated to control Strawbreaker foot rot

		88	89	90	91	92	93	Avg
Nugaines	CI013968	62	80	84	54	95	91	65
Daws	CI017419	66	117	81	38	113	106	75
Stephens	CI017596	45	101	78	7	110	97	62
Lewjain	CI017909	73	109	90	57	115	96	76
Hill-81	CI017954	69	102	93	36	123	117	73
W301	ORFW0301	39	107	93	3	116	126	74
MacVicar	ORF75336	52	112	81	31	116	107	76
Gene	OR830801	-	80	119	8	102	110	-
Malcolm	PI497672	52	90	71	49	107	104	73
Madsen	PI511673	82	101	101	39	124	110	89
Eltan	PI536994	69	112	87	60	107	95	74
Kmor	PI536995	73	110	87	73	104	97	80
Rod	PI558510	70	98	109	37	109	101	74
Tres	CI017917	62	93	67	48	124	97	76
Crew	CI017951	61	95	89	53	119	106	77
Rohde	OR000855	-	96	88	41	97	97	-
Hyak	PI511674	62	83	84	54	112	99	81
Rely	PI542401	77	-	83	41	114	-	-

Table 3. Yield data (bu/a) on soft white winter wheats grown with a medium rate nitrogen at Pullman (Planted 1st week of October) for the past six years.

		88	89	90	91	92	93	Avg
Nugaines	CI013968	59	106	110	70	79	74	83
Daws	CI017419	64	97	114	114	96	92	96
Stephens	CI017596	72	98	134	10	90	83	81
Lewjain	CI017909	86	112	114	61	90	83	91
Hill-81	CI017954	79	106	136	91	88	79	97
W301	ORFW0301	78	109	132	14	71	64	78
MacVicar	ORF75336	77	127	121	51	77	72	88
Gene	OR830801	-	95	117	8	77	75	-
Malcolm	PI497672	88	116	121	36	96	73	88
Madsen	PI511673	86	114	125	60	84	80	92
Eltan	PI536994	83	122	122	113	88	93	104
Kmor	PI536995	90	114	116	68	93	83	94
Rod	PI558510	94	129	119	37	100	84	94
Tres	CI017917	83	108	115	73	77	77	89
Crew	CI017951	62	98	120	57	85	80	84
Rohde	OR000855	72	105	117	29	85	73	80
Hyak	PI511674	73	108	121	92	71	77	90
Rely	PI542401	81	-	114	-	56	-	-

Table 4. Yield data (bu/a) on soft white winter wheats grown at Pomeroy (planted middle of September) for the past six years.

		88	89	90	91	92	93	Avg
Nugaines	CI013968	52	61	74	85	66	79	70
Daws	CI017419	51	66	69	90	54	91	70
Stephens	CI017596	52	61	78	61	62	84	66
Lewjain	CI017909	54	64	70	85	61	85	70
Hill-81	CI017954	49	71	72	92	62	83	72
W301	ORFW0301	51	70	79	39	67	89	66
MacVicar	ORF75336	56	67	84	65	66	94	72
Gene	OR830801	-	67	84	33	68	87	-
Malcolm	PI497672	54	66	90	72	64	92	73
Madsen	PI511673	52	63	85	81	61	88	72
Eltan	PI536994	57	68	68	92	57	81	71
Kmor	PI536995	51	74	72	84	59	93	72
Rod	PI558510	60	76	75	93	71	91	78
Tres	CI017917	47	70	67	74	52	83	66
Crew	CI017951	50	69	71	72	57	91	68
Rohde	OR000855	50	67	63	72	68	83	67
Hyak	PI511674	47	66	79	81	56	90	70
Rely	PI542401	51	-	72	-	56	-	-

Table 5. Yield data (bu/a) on soft white winter wheats grown at Walla Walla (planted middle of October) for the past six years.

		88	89	90	91	92	93	Avg
Nugaines	CI013968	47	104	91	115	81	82	87
Daws	CI017419	68	104	92	118	90	108	97
Stephens	CI017596	62	91	87	130	81	110	94
Lewjain	CI017909	65	86	85	95	83	82	83
Hill-81	CI017954	67	99	87	118	83	122	96
W301	ORFW0301	61	94	101	131	89	131	101
MacVicar	ORF75336	63	104	98	128	91	109	99
Gene	OR830801	-	104	98	125	88	122	-
Malcolm	PI497672	67	114	95	133	86	108	101
Madsen	PI511673	69	100	80	123	92	120	97
Eltan	PI536994	71	109	85	111	90	80	91
Kmor	PI536995	66	98	95	106	91	71	88
Rod	PI558510	74	113	89	116	105	98	99
Tres	CI017917	63	101	97	94	96	98	92
Crew	CI017951	61	89	91	108	90	89	88
Rohde	OR000855	66	101	92	136	88	119	100
Hyak	PI511674	65	95	96	108	98	97	93
Rely	PI542401	65	-	88	-	95	-	-

Table 6. Yield data (bu/a) on soft white winter wheats grown at Ritzville (planted 1st week of September) for four out of the past six years.

		88	89	90	91	92	93	Avg
Nugaines	CI013968	39	-	53	-	51	69	53
Daws	CI017419	49	-	54	-	51	94	62
Stephens	CI017596	37	-	64	-	57	75	58
Lewjain	CI017909	53	-	61	-	61	74	62
Hill-81	CI017954	43	-	60	-	56	77	59
W301	ORFW0301	43	-	61	-	64	67	59
MacVicar	ORF75336	37	-	55	-	57	75	56
Gene	OR830801	-	-	63	-	49	76	-
Malcolm	PI497672	39	-	62	-	53	76	58
Madsen	PI511673	51	-	65	-	57	78	63
Eltan	PI536994	50	-	57	-	64	76	62
Kmor	PI536995	53	-	62	-	63	74	63
Rod	PI558510	54	-	63	-	59	95	68
Tres	CI017917	44	-	61	-	53	69	57
Crew	CI017954	48	-	58	-	50	70	57
Rohde	OR000855	-	-	52	-	56	70	-
Hyak	PI511674	53	-	62	-	57	65	59
Rely	PI542401	48	-	61	-	49	-	-

Table 7. Yield data (bu/a) on soft white winter wheats grown at Cunningham (planted the last half of September) for four out of the past six years

		88	89	90	91	92	93	Avg
Nugaines	CI013968	89	-	82	-	119	127	104
Daws	CI017419	90	-	119	-	131	136	119
Stephens	CI017596	89	-	141	-	136	138	126
Lewjain	CI017909	100	-	96	-	134	129	115
Hill-81	CI017954	88	-	127	-	149	133	124
W301	ORFW0301	100	-	140	-	145	142	132
MacVicar	ORF75336	108	-	135	-	155	149	137
Gene	OR830801	-	-	138	-	127	129	-
Malcolm	PI497672	101	-	126	-	145	147	130
Madsen	PI511673	93	-	127	-	141	137	125
Eltan	PI536994	91	-	73	-	120	116	100
Kmor	PI536995	89	-	104	-	122	120	109
Rod	PI558510	105	-	131	-	137	149	131
Tres	CI017917	92	-	82	-	104	131	102
Crew	CI017951	89	-	104	-	103	115	103
Rohde	OR000855	93	-	113	-	138	132	119
Hyak	PI511694	81	-	98	-	110	128	104
Rely	PI542401	92	-	114	-	113	-	-

Table 8. Yield data (bu/a) on winter wheat varieties grown at Cavendish, ID for six years.

		88	89	90	91	92	93	Avg
Nugaines	CI013968	35	40	74	56	64	28	50
Daws	CI017419	56	73	78	53	58	47	61
Stephens	CI017596	45	61	82	27	63	35	52
Lewjain	CI017909	64	75	71	58	59	63	65
Hill-81	CI017954	57	71	82	52	61	43	61
W301	ORFW0301	51	58	86	35	65	39	56
MacVicar	ORF75336	64	59	81	50	64	40	60
Gene	OR830801	-	18	71	9	61	23	-
Malcolm	PI497672	70	49	82	52	67	40	60
Madsen	PI511673	61	70	85	64	67	55	67
Eltan	PI536994	61	81	67	66	60	56	65
Kmor	PI536995	67	84	75	58	64	55	67
Rod	PI558510	67	78	79	58	65	63	68
Tres	CI017917	68	72	76	65	62	34	63
Crew	CI017951	37	58	81	61	54	31	54
Rohde	OR000855	59	61	80	57	55	43	59
Hyak	PI511674	64	71	81	67	59	41	64
Rely	PI542401	63	-	81	64	63	-	-

Table 9. Yield data (bu/a) on soft white winter wheats grown at Coulee City (planted the last week of August) for the past six years.

		88	89	90	91	92	93	Avg
Nugaines	CI013968	48	39	53	26	32	-	40
Sprague	CI015376	50	37	44	29	35	-	39
Daws	CI017419	49	45	52	28	36	-	42
Lewjain	CI017909	48	44	51	28	32	-	41
Tres	CI017917	45	37	46	28	28	-	37
Crew	CI017951	53	34	47	24	30	-	38
Hill-81	CI017954	43	39	51	25	33	-	38
Stephens	CI017596	55	36	52	12	35	-	38
Malcolm	PI497672	53	44	61	26	36	-	44
Madsen	PI511673	40	45	48	21	34	-	38
Hyak	PI511674	51	39	46	25	25	-	37
Eltan	PI536994	64	48	59	39	33	-	49
Kmor	PI536995	61	44	53	27	32	-	43
Rod	PI558510	50	40	56	14	35	-	39
John	WA006819	44	35	50	36	39	-	41
Andrew	WA006820	45	36	51	26	43	-	40
Hyak	PI511674	51	39	46	25	25	-	37
Rely	PI542401	45	-	52	-	36	-	-

Table 10. Index (1= poor - 10 excellent) and/or disease ratings for 18 winter wheat cultivars. Emergence (EM), winter hardiness (WH), maturity (MAT), bushel weight (BW), common bunt (CB), dwarf bunt (DB), leaf rust (LR), stripe rust (SR), and cephalosporium stripe (CS)

VARIETY	EM	WH	MAT	BW	CB	DB	LR	SR	CS
Nugaines	5	6	Medium	8	R**	S	S	MS	MR
Daws	4	8	Medium	7	R	S	MS	MR	MS
Stephens	5	2	Early	7	R	S	MS	R	S
Hill 81	5	5	Medium	7	R	S	MS	MR	MR
Lewjain	6	5	Late	7	R	R	MS	R	MR
Kmor	5	6	Late	6	R	S	MS	R	MR
Dusty	5	5	Med-late	7	R	S	MS	MR	MS
Malcolm	5	2	Early	7	R	S	MS	R	S
Oveson	5	2	Medium	7	S	S	MS	R	MS
Madsen	5	5	Medium	7	R	S	R	R	MS
Eltan	6	8	Late	7	R	R	MS	MR	MR
John	6	5	Early	7	R	S	S	S	
Crew	6	5	Medium	6	MR	S	MR	MS	MS
Tres	6	5	Medium	7	MR	S	R	S	MS
Moro	8	5	Medium	5	R	MR	S	S	MS
Hyak	6	5	Medium	7	R	S	R	R	MS
Rod	5	3	Medium	7	R	S	S	R	MS
Rely	6	5	Medium	7	R	S	MR	R	MS
MacVicar	5	4	Medium	7		S		MR	
Gene	5	2	Early	7		S		MR	
Rohde	5	4	Medium	7		S		R	
W301	5	5	Medium	7		S		MR	

** R = resistant, MR = Moderate Resistance, MS = Mod. susceptible, S = Suscept.

USDA-ARS WHEAT GENETICS RESEARCH

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

Enhancing Club Wheat Quality

Improving the quality of club wheats is a major objective of our USDA-ARS breeding program. It is perhaps the most difficult and elusive attribute that we deal with in breeding. This is because most quality parameters are very complex and are controlled by several genes whose expression can be altered by environmental variation. We may now have a way to increase our odds for genetically enhancing club wheat quality. Recently S. Jones obtained evidence that many of the older Pacific Northwest club wheats with high quality often had unique sets of genes that code for glutenin type (*Glu1*) proteins. These genes can be readily and accurately identified in the laboratory and best of all they are not affected by environmental variation. We classified several of our club wheat breeding lines for their specific patterns of these *Glu1* subunits. Next we determined whether the key subunits could be used to help predict several important club wheat quality parameters. We found that specific subunits can be used to predict flour mixing time, water absorption, cookie diameter and kernel hardness. For instance short mixing time is a desirable trait for club wheat flour. Over 50% of the lines having 1 to 3 of the key subunits had desirably low mixing time compared to less than 10% of the lines lacking these subunits. Similarly nearly 40% of all lines with these key subunits had excellent cookie diameters while only 12% of the lines lacking the key subunits were good. The key subunits proved to be equally valuable for predicting low water absorption and kernel softness, both desirable attributes of club wheat.

Broader Variety Adaptation

Modifying the heading dates of varieties has potential for broadening their adaptation. It is relatively easy to change heading date of a variety by several days by modifying 1 or 2 genes by backcross breeding. Varieties such as Lewjain and Luke have high soft wheat quality and durable resistance to stripe rust and dwarf bunt. Because they head very late they are not widely grown. Backcross derived lines of Luke that head 3 to 7 days early have yielded over 25% higher than Luke at Walla Walla where Luke is generally not adapted. Similarly early heading backcross-derived lines of Nugaines have outyielded Nugaines by 20% or more at Pullman and Walla Walla. Nugaines has tolerance to cephalosporium stripe and is among the best soft white winter wheats for resistance to pre-harvest sprouting. Paha had limited adaptation but has the best overall club wheat quality. Backcross derived Paha lines 4 days earlier in heading have had 24% higher yields than Paha at some locations. Varieties which are exceptional for complexly inherited traits such as quality, seedling vigor, coldhardiness, and complex disease resistance would be ideal candidates for modifying their heading dates to extend their adaptation across more diverse environments.

Winter Wheats for the Low-Rainfall Zones

The goal of this program is to develop soft white winter wheat varieties that have emergence capability similar to Moro with higher yield capacity. The Moro multiline continues to perform well. In 1993 tests it averaged 10% higher grain yield than Moro. Quality of Moro ML has been very satisfactory. Tall versions of Nugaines and Tres had 8 to 12% higher mean yields than Moro with good emergence. Wheat selections with Balkan-type semidwarfing genes continue to look promising. The 1993 results identified four lines that had emergence characteristics similar to Moro yet were 3 to 6 inches shorter than Moro and Omar. Yield potential of these lines ranged from 10 to 20% of Moro in preliminary tests. Several of these lines are currently in 1994 advanced yield trials. We have over 2000 early-generation club wheat lines that either have the Balkan-type semidwarf genes or are non-semidwarf types that will be screened for rust resistance and plant type this year.

RULO Club Wheat

A new soft-white winter club wheat variety named 'Rulo' (WA7622) has been recommended for joint release by USDA-ARS and the Washington Agricultural Research Center. Rulo has the *Pch$_1$* gene for resistance to strawbreaker foot rot. It has field resistance to current races of stripe, leaf, and stem rust. Rulo has three race-specific genes for resistance to the stripe rust fungus. It has partial resistance to powdery mildew, moderately susceptible to cephalosporium stripe and is susceptible to both common and dwarf bunt pathogens.

Rulo was released to replace Hyak because it exceeds Hyak for yield potential, stripe rust resistance, partial mildew resistance, and some quality parameters. Rulo has strawbreaker foot rot resistance similar to Hyak. Strawbreaker foot rot-induced grain yield losses of Rulo and Hyak have averaged 9% in our 1987 to 1993 tests; losses measured in susceptible club cultivars have averaged 32%. In 6 years of strawbreaker foot rot-inoculated yield tests, Rulo had a mean yield of 112 Bu/Ac compared to Hyak with 105 Bu/Ac. Susceptible cultivars, Tres and Rely, each had mean yields of 77 Bu/Ac. When strawbreaker foot rot was not a factor, the grain yields of Rulo have been equal to or better than those of other commercially grown club wheat cultivars. In 70 tests-years in the state of Washington and other Pacific Northwest states the mean yields were 93 Bu/Ac for Rulo while Hyak, Rely, and Tres each averaged 89 Bu/Ac.

The grain volume weight of Rulo is similar to Rely but slightly lower than Hyak and Tres. Rulo is similar to Hyak for plant height, lodging resistance, and stand establishment properties. Rulo heads about 5 days later than Hyak and is similar to Rely in heading date. It has greater post-harvest grain dormancy than other club cultivars. Rulo has coldhardiness similar to Tres and Rely and is less hardy than Hyak.

Tests by the USDA-ARS Western Wheat Quality Laboratory indicate Rulo is equal to or better than Hyak for club wheat quality. Rulo is superior to Hyak for mixing time, water absorption, cookie diameter, flour viscosity, and Japanese sponge cake volume and score. It is similar to Hyak for flour yield, ash content, milling score, and protein content. It has harder grain than Hyak but similar to Paha. Rulo does not have outstanding club wheat quality comparable to Paha. It is less desirable than Paha for flour yield, cookie diameter, Japanese sponge cake volume and score. It excels Paha for milling score and ash content.

Rulo is adapted to the intermediate to high rainfall areas of northwestern USA, particularly where losses caused by strawbreaker foot rot and rusts frequently limit production. It should be grown where problems with emergence and coldhardiness occur infrequently. Foundation seed should be available in 1995.

New Promising Club Wheat Selections

Several semidwarf club wheat selections having improved milling and baking quality, high yield potential, and combined resistances to diseases are in the 1994 regional or our advanced trials. WA7752 was the highest yielding club wheat in the 1993 Regional Tests. Comparative yields were: WA7752 (105 Bu/Ac), Rohde

(94 Bu/Ac), Tres (92 Bu/Ac), Rulo (101 Bu/Ac) and WA7729 (100 Bu/Ac). WA7752 excels Hyak for cookie diameter, top grain score, sponge cake volume, viscosity, water absorption, and mixing time. It equals Paha for milling score and all club wheat flour quality parameters. WA7752 has foot rot resistance similar to Madsen and is resistant to stripe rust, leaf rust, and powdery mildew. It emerges better than Hyak and Tres. Two tall wheatgrass derived club wheat lines (ARS 9257 and ARS 9232) have yield potential equal to or higher than Rulo and Hyak. Based on tests by T. Murray and S. Jones these selections have unique resistance to cephalosporium stripe derived from tall wheatgrass. ARS 9257 also has resistance to strawbreaker foot rot. Both lines have better overall club wheat quality than Hyak. Our 1994 tests include 230 new club selections planted at four locations. They comprise 16 different families that contain 16 known or new genes for stripe rust resistance. Their 1993 yields ranged from 90 to 125% of Hyak. Approximately 70% of these lines also have resistance to leaf rust and powdery mildew and 30% have resistance to stem rust. Only lines with club wheat quality equal to or better than Tres and Paha will be saved.

Impact of Varieties Developed by ARS in Cooperation with WSU
Wheat varieties developed by the ARS Wheat Genetics, Quality, Physiology and Disease Research Unit continue to have significant impact. In 1993 Madsen became the leading wheat variety in Washington and was grown on 658,100 acres. Club wheats developed by our ARS unit were grown on 191,900 acres in 1993. The strawbreaker foot rot resistance of Madsen and Hyak also reduced the need for benzimidazole fungicide on an estimated 500,000 acres and saved growers in Washington, Oregon, and Idaho several million dollars in production costs and also lowered potential damage to the environment.

HARD WINTER WHEAT BREEDING AND TESTING

E. Donaldson, B.E. Sauer, S.R. Lyon, C.F. Morris
and P.E. Reisenauer

An estimated 295,000 acres of hard red winter wheat were planted for 1993 harvest. This represents about 11% of the winter wheat acreage. The three major varieties were Hatton, Weston, and Wanser. Seeding conditions varied greatly across the summer fallow area. Conditions were good in the Horse Heaven Hills for the first time in many years. Seeding conditions in the Lind and Harrington areas were poor with minimal moisture. Moisture for seeding at Waterville was good and moisture at Connell was adequate. Wheat seeded early yielded very good, while later seeding did poorly. Some reseeding in the Lind and Connell area was necessary due to untimely rains. Winter injury due to cold and/or snowmold was prevalent in areas north of Lind. Foliar diseases, stripe and leaf rust, were more prevalent than in recent years due to the cool moist spring. Stem rust became severe on the later plantings at Lind under irrigation. In general, the foliar diseases occurred late and caused little damage, although spraying in some areas was advisable. Dryland foot rot was prevalent in the Horse Heaven Hills and a few areas northward. Strawbreaker foot rot and fungal stripe were severe in some areas.

The primary objective of the hard winter wheat breeding program is to provide Washington hard winter wheat producers with good quality, consistently high-yielding, disease-resistant cultivars through varietal development and testing of advanced selections and varieties developed elsewhere. The Great Plains Yield Nurseries, grown at Lind, include selections from Texas to Canada, from both public and private breeders. The Western Regional Hard Red Winter Wheat nursery, grown under dry land and irrigated conditions at Lind, includes selections from Oregon, Idaho, Utah, Montana, and Washington. In varietal development, emphasis is placed on the agronomic characteristics of emergence, lodging resistance, and yield performance. A strong emphasis in disease resistance is currently placed on strawbreaker foot rot, stripe rust, leaf rust, dwarf bunt, and snowmold. Since 1991, an increased emphasis has been placed on improving end use quality. The challenge is to improve five characteristics of quality which are inherited somewhat independently and each controlled by multiple genes.

NEW LINES

WA007759 and WA007761 were entered into the regional nursery in 1992. Their quality and agronomic performance was very satisfactory. Two new lines (WA007773 and WA007774) were entered in the 1993/94 western Regional Nursery.

WA007774 is a hard white selection. Five selections were retained in the Tri-State Irrigated Hard Winter Nursery. Three new selections were added to this nursery.

NURSERIES

The Horse Heaven Extension and State Hard Winter Wheat Nursery was planted on September 18. It contained 9 commercially available hard red winter wheats, 4 hard wheat cultivars being considered for release, and 59 cultivars from the hard wheat breeding program. Seed zone moisture was fair to good. Deep seeding resulted in some stand differences between cultivars. Hoff (31.5 bu/a) had the highest yield. Of the commercially available cultivars, Andrews and Meridian had statistically lower yields. Whole grain protein content varied from 11.7% to 15.2% with a nursery average of 13.6%.

The Finley State Hard Winter Wheat Nursery was planted on September 18. This nursery contained 4 hard red winter wheats, 6 soft white winter wheats, 3 cultivars being considered for release, and 59 cultivars from the hard wheat breeding program. Seed zone moisture was good and uniform stands were obtained. The four hard red winter varieties yielded 45, 41, 40, and 40 bu/a for Weston, Hatton, Buchanan, and Blizzard, respectively. WA7678 (51.5 bu/a) was the highest yielding cultivar in the nursery. Whole grain protein ranged from 11.6% to 14.9% with a nursery average of 13.1%.

The Harrington Hard Winter Wheat Extension and State Performance Trial was seeded into poor moisture on September 9. The nurseries were seeded deep and a uniform stand was not obtained. Some winter damage was evident in the spring. This nursery contained 9 commercially available cultivars, 4 cultivars being considered for release, and 59 cultivars from the hard wheat breeding program. Buchanan (39.9 bu/a), Blizzard (39.1 bu/a),and Weston (38.5 bu/a) had the highest yield of the commercially available cultivars. The highest grain yield in the nursery was obtained from N9107801 (41.2 bu/a). Twenty four cultivars had yields not statistically different from the highest yield. Whole grain protein content varied from 12.6% to 15.5% with a nursery average of 13.9%.

The Waterville nursery was seeded September 10 into good moisture. A wind after seeding filled the furrows and restricted emergence on part of the nursery resulting in some stand variation. Snowmold was extensive across the nursery, but most cultivars recovered. The nursery contained 9 released varieties, 4 cultivars under consideration for release and 59 cultivars from the hard winter wheat breeding program. The highest yielding commercially available cultivar was Quantum Hybrid 542 (60.1 bu/a). Meridian and Buchanan yielded 53.6 bu/a. The highest yielding cultivar was N9106801 (66.5 bu/a). Whole grain protein content ranged from 10.7% to 14.4% with a nursery average of 12.6%.

The first seeding of the Lind Dryland nurseries were rained out. The nurseries were reseeded on September 19. Seed zone moisture was poor resulting in fair to poor stands. Fall plant development was slow; plants were small at the onset of winter. Some winter damage and winterkill occurred due to a combination of winter conditions including snowmold caused by *Typhula incarnata*. Forty five pounds per acre of anhydrous ammonia nitrogen was applied in the spring of the summer fallow year. The Extension and State Hard Winter Wheat Nursery included 9 released varieties and 4 cultivars being considered for release. Of the commercially available cultivars Buchanan (27.9 bu/a) had the highest yield. Batum (25.5 bu/a) and Weston (25.2 bu/a) had yields not significantly different. N9104002 (28.8 bu/a) and N9108302 (28.7 bu/a) had the highest grain yields in the nursery. Buchanan and Weston had the best stands of the commercially available cultivars, but only Hatton and Meridian had stands significantly lower. Forty of the 59 entries from the hard winter wheat breeding program had stands statistically equal to Buchanan. The highest whole grain protein was 16.7% and the lowest was 13.3%. Meridian (15.6%) had the highest protein content of the released varieties.

The Lind irrigated yield performance nurseries were seeded between September 25 and 30. Fertilizer deficiency (probably sulfur) was evident early in the spring. Considerable field variation in some of the nurseries was apparent. Application of starter fertilizer containing nitrogen, phosphorus, and sulfur through the irrigation system in April reduced the effects and allowed later than normal tillering and late tillers to develop. One hundred pounds per acre of anhydrous ammonia nitrogen was applied before seeding. Two applications of 50 lbs/ac each of nitrogen were applied through the irrigation system in early and late May. Foliar diseases, leaf rust, stripe rust, and stem rust, moved into the nurseries late and probably reduced yields of the most susceptible cultivars.

The Tri-State Irrigated Hard Winter Wheat Nursery contained 26 entries from Oregon, Idaho, and Washington. Seven cultivars had higher grain yields than Batum. Only two cultivars yielded significantly less than Batum. All of the cultivars in the nursery are equal to or shorter than Batum in height.

The Extension and State Hard Winter Wheat Nursery contained ten released varieties, four cultivars being considered for release, and 59 cultivars from the breeding program. Batum (99.5 bu/a) had the highest grain yield of the commercially available cultivars, followed by Meridian (93.7 bu/a) and Quantum Hybrid 542 (93.4 bu/a). Only Hoff of the released varieties had a statistically lower yield than Batum. The highest yielding cultivar in the nursery was WA7759 (103.5 bu/a). Whole grain protein content ranged from a low of 12.1% for Hatton to a high of 15.7% for N9107401.

DATA FOR TRI-STATE IRRIGATED NURSERIES GROWN IN WASHINGTON, OREGON AND IDAHO

1992/93	ABERDEEN, ID YIELD BU/AC	TEST WT.	PLANT HT.	LODGE %	HERMISTON, OR YIELD BU/AC	TEST WT.	PLANT HT.	PROT-EIN %	LODGE %	LIND, WA YIELD BU/AC	TEST WT.	PLANT HT.	PROT-EIN %	LODGE
WA7720	154	61.5	48.0	3.0	131	60.5	38	11.6	7.5	92	61.8	37	15.5	7.5
WA7722	160	63.3	46.0	1.5	153	60.8	39	12.8	5.0	104	64.0	34	15.1	0.0
WA7726	171	60.7	42.0	1.5	141	61.8	34	13.8	0.0	91	60.1	28	13.1	0.0
WA7727	168	60.8	46.0	1.0	130	59.5	36	12.7	0.0	109	62.2	33	14.8	0.0
WA7728	182	61.8	42.0	1.5	138	59.1	37	12.9	1.2	119	62.5	34	14.6	0.0
NEELEY	141	62.6	50.0	6.5	113	60.8	40	13.0	72.5	92	62.6	33	15.5	3.7
STEPHENS	183	60.7	43.0	1.0	143	60.6	35	12.7	0.0	92	59.7	32	12.8	0.0
BATUM	142	61.8	47.0	1.5	106	57.4	38	13.7	52.5	112	60.3	27	13.8	0.0

1992/93	ABERDEEN, ID YIELD BU/AC	TEST WT.	PLANT HT.	LODGE %	HERMISTON, OR YIELD BU/AC	TEST WT.	LIND, WA YIELD BU/AC	TEST WT.	PROT-EIN %	LODGE %	2-YEAR AVERAGE YIELD BU/AC	TEST WT.
WA7720	130	60.2	44	1.5	95	55	94.0	55.8	1.0	0.0	116.0	59.6
WA7722	131	62.4	42	1.0	80	57	111.0	57.3	12.2	0.0	123.0	60.8
WA7726	112	54.8	39	1.0	102	57	119.0	56.9	13.0	0.0	123.0	58.6
WA7727	134	56.7	42	1.0	87	53	107.0	56.7	13.0	0.0	123.0	58.2
WA7728	118	57.7	42	1.0	85	53	97.0	56.8	12.7	0.0	123.0	58.5
NEELEY	131	61.3	46	2.0	100	55	103.0	57.5	13.3	13.7	113.0	60.0
STEPHENS	133	56.8	38	1.0	104	53	122.0	54.1	13.7	0.0	130.0	57.5
BATUM	125	53.0	40	2.5			107.0	56.1	12.1	12.1	118.0	57.7

1993 HARD RED WINTER VARIETIES (YIELD BU/AC)

LOCATION:	HORSE HEAVEN	FINLEY	LIND DRY	HARRINGTON	WATERVILLE	AVE. YIELD
HATTON	28.6	41.1	23.7	35.7	45.0	34.8
WESTON	30.3	44.9	25.2	38.5	46.8	37.2
BLIZZARD	30.8	39.8	23.9	39.1	41.9	35.1
BUCHANAN	29.1	39.9	27.9	39.9	53.6	38.1
WA7759	29.2	40.1	21.7	32.2	57.4	36.1
WA7761	29.6	43.1	21.8	33.3	50.6	35.7
WA7773	30.4	39.8	25.1	34.5	45.4	35.0
WA7774	28.9	42.6	20.9	40.8	51.3	36.9
D9109101	27.4	39.1	25.1	32.6	53.9	35.6
N9100105	29.3	42.0	21.3	31.5	48.8	34.6
N9100902	25.7	39.5	21.6	28.5	47.5	32.6
N9101301	31.3	46.8	22.4	34.8	48.0	36.7
N9106002	32.1	39.8	19.8	35.3	55.9	36.6
N9107401	25.6	32.1	25.1	33.3	39.9	31.2
N9108603	30.4	39.4	23.4	26.1	42.9	32.4
NURSERY MEAN	29.3	40.7	23.3	34.4	48.6	35.2

1993 HARD RED WINTER EXTENSION VARIETIES (YIELD BU/AC)

LOCATION:	HORSE HEAVEN	LIND DRY	LIND IRR.	HARRINGTON	WATERVILLE
HATTON	28.6	23.7	85.4	35.7	45.0
WESTON	30.3	25.2	84.6	38.5	46.8
BLIZZARD	30.8	23.9	86.9	39.1	41.9
BUCHANAN	29.1	27.9	83.6	39.9	53.6
BATUM	29.8	25.5	99.5	33.5	44.9
ANDREWS	24.0	15.8	85.6	27.5	48.3
MERIDIAN	23.5	22.6	93.7	32.8	53.6
HOFF	31.5	21.6	74.0	36.3	50.5
QH542	29.7	24.1	93.4	35.8	60.1
ID421	30.3	23.5	74.5	34.3	41.6
ID355	26.8	22.4	83.4	28.1	42.5
NURSERY MEAN	28.6	23.3	85.9	34.7	48.1

1993 HARD RED WINTER VARIETIES (WHOLE GRAIN PROTEIN)

LOCATION:	HORSE HEAVEN	FINLEY	LIND DRY	HARRINGTON	WATERVILLE	AVE. PROTEIN
HATTON	12.4	13.2	14.7	15.5	12.4	13.6
WESTON	13.3	13.8	14.7	13.4	13.3	13.7
BLIZZARD	13.1	13.1	15.4	14.0	13.3	13.8
BUCHANAN	13.9	12.6	13.4	13.2	11.8	13.0
WA7759	13.7	13.7	15.8	13.9	13.0	14.0
WA7761	14.3	14.0	15.9	14.9	13.0	14.4
WA7773	13.8	13.3	14.7	13.7	12.6	13.6
WA7774	13.7	13.6	16.2	14.6	12.7	14.2
D9109101	13.2	13.4	16.1	13.9	12.5	13.8
N9100105	14.2	13.8	15.3	14.5	12.6	14.1
N9100902	13.4	13.4	15.1	14.2	12.9	13.8
N9101301	13.4	13.0	16.7	14.0	14.4	14.3
N9106002	13.8	13.8	15.3	13.6	12.7	13.8
N9107401	15.2	14.6	16.4	15.5	13.8	15.1
N9108603	14.6	14.9	15.7	15.3	14.0	14.9
NURSERY MEAN	13.7	13.6	15.4	14.3	13.0	14.0

1993 HARD RED WINTER EXTENSION VARIETIES (WHOLE GRAIN PROTEIN)

LOCATION:	HORSE HEAVEN	LIND DRY	LIND IRR.	HARRINGTON	WATERVILLE	AVE. PROTEIN
HATTON	12.4	14.7	12.1	15.5	12.4	13
WESTON	13.3	14.7	14.2	13.4	13.3	14
BLIZZARD	13.1	15.4	14.3	14.0	13.3	14
BUCHANAN	13.9	13.4	12.6	13.2	11.8	13
BATUM	13.2	13.9	12.6	13.4	12.4	13
ANDREWS	13.6	14.6	13.8	13.4	12.7	14
MERIDIAN	13.6	15.6	13.0	14.3	13.8	14
HOFF	12.4	14.7	13.6	13.3	12.7	13
QH542	13.5	14.6	15.0	13.5	11.7	14
ID421	14.4	15.9	15.2	13.7	13.1	15
ID355	13.3	16.0	15.3	14.6	13.2	15
NURSERY MEAN	13.3	14.9	13.8	13.9	12.8	14

1993 STATE/EXTENSION WINTER WHEAT

B.C. Miller, P.E. Reisenauer, C.J. Peterson Jr., R.E. Allan
and E. Donaldson

Twelve locations were planted, a total of 27 winter wheat (7 soft white club, 18 soft white, 1 hard white and 1 hard red) and 2 winter type triticale varieties were evaluated. At Dusty and Moses Lake an additional nursery with 12 hard red entries were included.

Fall planting conditions were excellent, with sufficient moisture for stand establishment at the time of planting. These planting conditions resulted in vigorous stand establishment. The Lamont site was seeded into an extremely deep dust mulch resulting in erratic stands. All locations went into the winter in excellent shape. The winter started out cold, yet adequate snowfall prevented winter injury, and the remainder of the winter season was quite mild.

The spring and summer were characterized by excessive amounts of rain and cool weather. The Moses Lake nursery was silted over as a result of an early spring thaw and an untimely rain. The fourth replicate was lost. The Dusty and St. John nurseries suffered from a very heavy infestation of Cephalosporium stripe and marked variety differences were noted. The Mayview nursery was also infected but not to the same degree. Wildlife ate all the beardless club wheats at Bickleton and Mayview.

With above normal rainfall and cooler temperatures, grain quality and yields were excellent, except in the varieties that were severely infected with Cepalosporium stripe. The outstanding differences in yield due to varietal resistance alone are a testimony to the effectiveness of the plant breeding programs.

1992-93 Washington State University Extension Winter Wheat and Triticale Yield Summary

Variety	Bickleton	Dusty	Fairfield	Farmington	Lamont	Asotin	Reardan	St. John	Creston	Mayview	Moses L.	MEAN
Soft White Club												
HYAK	.	59.5	71.3	73.4	72.6	83.4	98.9	103.3	100.6	.	104.2	85.1
RELY	.	74.1	65.1	80.3	94.0	94.4	85.8	102.0	98.4	.	99.8	87.7
ROHDE	56.9	78.2	68.0	66.4	90.1	97.1	97.9	105.5	95.3	102.6	91.5	86.1
TRES	.	78.7	65.9	78.2	88.2	92.2	99.1	102.0	104.4	.	116.7	91.1
WA7622	.	60.5	64.8	81.6	80.7	91.0	98.8	103.4	103.7	.	114.0	88.2
WA7697	48.5	64.4	63.5	77.5	78.9	85.7	91.6	102.7	95.1	99.5	98.8	82.1
WA7753	.	70.9	63.7	95.2	86.8	96.6	87.9	99.4	112.3	.	124.2	92.3
Soft White Common												
BASIN	50.0	75.8	74.1	96.2	85.4	84.4	95.4	119.3	83.9	114.9	116.9	90.1
CASHUP	54.8	79.9	79.4	93.8	95.1	93.2	103.9	124.1	96.3	124.9	119.2	96.3
DAWS	43.8	74.9	71.5	73.1	56.1	83.2	101.3	101.5	115.6	105.4	89.7	83.8
DURHEIM'S PRIDE	45.9	67.7	61.9	73.1	59.8	86.2	94.3	95.7	105.7	101.4	102.9	81.3
ELTAN	53.3	75.1	77.4	60.0	86.3	92.6	91.5	108.4	114.3	94.0	88.9	85.5
GENE	47.3	48.9	65.7	94.6	75.2	95.6	93.9	76.9	52.1	81.0	110.0	75.7
HILL 81	50.8	69.7	71.2	85.9	80.0	108.6	106.7	105.5	120.6	118.0	99.1	92.5
ID81277	34.8	55.8	66.6	99.5	64.7	79.5	95.2	93.0	94.0	100.7	117.8	81.5
KMOR	50.6	60.3	72.7	65.4	87.0	106.9	97.6	98.8	113.7	99.4	100.4	86.3
LEWJAIN	54.2	64.6	74.0	69.1	86.0	104.4	90.9	95.3	106.8	93.5	101.2	85.1
MACVICAR	40.5	46.9	73.0	67.9	86.0	109.3	108.0	86.5	114.0	110.1	103.0	85.5
MADSEN	50.8	74.7	70.3	90.8	81.5	91.3	96.4	101.7	98.1	105.3	102.8	87.4
MALCOLM	36.7	41.9	67.8	62.7	97.1	103.5	115.8	75.8	108.4	92.9	95.9	81.0
NUGAINES	54.3	67.3	64.2	66.1	83.0	90.4	95.5	100.2	84.3	96.6	90.9	81.2
ROD	51.4	68.2	66.3	74.9	86.1	99.2	105.1	103.8	122.1	111.9	91.8	89.1
STEPHENS	37.8	42.7	63.8	78.1	79.6	98.5	99.4	90.2	66.0	96.0	106.4	76.6
W-301	40.1	45.3	63.6	78.1	89.7	101.7	103.3	76.0	89.1	100.5	108.1	80.6
WPB 702	42.5	45.5	59.6	70.7	79.8	97.1	92.0	80.0	87.7	97.9	95.0	76.6
Hard Red and White												
HATTON	36.9	55.8	60.9	50.7	63.2	72.9	68.6	76.5	81.3	68.4	90.0	64.8
WA7679	42.4	59.0	64.6	64.8	80.3	101.1	82.8	88.7	111.1	85.1	89.6	78.8
Triticale												
CELIA	58.8	72.3	66.3	92.2	90.1	111.5	96.6	120.5	69.9	129.6	124.1	93.2
WHITMAN	16.4	20.4	64.4	78.0	66.1	105.2	83.7	82.5	57.8	93.9	134.6	72.8
MEAN	45.8	62.0	67.6	77.3	81.0	95.1	95.8	97.2	97.7	101.0	104.7	84.0
LSD .10	7.8	7.8	20.5	16.1	11.0	9.5	10.1	11.5	16.2	9.5	18.9	4.0
CV	14.4	10.7	25.8	17.6	10.0	8.5	8.9	10.0	13.4	18.0	12.9	13.0

1992-93 Washington State University Extension Winter Wheat and Triticale Test Weight Summary

Variety	Bickleton	Dusty	Fairfield	Farmington	Lamont	Asotin	Reardan	St. John	Creston	Mayview	Moses L.	MEAN
Soft White Club												
HYAK	.	54.0	56.9	58.3	60.0	59.5	58.3	57.9	58.7	.	58.3	57.9
RELY	.	55.1	58.7	58.1	60.1	59.8	57.5	57.3	58.7	.	57.0	58.0
ROHDE	59.8	56.5	60.6	58.6	61.9	59.7	60.4	58.1	60.1	59.9	59.6	59.5
TRES	.	57.7	58.9	56.7	60.4	60.2	59.2	57.7	59.0	.	58.0	58.6
WA7622	.	54.3	57.7	57.8	61.7	59.3	58.1	56.9	59.6	.	58.6	58.1
WA7697	56.9	56.1	59.3	57.4	59.7	59.2	59.0	58.1	58.5	59.5	56.6	58.2
WA7753	.	55.9	58.3	58.9	59.4	59.1	57.5	55.7	58.9	.	55.5	57.7
Soft White Common												
BASIN	60.5	57.8	59.8	59.5	61.3	59.7	58.1	59.5	58.7	59.3	59.5	59.4
CASHUP	59.2	57.3	59.3	60.3	61.4	60.9	59.0	59.6	60.2	60.6	58.6	59.7
DAWS	59.1	59.8	60.3	58.6	61.2	61.3	60.0	59.8	60.4	60.8	59.1	60.0
DURHEIM'S PRIDE	59.4	59.2	59.6	55.4	61.1	61.5	60.8	59.4	60.9	60.7	57.0	59.6
ELTAN	57.4	57.7	59.6	53.9	61.4	59.5	59.6	57.0	59.2	59.4	54.9	58.1
GENE	56.5	51.7	58.4	57.6	60.3	58.8	57.2	55.6	55.4	58.3	58.8	57.0
HILL 81	57.5	54.1	58.7	57.0	58.5	60.2	57.9	55.4	60.0	59.1	55.2	57.6
ID81277	55.2	51.0	58.3	58.3	58.9	59.6	57.6	55.4	58.0	59.1	57.0	57.1
KMOR	57.5	55.4	58.0	53.0	60.8	59.6	57.7	55.9	58.5	58.2	54.7	57.2
LEWJAIN	60.1	57.6	60.5	54.5	61.6	60.2	58.2	57.8	59.8	60.4	57.5	58.9
MACVICAR	56.1	55.3	60.5	57.2	61.2	60.1	59.4	56.0	59.8	59.5	55.7	58.3
MADSEN	58.1	59.3	60.5	59.2	62.0	60.4	59.5	59.3	60.4	60.0	59.6	59.8
MALCOLM	55.5	54.2	59.4	53.8	60.5	59.9	58.7	55.8	59.7	57.4	52.4	57.0
NUGAINES	60.4	59.2	61.3	58.3	62.5	61.2	60.1	58.8	60.9	59.4	59.5	60.1
ROD	57.4	52.8	58.8	53.1	59.5	59.5	58.7	54.7	59.6	58.8	54.6	57.1
STEPHENS	53.8	49.2	58.2	56.8	58.7	58.5	58.6	54.4	58.2	57.8	56.9	56.4
W-301	54.0	50.2	59.7	57.1	58.5	59.0	58.2	52.2	59.6	58.2	56.7	56.6
WPB 702	54.6	50.3	59.1	55.7	57.7	59.6	58.1	55.1	58.7	58.6	53.9	56.5
Hard Red and White												
HATTON	61.9	63.7	64.6	56.8	64.3	63.1	62.3	62.3	62.4	63.5	58.8	62.2
WA7679	60.5	59.9	61.1	59.4	60.8	61.0	61.3	61.0	61.1	61.0	58.7	60.6
Triticale												
CELIA	58.4	56.7	57.0	58.0	57.3	56.9	55.4	57.9	53.7	57.6	54.4	56.7
WHITMAN	49.4	47.4	54.8	55.1	52.9	55.5	54.2	54.1	48.9	54.2	52.2	52.9
MEAN	57.5	55.5	59.2	57.0	60.2	59.7	58.6	57.2	59.1	59.2	56.9	58.2
LSD .10	1.5	2.6	2.6	3.2	1.7	0.9	1.3	1.7	1.4	1.2	3.5	0.6
CV	2.2	3.9	3.7	4.7	2.1	1.3	1.8	2.6	2.0	1.7	4.4	2.9

1992-93 WASHINGTON STATE UNIVERSITY EXTENSION WINTER WHEAT AND TRITICALE PROTEIN (%) SUMMARY

VARIETY	BICKLETON	DUSTY	FAIRFIELD	FARMINGTON	LAMONT	ASOTIN	REARDAN	ST. JOHN	CRESTON	MAYVIEW	MOSES LAKE	MEAN
SOFT WHITE CLUB												
HYAK	.	10.6	9.5	10.1	11.2	10.7	9.0	8.6	9.8	.	9.3	9.9
RELY	.	11.5	9.3	9.6	11.4	10.2	9.7	9.2	8.9	.	8.8	10.2
ROHDE	8.9	11.7	10.4	10.2	11.6	11.1	9.7	9.5	9.6	9.3	9.5	9.6
TRES	.	10.0	9.4	9.6	11.3	10.9	9.1	8.2	8.9	.	8.9	10.1
WA7622	.	11.1	10.1	9.9	11.1	10.6	9.5	9.0	9.7	.	9.9	10.1
WA7697	9.0	11.4	10.2	9.8	11.6	10.7	9.7	9.2	10.0	9.0	10.1	10.6
WA7753	.	10.9	10.3	10.1	11.4	10.3	10.0	9.5	9.5	.	10.7	10.0
SOFT WHITE COMMON												
BASIN	7.6	11.1	9.7	10.1	10.9	10.6	9.5	9.4	9.8	8.9	9.6	9.9
CASHUP	7.2	11.9	9.9	10.0	11.3	11.2	9.5	9.6	10.4	8.8	9.7	9.8
DAWS	7.5	11.2	10.0	9.2	11.4	10.9	9.9	9.3	8.6	8.9	8.5	9.6
DURHEIM'S PRIDE	7.6	11.3	10.5	10.0	12.1	11.0	9.4	9.1	9.5	9.2	9.6	9.5
ELTAN	7.3	11.2	9.6	9.1	11.4	11.1	9.5	9.0	8.5	8.6	8.6	10.1
GENE	7.9	11.6	10.7	10.2	12.1	10.7	10.1	9.9	11.0	9.9	10.5	10.0
HILL 81	7.7	11.9	9.7	9.4	12.1	10.6	9.0	8.7	8.7	8.5	9.2	9.7
ID81277	8.4	12.4	11.0	10.2	12.6	12.2	10.4	10.5	10.1	9.3	10.0	9.6
KMOR	7.2	10.5	9.3	9.3	11.0	9.9	10.0	8.7	9.0	8.3	8.2	9.9
LEWJAIN	7.4	10.6	9.2	9.5	11.6	10.7	10.8	9.1	8.7	8.8	8.3	9.4
MACVICAR	8.3	11.3	9.5	9.7	11.0	10.3	9.2	8.8	9.0	8.6	8.8	10.4
MADSEN	7.6	11.5	10.4	10.3	11.9	11.3	10.5	10.2	10.1	9.9	9.0	9.6
MALCOLM	8.0	11.0	10.0	10.2	11.1	10.6	9.4	9.0	9.2	9.0	9.7	10.6
NUGAINES	7.8	10.8	9.6	9.7	11.8	11.0	9.8	8.3	9.7	8.9	8.5	9.5
ROD	7.7	12.2	9.7	10.2	11.4	10.7	9.4	9.0	8.6	9.4	9.5	9.7
STEPHENS	8.5	12.2	10.2	10.1	11.4	10.6	10.1	9.7	9.6	9.2	9.0	9.8
W-301	8.4	12.4	10.1	10.0	11.7	10.6	10.0	9.9	9.2	9.1	9.1	10.0
WPB 702	7.3	12.6	10.8	9.7	12.3	11.0	10.1	9.2	9.5	9.4	9.8	9.9
HARD RED AND WHITE												
HATTON	7.4	12.9	10.7	9.5	12.7	12.6	11.4	9.8	9.7	10.0	8.9	10.3
WA7679	7.9	12.4	11.6	10.3	13.2	11.7	10.6	9.4	9.5	9.7	10.5	10.6
TRITICALE												
CELIA	6.3	11.2	10.3	10.6	12.7	9.9	10.4	8.7	11.4	8.2	11.0	10.1
WHTIMAN	8.8	12.0	10.1	10.7	11.6	10.2	10.4	10.8	11.2	8.6	9.6	10.3
MEAN	7.8	11.5	10.1	9.9	11.7	10.8	9.9	9.3	9.5	9.1	9.4	9.9
LSD @ .10	1.6	0.9	2.4	0.8	0.6	0.8	0.8	0.9	0.7	0.9	1.1	0.3
C.V.	16.7	6.5	20.4	6.5	3.7	6.3	7.0	8.5	6.3	8.8	8.4	9.9

PROGRESS IN SPRING WHEAT DEVELOPMENT

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The cool, more rainy 1993 spring and summer weather delayed crop development which favored the development of diseases and insect infestations to levels previously unknown in Eastern Washington. The interval from planting to maturity ranged from 123 days for the annual crop nursery at Lind to 135 days at Mayview, where emergence and stands were reduced by heavy rains after planting.

Hessian Fly

The hessian fly caused significant losses to several varieties, especially in the Palouse region. Three cultivars in the Dayton trial showed high resistance to the hessian fly, (Wakanz, Wawawai, and WPB00926). Infestation by this insect varied with location, depending on the stage of crop development when the population of flies expanded. High amounts of lodging were the most obvious symptom noted by growers. This pest seems to have become widely distributed and abundant, through the increased use of conservation practices involving surface retention of crop residue in which the fly pupae reside and overwinter. Because of this wide distribution and great abundance of infested residue, this pest can be expected to remain a significant problem, especially for spring wheat and barley production. However, when conditions are favorable for the flies to hatch in the fall, winter wheats will be infested. The infested winter wheats will become an important source of flies available in the spring, which prefer to attack the smaller, more succulent spring wheat and barley.

Disease

The cool, wet spring also facilitated the development and infection of cereal crops by fungus diseases; especially damaging in the Palouse were the rusts: stripe, leaf and stem. As a result of the later seeding of nurseries at Pullman and Farmington, some varieties showed a vernalization response that delayed development, but did not greatly affect maturity.

Soft White

The performance of soft white spring wheats in Eastern Washington are shown in Tables 1 & 2. Except for its susceptibility to the hessian fly, Penawawa continued to be the high performer over the State. Likewise, Centennial continued to perform well at many locations, but it is even more susceptible to the hessian fly than Penawawa. Wakanz, the only SWS wheat with hessian fly resistance proved susceptible to stem rust, and suffered appreciable yield reductions, especially in Eastern Washington. Seed rate trials were established at both the Pullman and Lind stations. Using Penawawa as a check, Wawawai was planted at Pullman and Alpowa at Lind. The performance of these varieties are shown in tables 5 & 6.

Alpowa

Foundation seed for the new variety "Alpowa" will be produced in 1994. In 1993, yields of Alpowa were affected by stem rust infection at Pullman and Fairfield. However, its high test weight, stripe/leaf rust resistance, drought tolerance and superior soft white quality continue to be its main attributes in more normal seasons. The most notable of the quality characteristics are its low grain protein and low flour ash, along with excellent baking characteristics. Alpowa is also susceptible to the hessian fly.

Wawawai

The variety "Wawawai" was released for breeder seed production in 1994 to replace Wakanz. Wawawai is an F_5 pedigree selection from the cross ID000190//POTAM 70/FIELDER/5/TIFTON3725/WALLADAY//FIELDER//POTAM70/N7000315/ID00065/4/ID00065 /POTAM 70, made in 1982. The F_1, F_2, F_4 and F_5 generations were grown and selected at Pullman, while the F_3 progeny were screened at the Lind Dryland Experiment Station. Wawawai was evaluated from 1990 to 1993 in the Washington State Spring Nurseries, and from 1991 to 1993 in the Commercial and Tristate Spring Nurseries under low rainfall-fallow (10 inches of moisture), annual crop, and irrigated conditions. In these environments, Wawawai produced a equivalent yield and superior test weight compared to current varieties. Collaborative tests by the USDA Western Wheat Quality Laboratory at Pullman, Washington, indicate that Wawawai has superior milling and pastry processing properties. Wawawai appears to carry a favorable combination of resistances to stripe rust (caused by Puccinia striiformis West), including race-specific resistance of 'Fielder' and adult plant stage resistance of 'Potam 70'. It also inherited resistance to local races of leaf rust (caused by Puccinia recondita Rob. ex Desm. f. sp. tritici) from 'Potam 70', and resistance to local races of stem rust (caused by Puccinia graminis Pers. f. sp. tritici Eriks. and Henn.) from either or both parents. Wawawai is resistant to Hessian fly [Mayetiola destructor (Say)] but susceptible to the Russian wheat aphid [Diuraphis noxia (Mordvilko)].

Vanna

A new Western Plant Breeders SWS wheat entry, "Vanna", showed overall good performance, except for its susceptibility to the hessian fly. Quality properties have not yet been evaluated by the USDA-ARS Western Wheat Quality Laboratory, but these evaluations will be forthcoming.

Hard Red Spring

Among the hard red spring wheats, the variety "WPB 926" was resistant to the hessian fly at the Farmington nursery where the infestation of insects was especially severe. The yield, test weight and protein level of selected hard wheats grown in 1993 in Eastern Washington can be found in tables 2 & 3. The variety Spillman, while susceptible to the hessian fly proved to be an overall high performer in 1993.

In addition to the regular nurseries conducted under alternate year management, we established an annual crop hard red spring nursery in 1993 at the Lind Experiment Station to collect data on the performance of selected lines over several years. In 1993, growing conditions were favorable, except for the week of May 10^{th}, when high temperatures forced some heat sensitive lines. Yields ranged from 15 to 26 bu/ac, test weights of 53 to 59 lbs/bu and proteins from 16 to 18 percent (Table 4).

Hard White Spring

Hard white spring wheats were evaluated in preliminary, advance and regional nurseries in 1993. The line "ID377S" proved widely adapted to conditions in Eastern Washington with the exception to its' susceptibility to the hessian fly. ID377S may have superior noodle-making potential, but appears to have unsuitable milling and bread baking properties, when milled as a hard wheat. Another experimental HWS line WA007778, was identified in 1993 as having outstanding yield potential at three test locations. Its performance exceeded ID377S and all others in the trial, including Klasic.

1994 Research

The Russian wheat aphid (RWA) was not a major crop hazard in 1993, but was able to increase enough in Eastern Washington to cause some growers to apply an insecticide. The 1993 Pullman spring cereal plots were sprayed to prevent serious damage. However the continued presence of the RWA in the region represents a potential for serious losses until genetic resistance is available in new cultivars. Considerable progress in breeding RWA resistant cultivars has been made at WSU, Colorado, Idaho and Oklahoma. At WSU, RWA resistant recombinant lines exploiting the resistance of plant introductions identified in South Africa, were obtained two years ago. These derivatives were used in crosses to recombine RWA resistance with hessian fly resistance in hard and soft wheats. Double haploids of these latest crosses were evaluated in 1993 and selected for resistance to rust. This winter these lines will undergo further selection for RWA and hessian fly resistance via cooperators in CIMMYT and Kansas State University, respectively. In 1994, field testing for these insects will be expanded to include all preliminary lines in a late seeded nursery, at Pullman and Genesee, Idaho.

To minimize potential damage from RWA, hessian fly and stem rust in susceptible varieties, growers should plant spring crops as early as possible and monitor the development of the crop relative to these hazards. If conditions become favorable for infestation by the RWA and stem rust, the option of spraying with pesticides should be considered. The hessian fly is not controllable by foliar sprays. Grower's best option is to plant resistant varieties. Susceptible varieties will escape infestation, when sown early, so that weather conditions can delay fly development. Winter wheats can serve as a reservoir of hessian flies, which can infest spring wheats growing in the area.

TABLE 1.

1993 SOFT WHITE SPRING VARIETIES(YLD=BU/AC, TW=LB/BU PR=% PROTEIN)	LIND			FAIRFIELD			REARDAN			MAYVIEW**			PULLMAN			ROYAL SLOPE			VARIETY AVE.		
	YLD	TW	PR	YLD	TW	PR	YLD	TW	PR	YLD	TW	PR	YLD	TW	PR	YLD	TW	PR	YLD	TW	PR
CENTENNIAL	42	62.4	12.2	56	63.7	10.0	96	64.9	10.1	42	62.5	--	71	62.8	10.4	104	63.7	10.3	68	63.3	10.6
TREASURE	41	61.8	12.2	51	62.8	10.1	87	63.5	9.3	41	62.2	--	68	60.9	10.9	111	62.8	10.0	66	62.3	10.5
EDWALL	40	59.6	11.9	58	62.1	10.3	90	63.5	9.7	46	61.8	--	70	60.0	10.7	103	61.8	10.8	68	61.5	10.7
PENAWAWA	41	61.3	12.2	54	63.0	9.3	96	65.1	9.4	47	63.0	--	62	61.0	10.8	114	64.2	9.5	69	62.9	10.2
WAKANZ	41	61.7	12.4	48	62.3	9.9	84	64.1	9.1	45	62.4	--	54	59.8	10.9	102	63.1	9.8	62	62.2	10.4
CALORWA*	39	61.4	11.9	47	62.5	10.3	82	63.5	10.5	29	60.8	--	68	60.7	11.1	95	63.3	10.6	60	62.0	10.9
ALPOWA	42	62.4	12.3	47	62.3	9.0	93	65.0	9.7	37	63.0	--	57	60.2	10.3	102	64.1	9.2	63	62.8	10.1
WAWAWAI	39	62.2	12.8	57	64.4	10.4	91	64.2	10.7	48	63.5	--	78	63.4	11.1	98	65.0	9.5	68	63.8	10.9
WADUAL 94	34	61.7	14.4	47	63.3	11.3	85	64.7	10.6	41	61.3	--	63	59.8	11.5	87	63.4	10.1	59	62.4	11.6
VANNA	39	61.2	11.6	60	63.1	9.4	92	64.9	9.3	43	62.1	--	70	61.2	10.3	110	63.6	9.8	69	62.7	10.1
SPRITE	39	60.4	13.2	38	60.9	9.6	89	64.6	9.7	37	61.1	--	61	59.8	11.1	96	64.9	10.3	60	61.9	10.8
NURSERY MEAN	40	61.5	12.5	51	62.8	10.0	89	64.4	9.8	41	62.1	--	66	60.9	10.8	102	63.6	10.0	X.. 65	X.. 62.5	X.. 10.6
LSD (.05) BU/AC	3.65			8.92			12.38			10.52			6.09			10.56					
C.V.	4.44			6.73			4.91			7.75			6.69			4.76					

* club
** At the Mayview nursery the plots averaged 3 plants/ft^2

1993 STATE/EXTENSION SPRING WHEAT

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and G.B. Shelton

Seven locations were planted, a total of 25 spring wheat (13 soft white, 10 hard red, one hard white and one spring club) and 2 spring type triticale varieties were evaluated.

Spring planting was completed on a timely basis, but conditions were unusually wet and cool, resulting in later than normal planting dates. Good stands were established at all sites. The Moses Lake nursery was established, but later planted to potatoes by the cooperator, the season was too far along to re-establish another nursery. The Bickleton nursery was planted with a deep furrow drill, the rest of the locations were planted with a double disk drill and starter fertilizer (7# N, 21# P205 and micronutrients) was placed with the seed. The St. John nursery was abandoned due to herbicide injury resulting from a misapplication.

The spring and summer were characterized by abnormally high precipitation and cool temperatures. This resulted in higher than normal yields and test weights. The grain quality was excellent. With the excess moisture the plants produced were not rank nor taller than expected. Varietal differences were not as great as has been exhibited in average years.

Hessian fly damage was extensive and decimated most varieties at Farmington. There was up to 50% infestation at Dayton. The yields at the Farmington nursery were directly related to the Hessian fly damage. The variety Wakanz which was resistant to the Hessian fly but was eliminated by stem rust. The yield and test weight data are a direct indication of the destruction that can occur in varieties that are not resistant to these pests.

1993 WSU Spring Wheat Variety Evaluation Results

1993 SPRING WHEAT YIELDS (BU/A)

GRAIN TYPE	VARIETY	BICKLETON	DAYTON	DUSTY	FAIRFIELD	FARMINGTO	LAMONT	LIND DRY	MAYVIEW	PULLMAN	REARDAN	ROYAL SLP.	MEAN
SOFT WHITE CLUB	CALORWA	48.7	72.0	46.6	46.9	59.9	41.4	38.8	29.2	68.2	73.3	95.1	56.4
SOFT WHITE COMMON	ALPOWA	50.0	73.0	50.6	47.5	40.7	48.0	42.0	37.3	56.9	82.5	102.1	57.3
	CENTENNIAL	56.4	74.7	48.9	56.0	66.6	55.3	41.8	41.5	71.2	85.6	103.7	63.8
	EDWALL	45.2	61.5	41.6	57.6	49.7	31.5	39.8	46.5	70.1	79.8	103.3	57.6
	ID377S	52.9	75.8	49.4	59.6	79.0	54.0	40.9	51.2	84.1	86.9	100.8	66.8
	ID392	52.3	70.8	48.7	45.6	56.1	48.7	39.9	42.4	70.1	77.2	94.3	58.7
	PENAWAWA	53.4	72.8	45.5	53.6	44.4	39.5	41.4	47.5	61.8	85.0	114.4	59.9
	TREASURE	47.8	64.6	48.6	51.4	61.9	53.7	40.7	40.6	67.8	74.3	111.3	60.3
	WA7176	55.4	73.0	45.5	60.7	95.1	57.0	40.5	44.1	71.5	86.9	102.4	66.6
	WA7712	54.2	75.0	45.2	57.0	105.2	45.9	38.6	47.8	77.9	81.0	98.9	66.1
	WA7715	43.6	70.3	41.5	47.5	53.4	36.9	33.7	40.6	63.3	75.4	86.6	53.9
	WADUAL	49.1	76.2	43.0	55.2	48.7	38.1	34.5	33.9	61.8	77.2	100.2	56.2
	WAKANZ	46.4	76.0	41.6	48.1	37.6	23.9	40.6	45.5	54.3	74.6	102.0	53.7
	WESTBRED SPRITE	54.7	70.6	47.2	38.1	36.9	54.1	38.7	37.2	60.6	79.5	96.3	55.8
	WESTBRED VANNA	55.3	78.4	47.5	60.0	56.1	52.4	38.7	42.6	70.1	81.7	110.0	63.5
HARD WHITE	KLASIC	51.9	65.0	36.4	46.7	53.5	36.8	32.9	28.7	69.2	70.4	88.2	52.7
HARD RED	BUTTE 86	47.0	61.9	40.9	53.1	77.6	38.3	33.9	40.9	67.7	63.7	81.9	55.0
	ID420	47.8	76.3	42.2	45.9	71.7	53.6	41.2	35.0	70.1	73.5	106.0	60.3
	SPILLMAN	47.7	69.8	40.7	50.5	56.6	52.6	39.1	45.3	73.5	73.9	95.3	58.6
	WAMPUM	46.4	66.1	40.8	47.8	26.2	43.3	38.5	38.0	45.3	68.2	101.7	50.8
	WESTBRED 926	52.2	72.8	41.5	47.4	97.3	41.6	32.2	36.8	72.5	76.1	84.3	59.5
	WESTBRED 936	48.8	73.6	39.3	46.9	68.8	47.2	32.9	38.8	75.2	77.4	89.7	58.0
	WESTBRED EXPRESS	47.0	76.9	37.1	46.6	53.8	43.6	35.6	41.7	65.6	68.7	85.0	54.7
	WINDSOR GRAIN #205	45.1	64.4	42.2	34.9	56.7	48.6	37.3	38.0	62.3	75.3	83.4	53.5
	WINDSOR GRAIN #37	44.9	70.3	36.5	47.3	61.0	45.1	38.2	30.2	76.2	71.7	89.2	55.5
	WINDSOR GRAIN #99	48.2	76.1	37.2	46.0	87.5	40.3	31.3	27.0	71.8	72.0	81.2	56.2
	MEAN	49.7	71.6	43.3	49.9	61.6	45.2	37.8	39.5	67.7	76.6	96.4	58.1
	CV	11.6	10.7	13.5	14.8	10.0	19.7	8.5	21.4	8.5	10.2	12.0	12.8
	LSD @ .10	6.8	9.2	6.9	8.7	7.3	10.6	3.8	3.9	6.8	9.2	13.6	2.6

1993 SPRING WHEAT TEST WEIGHTS (LBS/BU)

GRAIN TYPE	BICKLETON	DAYTON	DUSTY	FAIRFIELD	FARMINGTO	LAMONT	LIND DRY	MAYVIEW	PULLMAN	REARDAN	ROYAL SLP.	VARIETY	MEAN
SOFT WHITE CLUB	61.3	59.3	63.2	62.5	59.0	58.7	61.4	60.8	60.7	63 5	63.3	CALORWA	60.7
SOFT WHITE COMMON	58.9	59.7	63.3	62.3	54.6	61.0	62.4	63.0	60.2	65.0	64.1	ALPOWA	60.3
	60.3	61.4	63.4	63.7	61.0	61.5	62.4	62.5	62.8	64.9	63.7	CENTENNIAL	61.9
	57.4	57.9	61.2	62.1	55.1	58.2	59.6	61.8	60.0	63.5	61.8	EDWALL	58.8
	57.2	61.6	65.1	64.9	61.3	61.6	62.6	63.4	63.1	65.6	66.1	ID377S	62.0
	58.0	60.0	62.4	62.7	58.1	61.4	63.1	62.8	62.4	64.8	63.8	ID392	60.7
	59.5	59.6	63.5	63.0	56.0	58.4	61.3	63.0	61.0	65.1	64.2	PENAWAWA	60.2
	57.9	58.6	62.2	62.8	56.3	59.8	61.8	62.2	60.9	63.5	62.8	TREASURE	59.8
	57.9	59.6	61.1	62.8	58.8	60.4	61.0	61.8	60.6	64.0	62.0	WA7176	60.1
	59.1	62.2	63.5	64.4	59.9	61.5	62.2	63.5	63.4	64.2	65.0	WA7712	61.8
	58.4	59.1	63.3	63.3	55.8	57.2	61.7	61.3	59.8	64.7	63.4	WA7715	59.6
	59.5	59.6	64.3	63.4	56.4	59.1	60.7	62.2	61.4	64.8	64.6	WADUAL	60.5
	58.6	58.3	62.2	62.3	50.8	56.8	61.7	62.4	59.8	64.1	63.1	WAKANZ	58.5
	58.5	59.7	63.4	60.9	52.5	60.8	60.4	61.1	59.8	64.6	64.9	WESTBRED S	59.7
	57.2	59.6	63.2	63.1	57.9	59.6	61.2	62.1	61.2	64.9	63.6	WESTBRED V	60.2
HARD WHITE	62.0	61.8	64.7	63.5	58.6	58.0	62.6	62.3	62.7	65.0	65.6	KLASIC	61.6
HARD RED	61.3	61.1	63.9	64.1	60.8	60.0	61.7	62.4	62.4	64.7	65.0	BUTTE 86	61.9
	59.1	60.4	61.9	62.4	57.6	60.3	62.0	62.5	61.4	62.7	64.1	ID420	60.5
	59.3	59.0	61.7	62.3	55.6	59.0	61.1	62.0	60.5	62.5	64.0	SPILLMAN	59.7
	57.5	58.8	60.5	60.9	48.5	56.5	61.8	60.8	57.2	63.8	64.2	WAMPUM	57.5
	60.1	60.4	62.4	63.6	60.7	60.3	61.9	63.2	61.8	64.3	63.8	WESTBRED 9	61.3
	59.7	60.1	62.3	63.2	59.9	61.1	61.6	61.6	61.5	64.9	64.7	WESTBRED 9	61.2
	59.0	60.5	62.6	61.1	53.5	58.7	62.0	61.3	61.0	64.2	63.3	WESTBRED E	59.6
	58.6	59.1	61.7	61.6	51.4	60.0	61.9	62.4	61.6	62.3	63.6	WINDSOR GR	59.1
	61.6	60.3	64.0	63.4	60.0	59.3	62.7	62.9	63.2	65.2	64.5	WINDSOR GR	61.7
	61.2	61.1	63.3	63.6	61.1	60.1	62.5	62.7	61.7	64.4	65.0	WINDSOR GR	61.8
	59.2	60.0	62.9	62.8	57.0	59.6	61.7	62.2	61.2	64.3	64.0	MEAN	60.4
	3.0	0.8	1.6	*	2.8	1.8	*	*	*	*	*	CV	2.1
	2.1	0.6	1.1	*	1.9	1.3	*	*	*	*	*	LSD @ .10	0.6

1993 WSU Spring Wheat and Triticale Variety Evaluation Results

PROTEIN (%)

GRAIN TYPE	VARIETY	BICKLETON	DAYTON	DUSTY	FAIRFIELD	FARMINGTON	LAMONT	LIND DRY	PULLMAN	REARDAN	ROYAL SLP.	MEAN
SOFT WHITE CLUB	CALORWA	11.6	11.2	9.5	10.3	10.5	13.5	11.9	11.1	10.5	10.6	11.2
SOFT WHITE COMMON	ALPOWA	11.0	10.1	9.4	9.0	8.3	12.5	12.3	10.3	9.7	9.2	10.2
	CENTENNIAL	9.9	10.1	9.5	10.0	9.6	13.6	12.2	10.4	10.1	10.3	10.6
	EDWALL	10.6	11.2	9.7	10.3	10.3	13.9	11.9	10.7	9.7	10.8	10.9
	ID377S	10.6	11.8	10.4	11.1	11.0	15.9	14.2	11.8	11.3	10.7	11.9
	ID392	10.6	10.4	9.4	9.4	9.0	13.3	11.7	9.7	9.6	10.3	10.5
	PENAWAWA	10.7	11.0	9.1	9.3	9.4	13.7	12.2	10.8	9.4	9.5	10.7
	TREASURE	11.1	10.6	10.2	10.1	9.6	13.3	12.2	10.9	9.3	10.0	10.9
	WA7176	10.5	10.9	10.2	10.1	9.5	13.4	12.7	11.1	9.9	9.4	10.9
	WAWAWAI (WA7712)	11.7	11.0	10.0	10.4	9.4	14.5	12.8	11.1	10.7	9.5	11.3
	WADUAL 94 (WA7715)	12.4	11.9	10.7	11.3	11.8	15.7	14.4	11.5	10.6	10.1	12.3
	WADUAL	11.1	11.3	11.0	10.9	11.2	14.9	14.0	10.7	10.1	10.4	11.8
	WAKANZ	11.4	10.3	10.4	9.9	10.5	13.6	12.4	10.9	9.1	9.8	11.1
	SPRITE	11.6	10.5	9.7	9.6	10.8	13.2	13.2	11.1	9.7	10.3	11.1
	VANNA	11.0	10.2	9.4	9.4	9.7	13.4	11.6	10.3	9.3	9.8	10.6
HARD WHITE	KLASIC	10.2	12.5	10.8	11.4	11.9	14.9	15.2	11.7	11.7	11.2	12.1
HARD RED	BUTTE 86	11.1	11.8	11.6	12.7	14.1	16.9	15.7	12.7	11.7	13.5	13.2
	ID420	11.2	11.9	11.7	12.6	12.8	14.7	14.4	12.8	12.0	12.7	12.6
	SPILLMAN	10.9	11.6	12.1	13.6	12.7	15.9	15.0	12.6	12.2	11.9	12.7
	WAMPUM	10.5	10.2	11.1	9.2	11.0	13.2	13.4	10.7	9.4	11.4	11.2
	WESTBRED 926	10.7	11.7	11.5	11.9	13.3	16.7	16.4	13.3	12.6	12.7	12.9
	WESTBRED 936	10.7	11.9	11.5	12.9	12.9	16.7	16.2	12.9	11.6	11.2	12.8
	EXPRESS	11.4	11.5	12.5	11.9	12.3	15.9	15.7	13.2	11.9	11.9	12.8
	WINDSOR GRAIN #205	11.0	10.6	10.2	11.3	12.4	14.2	13.5	12.7	11.7	11.2	11.8
	WINDSOR GRAIN #37	11.2	11.8	11.8	12.8	13.2	16.4	15.5	12.9	11.7	12.7	12.9
	WINDSOR GRAIN #99	10.5	12.1	11.2	12.2	13.0	16.2	16.3	13.0	12.6	10.9	12.7
TRITICALE	JUAN	9.3	9.9	9.7	.	11.2	13.1	.	.	.	.	10.6
	VICTORIA	10.1	10.5	9.8	.	10.8	14.0	.	.	.	.	11.0
	MEAN	10.9	11.1	10.5	10.9	11.2	14.6	13.7	11.6	10.7	10.8	11.6
	C.V.	9.5	5.6	5.7	.	6.6	7.4	.	.	.	.	7.2
	LSD @ .10	1.2	0.7	0.7	.	0.9	1.3	.	.	.	.	0.4

COMPARISON OF SEVERAL THICKSPIKE WHEATGRASS ECOTYPES

Mark Stannard, Wayne Crowder, Clarence Kelley
USDA-SCS Plant Materials Center

Thickspike wheatgrass is a rhizomatous wheatgrass native to much of the western United States. It is a common range grass on sand, loamy sand, and sandy loam soils in areas receiving 6-20 inches of annual precipitation. It occurs less commonly on silt loam and granular clay soils. Thickspike wheatgrass may be found growing in Washington at elevations between 300 and 2000 feet. Thickspike wheatgrass is similar in appearance to western wheatgrass and slender wheatgrass. Its drought tolerance and soil stabilizing characteristics have interested the Soil Conservation Service for many years.

The SCS plant materials centers at Bridger, Montana; Aberdeen, Idaho; and Pullman, Washington collected seed of thickspike wheatgrass from sites across the Northwest. Each seed collection represented an ecotype and common garden trials were utilized to compare these ecotypes. Four ecotypes that have undergone advanced testing include: 'Critana' - a cultivar developed from seed collected near Havre, MT; 'Schwendimar' - a cultivar developed from seed collected on the banks of the Columbia River near The Dalles, OR; 'T-21076' - unreleased ecotype collected near Pocatello, ID; and 'PI 236663' - unreleased ecotype collected near Waterton Lakes, Alberta.

Seedling emergence was evaluated at three dryland sites in Washington. Little emergence difference was observed between the ecotypes (Table 1). There was considerable variability between sites which indicates that emergence is largely governed by the environment. Emergence of the thickspike wheatgrasses was much more rapid than the two western wheatgrasses. Thickspike wheatgrass has required approximately 6.5 days to reach 50% emergence in trials conducted both in the field and in the lab. Western wheatgrass typically has required 13 days to reach 50% emergence in lab trials.

Table 1. Number of wheatgrass seedlings emerged in 1988 at Central Ferry and Saddle Mountain, WA and in 1989 at Lind, WA. Average of 4 replications.

Accession	Species	Ecotype	Site: Lind	Central Ferry	Saddle Mountain
				(plants/m^2)	
Critana	Thickspike	NC Montana	17	13	26
Schwendimar	Thickspike	SC Washington	17	12	36
T-21076	Thickspike	SE Idaho	14	12	16
PI 236663	Thickspike	SW Alberta	8	17	30
Rosana	Western	SE Montana	5	14	16
T-7213	Western	SE Washington	5	18	29
Mean			11	14	21

Biomass production of three and four year old stands of thickspike wheatgrass was measured in 1992, a very dry year (Table 2). 'Critana' and 'PI-236663' originated east of the Rocky Mountains and generally did not produce as well as the accessions originating from the intermountain region. Biomass production of thickspike wheatgrass varies with the age of the stand. Maximum production typically occurs within 3-4 years of seeding and decreases considerably after maximum production is achieved. A study conducted in southwestern Montana showed a three year old stand of 'Critana' thickspike wheatgrass producing 1848 lb/acre and only 246 lb/acre five years later.

Table 2. Biomass production of four accessions of thickspike wheatgrass sampled at three semiarid sites in 1992.

Accession	Central Ferry	Lind	Saddle Mountain	Mean
		(lbs/acre)		
P-1822	1103	1151	564	935
T-21076	480	1271	828	864
Critana	864	360	252	540
PI-236663	1049	90	28	389
Mean	874	718	418	

Ground cover of the ecotypes originating west of the Rocky Mountains improved with each year in trials conducted in Washington (Table 3). The ecotypes originating east of the Rocky Mountains did the opposite. However, trials established in 1977 at Lind and Central Ferry show stands of Schwendimar decreasing to almost zero after the ninth year.

Table 3. Second, third, and fourth year ground cover of 4 thickspike wheatgrasses at three semiarid sites. Averages of 4 replications.

Accession	Ecotype	Lind 2yr	Lind 3yr	Central Ferry 2yr	Central Ferry 3yr	Central Ferry 4yr	Saddle Mountain 2yr	Saddle Mountain 3yr	Saddle Mountain 4yr
					(percent)				
Critana	NC Montana	23	11	24	61	38	18	26	18
Schwendimar	SC Washington	41	55*[1]	28	43*	53	48*	51*	54*
T-21076	SE Idaho	34	45*	18	44*	51	18	19	30
PI 236663	SW Alberta	23	11	13	33*	13*	4	4	4

[1] Ground cover percentages within a column followed by an asterisk (*) are significantly different from 'Criatan' ground cover as determined by Fischer's Protected LSD test at the 5% level.

A similar ground cover study conducted at Bridger, Montana showed that the western ecotypes performed more poorly than the eastern ecotypes (Table 4). The ecotypes originating east of the Rockies appear to be more tenacious in their own environment.

Table 4. Stand percentages of 4 thickspike wheatgrasses grown at Bridger, MT (1967-1972). Averages of 3 replications.

Accession	Ecotype	1967	1968	1969	1970	1971	1972
		--------	Stand	Percentages	(%)	--------	
Critana thickspike	NC Montana	57	97	98	99	96	98
Schwendimar thickspike	SC Washington	70	88	98	98	78	70
T-21076 thickspike	SE Idaho	48	83	87	96	85	84
P-15645 thickspike[1]	SE Montana	43	80	100	100	100	96

[1] PI-236663 was not available for testing at this time.

Clearly, ecotypes of thickspike wheatgrass perform better in their own environment. Ecotypes originating east of the Rockies perform better in areas that receive summer rainfall. Eastern ecotypes are more tenacious but are poor forage producers.

Western ecotypes are better adapted to the winter moisture patterns and coarse textured soils which occur in the intermountain West. Like a wave, western ecotypes tend to establish rapidly, quickly colonize bare ground, produce large amounts of forage in the first few years, then fade away.

PRE-HARVEST SPROUTING RESISTANCE - WHEAT CULTIVAR TESTING

M.K. Walker-Simmons and Janet Warner
USDA, Agriculture Research Service, Washington State University

Overview: Soft white wheat cultivars are vulnerable to pre-harvest sprouting and losses can be severe. This project was initiated in 1993 to assess sprouting resistance in recently released cultivars and promising advanced lines grown in the WSU winter wheat variety trials. Newly released cultivars from Washington, as well as Oregon and Idaho, are being evaluated for sprouting resistance. Germination tests are conducted both at a cool and a warmer temperature in order to test for varying weather conditions. Results of this project will assist Pacific Northwest breeders select more sprouting-resistant cultivars, and to identify and discard lines with deficient sprouting resistance.

Accomplishments: Sprouting resistance has been assessed in advanced lines and newly released cultivars grown at 13 locations in Washington. Germination rates were measured at 15°C(59°F) and 30°C(86°F). We have determined that a newly released cultivar, Gene, and an older cultivar, Nugaines, have the highest levels of sprouting resistance, in our high temperature germination tests. Results from low, intermediate and higher rainfall areas showed consistently that these cultivars have the highest levels of high temperature dormancy at harvest. The majority of the other cultivars exhibited similar low levels of sprouting resistance. This means that there would be no advantage in using any of these cultivars in breeding efforts to enhance sprouting resistance levels. The lowest levels of sprouting resistance were found in Kmor and ID810277 suggesting that these cultivars may be vulnerable to sprouting damage.

We are applying these results to our on-going research focused on determining the biological processes that control pre-harvest sprouting and seed dormancy. Effects of dormancy-breaking chemicals including plant hormone-like chemicals are being evaluated. These results also support our research aimed at identifying molecular markers for sprouting resistance for use in genetic selection. Ultimately, the wheat industry will benefit as breeders incorporate more sprouting-resistant parents into their breeding programs.

Cooperators: Baird Miller, Pat Reisenauer, R.E. Allan and C.J. Peterson, Jr.

HOW WHEAT PLANTS RESPOND TO DROUGHT AND COLD -- IDENTIFICATION OF A NEW KINASE GENE

L. Holappa, S.Verhey, E. Cudaback and M.K. Walker-Simmons
USDA, Agriculture Research Service, Washington State University, Pullman

As water supplies become less available, it becomes increasingly important to select and develop crop plants that can thrive under reduced moisture. Cultivars are required that can tolerate environmental stresses such as drought and extreme cold. Better genetic tools are needed to select those environmental stress tolerant cultivars. Improved knowledge of the mechanisms of plant perception and adjustments to environmental stress is vital to obtaining new selection markers for stress tolerance.

We are characterizing a class of enzymes called protein kinases, which are known to function as molecular switches, controlling a wide range of biological activities in both plants and animals. We have identified a new type of protein kinase in wheat that responds to environmental changes. This kinase gene is induced when wheat plants are subjected to drought, salt stress or cold temperatures. For example, winter wheat plants growing at Spillman Farm in Dec. 1993 had high levels of the kinase mRNA. Transfer of the plants to room temperature resulted in a disappearance of the mRNA within 24 hrs.

DNA sequence analysis of the kinase gene has shown that this is a novel protein kinase, unlike any previously reported protein kinase. Next, we intend to elucidate the role of this protein kinase in stressed wheat. Our long-term goal is to exploit the results to develop new genetic tools for selection of cultivars that are more environmental stress tolerant.

THE USDA-ARS WESTERN WHEAT QUALITY LAB

Craig F. Morris, Director

The USDA-ARS Western Wheat Quality Lab (WWQL) is one of four federally supported regional wheat quality labs. The other labs reside in Kansas, North Dakota and Ohio. The primary function of the WWQL is to evaluate the milling and baking properties of experimental wheat germplasm, thereby aiding in the development of new public varieties in the western U.S. The WWQL is housed on the WSU campus as part of the new Food Science and Human Nutrition complex (recently completed).

Each year the WWQL analyzes several thousand experimental lines ranging from the F_3 generation (third year after the cross) to final variety release. The classes soft white winter, soft white spring, hard red winter, hard red spring, club (mostly winters, some springs) and now, hard white winters and springs are evaluated. The largest number of samples come from Drs. Allan, Peterson, Jones, Donaldson and Konzak (Washington) and Kronstad and Zwer (Oregon). Breeding programs in Idaho and California are assisted by coordinating activities with their State quality labs. Two breeding programs in Utah recently renewed their ties with the Lab. Advanced lines which are nearing release from private breeding companies, are examined as resources permit.

In addition to working closely with individual breeders, the WWQL plays a more formal role in variety release by the appointment of the WWQL director to the WSU variety release committee.

Although variety development is the Lab's central and most important role, as a part of the USDA Agricultural Research Service it is expected to carry on focused mission-oriented research. Currently, this research includes the study of a protein that may cause softness in the endosperm of soft wheats, and the development of predictive methodologies for Japanese-style sponge cake and oriental noodles.

Current staff include ARS personnel, Herbert C. Jeffers, Arthur D. Bettge, Douglas A. Engle, Mary L. Baldridge, Brenda S. Patterson and Renee L. Ader. WSU personnel include Garrison E. King, Barbara C. Davis; Drs. Gerald A. Greenblatt and Michael J. Giroux; and Victor L. DeMacon and Ming Zeng.

The WWQL is open to visitors. Please call Dr. Craig F. Morris, 509-335-4062 to arrange a tour.

BARLEY IMPROVEMENT RESEARCH

S.E. Ullrich, C.E. Muir, J.A. Clancy, J.S. Cochran, A. Kleinhofs, Z. Huang, F. Han, B.C. Miller, P.E. Reisenauer and J.A. Froseth.

Cultivar Development/Variety Testing

The latest WSU winter barley cultivar release is Hundred, which is a high yielding semi-dwarf 6-row type. Hundred has had consistently high yields across eastern Washington (Table 1). The newest WSU barley cultivar is Crest, a 2-row spring malting type with high yield (Table 2), good kernel quality and good feed quality. Final testing prior to release is underway for a new hooded hay type and a new hulless type.

Whereas winter and spring and 2-row and 6-row types are bred, emphasis is on 6-row spring types. This emphasis is due to Northwest barley breeding program collaboration. In 1993, 200 spring barley crosses were made. In 1994, plants will be selected from 86 segregating F_3 - F_4 populations (50-100/populations) from previous years' crosses. In addition, there are 93 F_2 populations in the field and 107 F_3 single seed descent populations in the greenhouse. Lines will be selected from approximately 10,000 head rows and 1,400 homozygous doubled haploid (from anther culture) plant rows. There are 34 24-entry preliminary yield trials planted at Spillman Farm this year; the entries of which mostly came from 1993 head/plant rows. The more advanced lines are tested in 23 30-entry major yield trials at Spillman and throughout eastern Washington. In addition, there are seven spring barley yield trials conducted by Baird Miller and Pat Reisenauer and there are 40 grower-conducted on-farm tests in 10 counties in 1994.

The winter barley program is much smaller in scope. In 1994, there are about 1,000 winter barley plots and about 7,100 spring barley plots in total. Carl Muir and Judy Cochran are field research technologists working with the program. Barley performance in 1993 was presented in the February 18, 1994 Greensheet for small plot trials and in the March 1994 Wheatlife 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, WI. Feed quality evaluations are conducted in the Department of Animal Science 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 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, OK. Barley stripe rust is a new disease to the Pacific Northwest, 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 stripe rust reaction the past several years in Bolivia and Texas. Soil borne pathogens probably affect barley production more than we realize. A new effort was initiated in 1994 in collaboration with Jim Cook to screen for reaction to soil borne pathogens in the field.

Application of Biotechnology

Anther culture techniques are used to develop doubled haploid lines (DHL) from F_1 plants from crosses in the breeding program. This is a rapid (~1 year) method of 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_{5-8}. 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 DHLs. In 1994, 1400 DHLs from 20 crosses made in 1992 are in the field for selection and DHL production is underway from F_1s of 20 new crosses made in 1993. Z. Huang is a visiting scientist in charge of DHL production in the program.

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. 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 for these important economic traits.

TABLE 1 - WINTER BARLEY YIELD AVERAGES THROUGH 1993, LB/A (% OF BOYER)

VARIETY	PULLMAN 10 YR	POMEROY 8 YR	WALLA 9 YR	LIND IRR 4 YR	EXTENSION 69 LOC-YR
HUNDRED	5995(113)	4770(104)	4940(96)	4580(112)	4550(105)
HESK	5955(112)	4835(105)	4875(94)	4310(105)	4490(103)
BOYER	5315(100)	4590(100)	5155(100)	4090(100)	4490(103)
SHOWIN	5180(97)	4500(98)	5070(98)	4200(103)	4255(98)
KAMIAK	4850(91)	3920(85)	4580(89)	2600(63)	3950(91)

TABLE 2 - SPRING BARLEY YIELD AVERAGES THROUGH 1993

VARIETY	PULLMAN 13 YR	POMEROY 13 YR	WALLA 11 YR	DAVENPORT 9 YR
CREST	4910(100)	3324(99)	3530(96)	2844(107)
STEPTOE	4910(100)	3365(100)	3690(100)	2660(100)
	CONNELL 8 YR	LIND 9 YR	MEAN-63 LOC - YR	EXT MEAN 68 LOC - YR
CREST	1920(107)	1785(97)	3220(100)	3805(98)
STEPTOE	1790(100)	1835(100)	3215(100)	3900(100)

1993 STATE/EXTENSION WINTER BARLEY

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

Fourteen locations were planted, with 9 varieties or lines were evaluated at each location. At Pomeroy and Walla Walla 7 additional breeder lines were also tested.

Fall planting conditions were excellent, with sufficient moisture for stand establishment at the time of planting. These planting conditions resulted in vigorous stand establishment. The Lamont site was seeded into an extremely deep dust mulch resulting in erratic stands. The first replicate was discarded. All locations went into the winter in excellent shape. The winter started out cold, yet adequate snowfall prevented winter injury, the remainder of the winter season was quite mild. The Creston site had no snow cover when the early cold weather hit and the nursery was lost to winterkill. The Reardan nursery also suffered winter injury in the same storm, but survived and was harvested.

The spring and summer were characterized by excessive amounts of rain and cool weather. The Moses Lake nursery was silted over as a result of an early spring thaw and an untimely rain, and was later abandoned. The Fairfield nursery was stressed very early in the year prior to the rains and cool weather, and never recovered.

With above normal rainfall and lower temperatures, yields were excellent. The test weights were below normal at some locations and grain quality was not as good as would be expected with the extra moisture that was available. The plant heights were also shorter than expected under these conditions.

1992-93 W.S.U. Winter Barley Yield Summary

Variety	Bickleton	Fairfield	Reardan	Dusty	Lamont	Pomeroy	Asotin	armingto	St. John	Mayview	Walla Walla	Pullman	Mean
HUNDRED	3951*	3548	4596*	4068	3956	4693*	5073	5817*	5428*	6021*	5959*	7476*	5074*
1997-87	2934	3878	4241*	4505	4185	4973*	4695	5984*	5080	5996*	6364*	6193	5014*
HESK	3962*	3879	4713*	4452	5459*	4681*	4654	5041*	5879*	5781*	5622*	7278*	5012*
2607-80	3110	3926	4055	4289	4733*	4248*	4463	5214*	5849*	5529	6210*	6835	4902*
BOYER	3008	3823	4387*	4138	4220	4753*	4768	4528	5508*	4854	6248*	6079	4765
SHOWIN	3512	3433	4326*	4065	3253	5008*	4436	5485*	4754	5521	6331*	5719	4761
EIGHT-TWELVE	3610*	3404	4423*	4555	4106	4554*	4425	4716	4991	5362	5016	5552	4586
KAMIAK	3225	3137	3490	3544	4080	3363	4476	4860	4571	5644*	6079*	6312	4456
GWEN	1856	3630	3194	4057	4386	3234	4732	4417	4887	5511	5926*	6580	4384
Mean	3241	3636	4158	4186	4264	4390	4636	5118	5216	5580	5973	6447	4783
LSD .10	400	1099	678	1041	1015	876	907	1109	583	385	808	566	236
CV	10.2	24.1	13.5	20.7	16.8	20.6	16.3	18.0	9.3	5.7	13.6	7.3	15.0
													12

1992-93 W.S.U. Winter Barley Yield Summary

Variety	<4000 lbs/A	4-5000 lbs/A	>5000 lbs/A	12 Location Mean
HUNDRED	3749*	4523*	6132*	5074*
1997-87	3338	4579*	5963*	5014*
HESK	3920*	4750*	5906*	5012*
2607-80	3518*	4329	5953*	4902*
BOYER	3416*	4493*	5516	4765
SHOWIN	3473*	4339	5632	4761
EIGHT-TWELVE	3507*	4441*	5117	4586
KAMIAK	3187	3736	5546	4456
GWEN	2743	3833	5506	4384
Mean	3433	4336	5694	4783
LSD .10	556	404	333	236
CV	19.1	18.2	11.7	15.0
# of Locations	2	5	5	12

1993 STATE/EXTENSION SPRING BARLEY

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

Seven locations were planted, 19 varieties, eight 6-row and eleven 2-row, were included in the evaluation trials.

Spring planting was completed on a timely basis, but conditions were unusually wet and cool, resulting in later than normal planting dates. Good stands were established at all sites. The Moses Lake nursery was established, but later over-planted to potatoes by the cooperator, the season was too far along to re-establish another nursery. The Bickleton nursery was planted with a deep furrow drill, the rest of the locations were planted with a double disk drill and starter fertilizer (7# N, 21# P2O5 and micronutrients) was placed with the seed.

The spring and summer were characterized by abnormally high precipitation and cool temperatures. This resulted in higher than normal yields and test weights. The grain quality was excellent. With the excess moisture the plants produced were not rank nor taller than expected. Varietal differences were not as great as has been exhibited in average years. Steptoe was often not the highest yielding variety as has been the norm in previous years.

Although Hessian fly damage was extensive in the spring wheats at Farmington and to a lesser degree at Dayton, the spring barley suffered minor or negligible damage.

1993 WSU Spring Barley Variety Evaluation Results

1993 SPRING BARLEY YIELDS (LBS/A)

VARIETY	BICKLETON	DAYTON	DUSTY	FAIRFIELD	FARMINGTON	LAMONT	LIND DRY	MAYVIEW	PULLMAN	REARDAN	ST. JOHN	MEAN
6 Row												
11163-86	3059	4815	2429	3392	5697	2844	2592	4187	6625	5268	4778	4153
9593-87	3021	6120	2417	3629	6396	2839	2575	3831	6590	5818	5771	4455
COLTER	3596	5571	2656	3115	5481	3381	2547	3798	6006	5527	5825	4318
EXCEL	3159	4915	2681	3350	5964	3264	2250	3082	6298	5130	4128	4020
MARANNA	3530	6208	2564	3260	6151	3594	2526	4121	5669	5979	5361	4451
MOREX	3105	4018	2330	2920	4395	2360	2409	3140	5786	3767	3734	3451
RUSSELL	3643	5120	2529	3040	5355	2599	2438	3054	5750	5035	4796	3942
STEPTOE	3917	5285	2859	2905	5121	2971	2579	3202	5689	3977	4738	3931
2 Row												
16277-85	3012	5700	2469	4182	5793	3159	2551	4709	5759	4647	5069	4277
9035-84	3102	5236	2796	4284	5208	3347	2651	4828	5653	5199	4522	4257
9448-83	2918	5939	2555	4910	6033	3151	2564	4603	6182	5422	5120	4490
BARONESSE	4290	6202	2850	4613	6807	3844	2583	5195	6239	5471	6420	4956
CAMELOT	3037	5198	2529	4630	5627	2894	2736	4473	5813	5128	4731	4254
CREST	2972	5313	2268	4093	4491	2838	2396	4120	5516	4719	4533	3933
CRYSTAL	3172	5117	2482	4374	6327	3847	2700	3945	5524	4547	4645	4243
GALLATIN	3555	5058	2852	4104	5391	2973	2676	4650	5925	5144	5070	4309
HARRINGTON	3320	5180	2608	4636	5329	2998	2339	3908	5565	4944	4896	4157
MELTAN	3161	6237	2508	3955	6059	2281	2685	4221	5713	5583	5139	4322
TARGHEE	3436	5664	2615	4121	5915	3861	2700	3944	6014	4566	4986	4348
MEAN	3316	5415	2579	3869	5660	3108	2553	4053	5911	5046	4961	4225
CV	11.7	7.6	13.2	14.8	9.3	17.9	13.0	10.6	8.4	12.1	10.1	10.6
LSD @ .10	460	487	401	677	620	656	391	509	586	720	593	168

1993 SPRING BARLEY TEST WEIGHTS (LBS/BU)

VARIETY	BICKLETON	DAYTON	DUSTY	FAIRFIELD	FARMINGTON	LAMONT	LIND DRY	MAYVIEW	PULLMAN	REARDAN	ST. JOHN	MEAN
6 Row												
11163-86	47.8	52.2	49.2	50.6	47.7	49.2	46.9	50.0	46.9	49.1	50.7	49.1
9593-87	45.8	50.0	48.6	49.1	47.1	45.7	46.8	48.2	44.1	47.8	50.1	47.6
COLTER	47.9	52.0	50.8	49.6	46.7	50.0	46.2	50.0	47.0	48.8	50.5	49.1
EXCEL	49.0	50.8	51.1	51.9	49.4	49.6	48.6	51.0	48.8	50.7	51.6	50.2
MARANNA	48.6	50.5	50.8	51.2	46.8	50.1	44.9	51.7	47.9	51.5	51.7	49.6
MOREX	49.4	52.0	52.3	50.2	46.6	49.5	48.2	51.1	48.1	49.0	51.5	49.8
RUSSELL	50.3	53.1	52.7	50.1	47.1	50.4	48.7	52.0	48.4	49.7	51.1	50.3
STEPTOE	47.7	50.2	48.3	48.0	43.7	48.1	44.4	48.0	44.6	46.0	49.7	47.1
2 Row												
16277-85	50.1	54.5	52.3	53.5	49.8	49.3	45.8	52.9	51.9	52.8	52.1	51.4
9035-84	50.2	54.5	52.6	53.9	48.3	50.6	46.7	53.5	53.4	52.2	51.5	51.6
9448-83	48.3	53.7	50.8	53.3	48.1	50.1	45.0	52.7	51.9	52.6	51.1	50.7
BARONESSE	50.8	54.6	53.1	54.8	51.3	51.9	47.7	53.9	54.0	54.3	55.0	52.9
CAMELOT	53.0	55.0	54.9	55.6	53.9	51.6	50.7	54.2	55.6	53.7	54.4	53.9
CREST	49.8	54.1	53.1	54.3	45.7	51.5	47.5	53.1	54.8	51.8	54.7	51.9
CRYSTAL	51.6	54.6	52.5	54.5	51.9	51.7	45.4	54.2	53.6	53.4	54.4	52.5
GALLATIN	53.6	55.4	53.7	55.0	51.0	51.1	48.2	54.6	55.3	53.6	54.9	53.3
HARRINGTON	49.6	54.5	51.4	54.9	48.0	49.7	47.1	54.4	52.2	52.1	54.3	51.7
MELTAN	51.4	54.7	54.3	54.3	52.4	51.9	52.4	54.3	54.1	53.7	54.2	53.4
TARGHEE	50.7	53.8	53.1	54.9	50.2	52.5	46.4	53.9	54.3	54.5	54.6	52.6
MEAN	49.8	53.2	51.9	52.6	48.7	50.3	47.2	52.3	50.9	51.4	52.5	51.0
CV	1.6	1.9	3.1	*	3.0	2.1	*	*	*	*	2.5	2.0
LSD @ .10	1.9	1.2	1.9	*	1.7	1.3	*	*	*	*	1.6	0.4

1993 SPRING BARLEY ON-FARM VARIETY TESTING RESULTS

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

The spring barley on-farm variety testing program was successfully continued in 1993. The success of this program has depended on the active participation from growers, industry and the University (see Table 1 for a list of participants). This year 30 growers seeded managed and harvested the trials throughout eastern Washington. Chuck Goemmer with Washington State Crop Improvement Association and Keith Bailey with Great Western Malting Company acquired the certified seed for the trials. The certified seed was donated by Spectrum Crop Development, Walla Walla Grain Growers, Wilhelm & Son, Stegner Grain & Seed, McKay Seed, Reardon Seed, Great Western Malting and United Grain Growers. The seed was distributed by the Ritzville Warehouse. Larry Morrow from NuChem provided complementary soil testing for interested growers. The county coordinators from 10 counties coordinated the seed delivery, data and grain sample collection and distribution of results. Baird Miller, Steve Ullrich and Pat Reisenauer from Washington State University handled the grain processing (test weight, protein, plump and thins), data analysis and summary. Mary Palmer-Sullivan, representing the Washington Barley Commission, was responsible for the overall coordination and communication of the program.

We had more than 40 growers sign up to participate in the program, but the wet spring conditions resulted in only 30 growers being able to establish trials. Five standard varieties were included at all testing sites: Steptoe, Crest, Camelot, Harrington and Russell. Each county had the option of adding varieties of their choice. Great Western Malting provided malting varieties to interested participants.

The growers participating in this program were asked to establish the drill strips so that the strips traversed (or ran perpendicular) to the natural variability (soils and terrain) in the field. This way all the varieties would uniformly include the variability in the field and approximated the average conditions of a given field. It was also critical that the placement of varieties in the field did not favor or penalize a particular variety. For example, it was recommended that the drill strips not border a weedy fenceline or bottom-land area. The drill strips were typically wider than the combine header width and ran from 800 to 2500 feet in length. The drill strips were harvested with the grower's combine and weighed individually with weigh wagons or portable weigh scales. A grain sample from each variety was taken for processing at WSU.

The grain yields and test weights from this year is summarized in tables 2-6. Results from 3 of the grower's sites are not reported due to problems with the layout of the trial or incomplete data availability. **It is critical to understand that each testing site represents only one replication. You should not make comparisons among the varieties or conclusions about the variety performance at any one site or replication. Your comparisons and conclusions should be made by including several sites either within a county or similar growing conditions.** For the results of the individual county choices, contact your local county coordinator or county agent.

The spring barley on-farm variety testing program will continue in 1994. The statewide leadership and coordination will remain the same. This year's varieties will be Steptoe, Crest, Harrington, Camelot and Baronesse, plus the county choices. Great Western Malting will provide seed of varieties Galena, B1202, Colter, MT140523 and Crystal for those growers interested in testing malting varieties. Larry Morrow with NuChem will provide soil tests for interested growers.

Anyone interested in participating in the testing program can contact your county coordinator, county agent or Mary Palmer-Sullivan at the Barley Commission (456-4400).

Table 1. 1993 Spring Barley On-Farm Variety Testing Participants.

Statewide Organization:

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

Contributors of Certified Seed:

CAMELOT:	Curtis Hennings/Andy Thostenson, Spectrum Crop Development Corp.
CREST:	Mike Klicker, Walla Walla Grain Growers, Inc. Edgar Wilhelm, W.F. Wilhelm & Son, Inc.
GALLATIN:	Wayne Carrick, Stegner Grain & Seed Company
HARRINGTON:	Dan McKay, McKay Seed Company, Inc. Fred Fleming, Reardan Seed Company
RUSSELL:	Keith Bailey, Great Western Malting Company
STEPTOE:	Duane Erickson, United Grain Growers
MALTING:	Keith Bailey, Great Western Malting Company

Storage and Distribution of Seed: Dave Gordon and Gary Reilly, Ritzville Warehouse

Soil Testing: Larry Morrow, NuChem

County Coordinators:

Adams:	Curtis Hennings
Asotin:	Frank Johnson
Columbia:	Carl Nordheim, Roland Schirman
Garfield:	Dave Bragg, David Ruark
Kittitas:	Tom Hoffmann
Klickitat:	John Fouts
Lincoln:	Fred Fleming
Spokane/ Stevens:	John Jamieson, Paul Peterson
Whitman:	Keith Becker

Farmer Cooperators:

Adams:	Curtis Hennings, Allen Jones, Eric Maier
Asotin:	Frank Johnson, Carroll Johnson, Pat Wolf
Columbia:	Dean Nichols, Lawrence Ranches (Des Witt)
Garfield:	David Ruark, Scott Seed Farm, Tom Herres, Gary Houser
Kittitas:	Don Rhinehart, Pat Clerf
Klickitat:	Tex and Neal Brown, Dean and Dale Bowdish, Marvin Norris, Fred Wilkins
Lincoln:	Tom Schultz, Dale Dietrich
Spokane/ Stevens:	Lyle Wiltse, Gerald Scheele, Cliff Carstens, Hal Meenach
Whitman:	Mark Hall, Mike Stubbs, Roy Dube, Dave St. John, Norm Druffel & Sons, Schroetlin Bros.

Table 2. 1993 Spring Barley On-Farm Variety Testing Results.

Yield (lbs/acre)

COUNTY	LOCATION	STEPTOE	CAMELOT	HARRINGTON	RUSSELL	CREST	AVERAGE
Adams	1	2035	2258	2077	2074	1644	2018
	2	2197	2891	2464	2667	1776	2399
	3	1500	1640	1750	1409	1853	1630
	Average	1911	2263	2097	2050	1758	1969
Asotin	1	4758	4515	4466	4264	4375	4476
	2	3342	2752	2930	2923	2958	2981
	3	2797	2836	3039	2646	2676	2799
	Average	3632	3368	3478	3278	3336	3469
Columbia	1	3296	4480	4667	4032	3070	3909
	2	4963	4249	4722	4493	4175	4520
	Average	4130	4365	4695	4263	3623	4272
Garfield	1	2573	2694	2332	2418	2383	2480
	2	3412	2765	3182	2677	2982	3004
	3	4771	4789	4661	4165	4358	4549
	4	3833	3589	3764	3415	3624	3645
	Average	3647	3459	3485	3169	3337	3558
Kittitas	1	4521	4496	4675	3144	3961	4159
Klickitat	1	1940	1964	1598	1598	1720	1764
	2	3666	3574	3080	3098	3148	3313
	3	4214	3626	3710	3280	3468	3660
	4	3196	3902	3012	2940	3104	3231
	Average	3254	3267	2850	2729	2860	2950
Lincoln	1	4002	3718	3945	2806	3300	3554
	2	2977	2991	2832	2376	2956	2826
	Average	3490	3355	3389	2591	3128	3364
Spokane	1	1483	3957	3969	2945	3464	3164
	2	4706	4474	4933	4110	4063	4457
	3	5001	5163	5507	4152	4840	4933
	4	2725	3255	2784	2824	2667	2851
	Average	3479	4212	4298	3508	3759	4160
Whitman	1	3433	3467	3667	3500	3400	3493
	2	5113	4784	5172	4941	4379	4882
	3	3343	3791	3835	3716	3238	3585
	4	4780	5372	5565	5481	4585	5157
	Average	4167	4354	4560	4410	3901	4428

Test Weight (lbs/bu)

COUNTY	LOCATION	STEPTOE	CAMELOT	HARRINGTON	RUSSELL	CREST	AVERAGE
Adams	1	42.2	49.7	47.1	45.4	45.7	46.0
	2	49.4	54.8	52.4	52.0	53.8	52.5
	3	46.8	.	44.7	48.1	45.5	46.3
	Average	46.1	.	48.1	48.5	48.3	48.2
Asotin	1	47.5	52.6	50.0	48.7	50.8	49.9
	2	48.5	51.2	50.5	47.8	50.6	49.2
	3	50.7	54.1	54.5	53.1	54.6	53.4
	Average	48.9	52.6	51.7	49.9	52.0	50.9
Columbia	1	39.9	51.5	52.0	50.8	46.0	48.0
	2	49.7	54.7	53.8	53.0	53.9	53.0
	Average	44.8	53.1	52.9	51.9	50.0	50.1
Garfield	1	44.1	49.5	43.7	50.0	47.9	47.0
	2	47.4	51.8	50.8	47.7	52.0	49.9
	3	46.8	54.6	54.2	49.7	53.0	51.7
	4	41.8	52.1	47.4	49.2	50.6	48.2
	Average	45.0	52.0	49.0	49.2	50.9	49.7
Kittitas	1	50.1	55.1	53.2	52.2	54.7	53.1
Klickitat	1	51.1	53.2	54.0	53.7	53.6	53.1
	2	48.0	53.3	53.6	48.7	52.1	51.1
	3	49.4	52.8	51.5	50.6	52.3	51.3
	4	46.5	52.8	50.5	48.9	51.9	50.1
	Average	48.8	53.0	52.4	50.5	52.5	51.4
Lincoln	1	48.3	53.3	49.8	46.6	52.6	50.1
	2	47.5	49.9	50.0	48.8	.	49.1
	Average	47.9	51.6	49.9	47.7	.	50.2
Spokane	1	45.2	50.4	49.5	49.4	48.8	48.7
	2	46.2	52.0	50.6	46.6	50.1	49.1
	3	48.0	53.6	53.1	48.7	52.9	51.3
	4	46.6	52.6	51.7	50.8	51.2	50.6
	Average	46.5	52.2	51.2	48.9	50.8	50.0
Whitman	1	44.3	53.0	50.2	51.0	52.0	50.1
	2	45.7	52.3	51.2	51.2	49.5	50.0
	3	47.2	48.9	46.6	42.2	46.7	45.0
	4	43.3	52.2	52.0	48.0	49.4	49.0
	Average	45.1	51.6	50.0	48.1	49.4	49.3

Table 3. 1993 spring barley on-farm variety testing yield performance summarized among production zones.

Variety	Production Zone (lbs/acre) < 2000	2000-3000	3000-4000	>4000
	Yield (lbs/acre)			
Camelot	1802	2811	3686	4730
Crest	1786	2437	3279	4342
Harrington	1674	2636	3683	4962
Russell	1503	2561	3240	4343
Steptoe	1720	2664	3387	4829
Average	1697	2622	3455	4641
Locations	2	7	10	8

Table 4. 1993 spring barley on-farm variety testing test weight performance summarized among production zones.

Variety	Production Zone (lbs/acre) < 2000	2000-3000	3000-4000	>4000
	Test Weight (lbs/bu)			
Camelot	53.2	51.7	52.0	53.3
Crest	49.6	50.6	50.5	51.7
Harrington	49.4	50.0	50.2	52.2
Russell	50.9	49.7	48.5	49.7
Steptoe	49.0	46.6	45.2	47.1
Average	50.4	49.7	49.3	50.8
Locations	2	7	10	8

Table 5. Yield summary across years for the spring barley on-farm variety testing program.

VARIETY	1993	1992-93	1991-93	1990-93
	lbs/ac	lbs/ac	lbs/ac	lbs/ac
CAMELOT	3629	2908	2801	2754
CREST	3265	2717	2674	.
HARRINGTON	3642	2880	2730	2685
RUSSELL	3263	2702	.	.
STEPTOE	3504	2938	2894	2872
AVERAGE	3461	2829	2775	2770
LOCATIONS	27	53	119	153

Table 6. Test weight summary across years for the spring barley on-farm variety testing program.

VARIETY	1993	1992-93	1991-93	1990-93
	lbs/bu	lbs/bu	lbs/bu	lbs/bu
CAMELOT	52.5	50.7	51.0	50.6
CREST	51.0	49.4	50.2	.
HARRINGTON	51.0	49.2	49.6	49.0
RUSSELL	49.6	47.9	.	.
STEPTOE	46.3	45.0	46.1	45.7
AVERAGE	50.1	48.4	49.2	48.4
LOCATIONS	24	50	115	149

DRY PEAS, LENTILS, CHICKPEAS, AND AUSTRIAN WINTER PEAS

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

Potential new varieties of dry peas, lentils, chickpeas and Austrian winter peas are being tested in the Palouse region of eastern Washington and northern Idaho. The goal is to identify lines with multiple pest resistance, stress resistance, yielding ability, and acceptable quality traits. Breeding efforts in each of these crops is described as follows:

Dry Peas: The goals of the research program for green, dry peas is to incorporate better color into higher yielding Alaska type varieties. Root diseases of peas caused by a complex of several organisms are a major reason poor yields have been common to the area. Most of our efforts have been in identifying resistant lines for use as parents, hybridizing the resistant lines with commercial varieties, and screening the resulting populations for root rot resistant segregants with good plant type, good seed color qualities, and adaptability to local conditions. Quality tests to determine resistance to seed bleaching, cooking time, and adaptability to reconstitution and canning are also conducted.

Pea enation mosaic virus and pea leaf roll virus have become extremely serious on peas and lentils in recent years, and consequently we have started to screen for genetic resistance in the field and greenhouse. Good resistance is available in peas, and we have recently identified resistance to the virus in lentils. The goal is to incorporate resistance to these viruses into new varieties.

Variations in leaf morphology in peas are being studied to improve standing ability and reduce foliar disease infection. The semi-leafless type with increased tendril number appears to hold particular promise for reducing foliar disease and at the same time producing seed yields that are equal to normal plant types. Future germplasm improvement efforts are being directed toward developing virus-resistant semi-leafless types. The afila or "semi-leafless" type has particular promise for yellow pea varieties because the reduced foliage allows better light penetration to the pods and results in brighter yellow peas. Also, the reduced leaf area hastens maturity. Development of peas with shatter resisting pods is currently underway.

Varieties of peas developed are as follows:

'Alaska 81' was released to growers in 1984. The cultivar is early to flower (10th node) and early to mature. Alaska 81 has resistance to Fusarium wilt race 1 and is tolerant to pea root rot. Alaska 81 is immune to pea seedborne mosaic virus.

'Garfield' is resistant to Fusarium wilt race 1, is larger seeded, and has a longer vine habit when compared with most Alaska strains. Garfield flowers at the 14th node and has tolerance to pea root rot, two factors which delay maturity about one week when compared with most Alaska strains.

'Tracer' is a small-sieve Alaska type that is higher yielding than most other small-sieve varieties. Other major improvements of Tracer include greater plant height; a reduced susceptibility to seed bleaching; and resistance to Fusarium wilt race 1. The increased height of Tracer improves harvesting ease on the ridges where poor vine growth has been a problem. Tracer tends to set triple pods at one or more of the reproductive nodes.

'Umatilla'. When compared with 'Latah', Umatilla is about 7 inches shorter and 13% higher yielding. Umatilla sets double pods compared to the single podding habit for Latah. The seeds of Umatilla are larger and have averaged 18.7 grams per 100 seeds compared to 17.1 for Latah. Seeds of Umatilla are bright yellow and represent a significant improvement in seed quality when compared to Latah in which the seeds have an undesirable green cast. Umatilla is very well adapted to splitting; however, the variety seems to be susceptible to mechanical damage during processing.

Lentils: Current objectives in lentil breeding are toward developing an early maturing 'Laird' type. Laird is a large-seeded non-mottled variety developed for use in Canada; however, Laird is somewhat late maturing and, on the average, lower yielding than 'Brewer' when grown in the Palouse. An early maturing Laird type, 'Palouse', was recently released and is now available to growers. We are now developing a larger seeded type with green seedcoats to better compete with Laird in certain markets in South America and Spain.

Varieties of lentils developed are as follows:

'Chilean 78' is a composite of selections made from common Chilean lentil seed stocks and, therefore, performance is nearly identical to that expected for Chilean. The primary advantage of Chilean 78 is the absence of vetch-type rogues, particularly those rogues that have seeds similar in size, shape and color to lentils. Chilean 78 has largely been replaced by Brewer.

Brewer consistently has been the highest yielding lentil variety in yield trials. The variety has averaged about 300 pounds per acre more than Chilean 78 and is larger seeded. Brewer is earlier to flower and mature and matures more evenly.

'Redchief', a variety released in 1978, has shown a consistent yield advantage over Chilean 78. Redchief has red cotyledons and is now used to produce decorticated large, red lentils.

'Emerald', a bright green-seeded lentil with distinctively green cotyledons, has performed well in yield trials. Emerald is a specialty type lentil because of its distinctive green cotyledon color. The variety stays somewhat green at maturity and therefore must be closely followed in order to avoid excessive seed shattering.

Palouse. Released in 1988 is a large yellow-seeded lentil that is similar in size to the Canadian laird lentil. However, Palouse is earlier to mature and is comparable to Brewer for yield. Palouse has seeds that are free of mottling. The principal disadvantage of Palouse is its tendency to lodge at maturity making the crop difficult to harvest.

'Crimson' is a small red lentil that was approved for release in 1990. Crimson has small brown seeds with red cotyledons. The variety is typical of the lentils grown in the Middle East and northern Africa. The variety is well adapted to all areas of the Palouse and to intermediate rainfall zones (15-18 inches annually) and therefore could become an alternative crop in rotation with wheat in those areas. Expected yields are compared to that of Brewer while in the drier areas yields of between 750 and 1000 pounds per acre can be obtained. Marketing of small red lentils will depend upon availability of equipment for decortication and splitting.

Chickpeas: (Garbanzos) are grown throughout the world in similar environments to those where lentils are grown. There are basically two types of chickpeas: the "kabulis", with large cream-colored seeds and the "desis", with smaller seeds that are variously pigmented. Kabulis represent less than 20% of the world's production of chickpeas; the remainder are desi types. The desis are grown primarily on the Indian subcontinent and parts of Ethiopia; whereas, the kabulis are grown primarily in the Mediterranean basin and North and South America.

The Palouse environment is well suited to chickpeas and very favorable yields have been obtained; however, Ascochyta blight has made the corp extremely risky for producers. Over the past 5 years we have been doing extensive evaluations of germplasm for resistance to the disease. The resistant germplasm which has been identified was intercrossed with otherwise acceptable varieties and resulting progenies screened for resistance. As a result of these efforts, two selections (CA188220 and CA188359) have been proposed for release.

Varieties of chickpeas developed are as follows:

'Tammany'. This variety has a unifoliate leaf structure which differs from the firm leaf structure that is typical of most chickpea cultivars currently is use. Tammany is earlier to mature and has larger seeds when compared to 'UC-5'; the commonly grown cultivar in the region. Seeds of Tammany average 58 grams per 100 seeds compared to 52 grams for UC-5. The uniformly large light cream-colored seeds of Tammany are highly desired by domestic processors and by exporters.

'Garnet'. This variety originated as a plant introduction from Ethiopia that was mass selected for uniformity. Garnet has produced yields that were equal to or better than other desi lines. Garnet matures in about 110 days from planting. The seeds are reddish-tan, uniform in size, and weigh 16.4 grams per 100 seeds.

'Sarah'. This variety originated from India where it was selected as an Ascochyta blight resistant desi type and designated as C235. The variety is also produced extensively in Australia under the name 'Tyson'. Sarah has shown excellent resistance to Ascochyta blight in the Palouse region. Yields and quality are also very good.

'Sanford'. (CA188220), proposed for release in 1993, is a selection with very good resistance to Ascochyta blight and was also higher yielding when compared to Surutato in 1992. Sanford has large (100 seeds weigh 54 grams) cream-colored seeds which are considered acceptable to canners.

'Dwelley'. (CA188359), proposed for release in 1993, is a selection with very good resistance to Ascochyta blight. Yields were comparable to Surutato when compared in 1993. Seed size of Dwelley is somewhat larger (100 seeds weigh 59 grams) when compared to Sanford. Seeds are cream-colored and are considered acceptable by canners.

Austrian Winter Peas: We have set a number of objectives in the Austrian winter pea breeding program including the following: 1) identification and incorporation of resistance to Aphanomyces root rot, and 2) develop types with high biomass production and high yields that can be used for several purposes including green-manuring, and seed production.

Varieties of Austrian winter peas are as follows:

'Glacier'. Released in 1981 by the University of Idaho is a dwarf type pea variety with relatively stiff stems. Similar in yield to other Austrian winter pea varieties under ordinary conditions; but, when grown under a higher level of management can produce greater seed yields. Susceptible to foliar diseases and to Aphanomyces root rot.

'Fenn'. Released in 1972 by the University of Idaho is a tall type variety that was developed by direct selection from the old Common Austrian winter pea. Also susceptible to foliar diseases and to Aphanomyces root rot.

'Common' is the original Austrian winter pea that was introduced into northern Idaho and eastern Washington in the early 1930's. Susceptible to foliar diseases and to Aphanomyces root rot.

'Melrose'. Released in 1978 by the University of Idaho and is a tall variety, similar to Fenn and Common. Susceptible to foliar diseases and to Aphanomyces root rot.

Maintaining crop residues on soil surfaces is one of the most effective and practical ways to control soil erosion. Unfortunately lentils often do not produce adequate amounts of residue for conservation compliance requirements. The objectives of this research were to measure the quantities of lentil residue and grain yield which are produced by a diverse set of cultivars across range of environments important to crop production in this region. We wanted to evaluate the needs for additional residue and the potential for increasing the amount of residue left after production of lentil. On lower slope positions, grain yield and residue yield were inversely related among cultivars. On upper slope positions, grain yields were nearly constant among cultivars, but Laird produced more residue than other cultivars. It produced an average 1.36 times more residue than the check, Brewer. Therefore, no single cultivar met breeding objectives across all positions. If growers are willing to use site specific cultivar selection, Laird or lines derived from it, may have potential to help control erosion with additional residues.

GENETIC ENGINEERING OF PEAS AND LENTILS FOR HERBICIDE AND DISEASE RESISTANCE

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Department of Genetics and Cell Biology

Weed, insect, and disease management in both peas and lentils cause serious production problems. Developing the capability to genetically engineer these crops for herbicide, insect, and/or disease resistance would aid the management of these pests in pea and lentil crop production systems. Several gene transfer techniques, including the Biolistic gene gun, *Agrobacterium*-co-cultivation, and *in planta* electroporation, are being testing in our labs for their efficiency to produce transformed plants. Genes that cause resistance to nonselective herbicides, such as Ignite or Roundup, are being used in our studies. Scientists at Washington State University and the University of Idaho are also isolating genes for resistance to viruses such as pea enation, bean common mosaic, bean yellow mosaic, and bean leafroll viruses. These characteristics could be engineered into peas and lentils if the gene transfer technology were available.

Progress made in tissue culture experiments during the past year has resulted in the development of efficient regeneration systems from two varieties of pea, Melrose and Rondo and three varieties of lentil, Crimson, Eston and Laird. Pea embryos attached to cotyledons (from immature seeds) produce large numbers of shoots when cultured with various concentrations of thidiazuron (thidiazuron is a synthetic chemical that has properties similar to plant hormones). A similar response occurs when mature lentil seeds are cultured in the same media. The shoots appear to regenerate from single cells. Optimization of this system and testing of other varieties (such as Puget and Columbia peas and Brewer lentils) are being done.

The origin of adventitious shoots (multiple shoots arising from "unusual" places) developing in TDZ-treated pea embryo/cotyledons and the lentil mature seeds must be determined so as to better direct where the DNA/particles are delivered from the particle gun. Samples of developing plant tissues growing on thidiazuron were taken daily, preserved, embedded in paraffin, sectioned, and are currently being studied. The origin of adventitious shoots will be determined by light and electron microscopy.

The particle gun delivers foreign DNA into intact cells. Gold particles are coated with DNA and accelerated to high velocities to cause penetration of intact tissues. The DNA is then randomly incorporated into the plant's genome. To determine where the gold/DNA particles are penetrating the target tissues, assays with the *gus* marker gene are being conducted. The *gus* gene produces the enzyme β-glucuronidase, and cells containing this gene can be easily identified because they turn blue when treated with the proper chemicals. This data will allow us to quickly modify our "shooting" parameters and better control DNA delivery.

Pea and lentil tissues are being subjected to accelerated particle bombardment with either the Ignite resistance gene or the glyphosate resistance gene, and then cultured on media containing the herbicide. Those cells that carry the new gene will be resistant to the herbicide and survive on the media. Shoots developing from the resistant tissues will be transformed.

Another gene transfer method, *Agrobacterium*-co-cultivation, utilizes a bacteria's ability to naturally insert genes into plants as a part of their life cycle. We have received modified *Agrobacterium* strains that carry either of the herbicide resistant genes described above. Experiments utilizing *Agrobacterium*-co-cultivation alone, or in combination with Biolistic wounding and/or vacuum infiltration, have recently been initiated.

Electroporation has been used to transfer DNA into pea and lentil meristems and transgenic plants, carrying the *gus* reporter gene, have been produced at high frequencies. The meristems (growing points) from intact plants were immersed in a DNA solution and then subjected to an electric current which allows DNA to enter the cells. The resulting transgenic plants, carrying the *gus* gene, will be selfed and homozygotes will be identified by testcrossing with wild type individuals and assaying for the presence of the *gus* gene. Pea and lentil plants which have been electroporated with DNA for resistance to the pea enation virus and bean yellow mosaic virus will be identified through molecular biology assays. Plants will be further propagated and subjected to the viruses as a test for functional resistance. Other plants have been electroporated with DNA coding for resistance to the Ignite herbicide or the glyphosate herbicide. These will be tested for their tolerance foliar applications of the herbicides.

This project is developing gene transfer techniques that we will use to produce herbicide, insect, or disease resistant pea and lentil plants which will aid in the improvement of pest management. We have started using genes that confer herbicide resistance because they provide a method to detect cells carrying the new gene. This technology will be shared, via scientific publications and presentations, laboratory manuals, and in-house laboratory training, with other researchers. Resistant plants/seeds will be turned over to the legume breeder, Dr. Fred Muehlbauer, for breeding and field testing, and seed will eventually be made available for growers. Support for this project has been provided by the Washington and Idaho Pea and Lentil Commission, the Northwest Agricultural Research Foundation, Alternative to Dinoseb, and a USDA Cool Season Legume grant.

RESIDUE AND TILLAGE MANAGEMENT IN LOW PRECIPITATION WHEAT-FALLOW CROPPING SYSTEMS

William Schillinger, Keith Saxton, Edwin Donaldson, Roger Veseth,
Robert Papendick, Peggy Chevalier, Richard Hoffman,
Dale Wilkins, John Zuzel, and Craig Curtis

Introduction

Several applied agronomy research projects were initiated in the semiarid wheat-fallow areas in 1993. We began these experiments in response to the needs expressed by numerous growers for agronomic research directly applicable to low precipitation zones. The objective of these studies is to refine management methods which maintain or improve soil productivity, maximize water conservation, control wind and water erosion, and enhance economic return to growers. These studies are funded by the Washington Wheat Commission, STEEP II, and the USDA-CSRS Wind Erosion/PM-10 project. First year results from four experiments are briefly outlined in this report.

Depth of Tillage Effects on Seedzone Water Retention and Wheat Seedling Emergence

Cooperator : Curtis Hennings
Location : 14 miles south of Ritzville, 11.5" annual precipitation
Soil Type : Ritzville silt loam

Objective

To determine the effects of soil mulch depth during summer fallow on: (1) seedzone water content and; (2) winter wheat emergence and plant establishment.

Treatments

1. Shallow/Shallow : Primary spring tillage at 4", rodweedings at 2".
2. Shallow/Deep : Primary spring tillage at 4", rodweedings at 4".
3. Deep/Deep : Primary spring tillage at 6", rodweedings at 4".

Field Operations

May 13: Primary tillage with Haybuster undercutter with aqua injection + rotary hoe (pulled backwards). June 25: First rodweeding. July 28: Second rodweeding. Sept. 20: Seeded to Eltan winter wheat at 35 lb/ac with HZ split packer drills. Precipitation from May through September was 2.83 inches.

Results

Seedzone Water Content. Depth of tillage had a highly significant effect on seedzone water content between the 3.5 and 5.5 inch depths. Deeper tillage produced a higher seedzone water content. We did not expect to find these differences on such a wet year.

Wheat Seedling Emergence. There were no differences among treatments in wheat seedling emergence nor final stand establishment. Seedzone water content was more than adequate in all treatments. Fall seeding conditions were excellent throughout the wheat-fallow production region in 1993.

Water in the 6 ft Profile. There was 11.73" of water in the 6 ft soil profile on May 20, and 10.13" on September 1, on average. Thus, an average of 1.6" of soil water was lost despite 2.68" of precipitation occurring between May 20 - Sept. 1. There were no 6 ft soil profile water differences among treatments.

Residue and Clods. Although not measured this year, there appeared to be considerably more residue and clods on the soil surface after seeding in plots which had been deep rodweeded. This will be measured in 1994 as it may have important implications for controlling blowing dust (i.e. PM 10) after seeding.

Coil Packing Before Seeding Summer Fallow: agronomic benefits and environmental concerns

Cooperators : Ron Jirava and Grant Miller
Location : 7 miles NW of Ritzville, 11" annual precipitation
Soil type : Ritzville silt loam

Objective

To determine the effects of compressing the dry surface soil mulch of summer fallow on seedzone water content, soil bulk density, winter wheat emergence, and soil susceptibility to wind erosion.

Treatments

1. Check - no packing
2. Coil packed

Field Operations

Coil packing was conducted on August 25. Plots were seeded to Lewjain at 35 lb/ac on August 27 with a HZ split-packer drill. Plots were seeded at two depths: shallow - approximately 4" and; deep - approximately 6". There were six replications.

Results

Soil Bulk Density. Coil packing significantly increased soil bulk density (i.e. the weight of dry soil per unit volume) between the 2.5 and 5" soil depths.

Seedzone Water Content. Volumetric soil water content was significantly increased with coil packing between the 3 and 5" depths. There are two reasons why seedzone water content increased with coil packing: (1) soil bulk density was increased (i.e. more water per unit volume of soil) and; (2) coil packing reduced the thickness of the dry soil mulch layer, thus decreasing the distance from the soil surface to adequate seedzone water.

Wheat Seedling Emergence. With shallow seeding, the number of wheat seedlings emerged was significantly higher in coil packed plots between 7 and 9 days after planting (DAP). This would have been important, for example, if a crusting rain had occurred between 7 and 9 DAP. For 10 DAP onwards there were no differences in seedling emergence nor final stand establishment between treatments.

With deep seeding, coil packing resulted in significantly better seedling emergence on all sampling dates as well as the best final stand establishment. The reason for these differences in not clear, although roll-back of large soil clods into the furrow may have hindered seedling emergence in control plots. Note: Because of the excellent seeding conditions in 1993, deep seeding was somewhat of an "artificial" treatment. The effects of coil packing on a "normal" year, when deep seeding into marginal seedzone water is commonly practiced, has yet to be measured.

Soil Clods. Coil packing reduced the number and weight of clods in all size groups. For example: there were 6.5 tons/acre of 2" diameter clods in control plots, but only slightly more than 3 tons/acre of 2" clods after coil packing. Clods larger than 5" were eliminated with coil packing.

Summary

Agronomic benefits (i.e. faster wheat seedling emergence) were apparent from coil packing even during a wet year. Elimination of very large clods (> 5") likely contributed to better seedling emergence in coil packed plots. On the other hand, as coil packing reduced number and weight of all clod size groups, this study suggests that the coil packer may need to be used judiciously on soils susceptible to wind erosion. The study will be repeated for at least on more year.

Residue Management in Very Dry Wheat-Fallow Cropping Systems

Location : Lind Dryland Research Unit, 9.5" annual precipitation
Soil Type : Shano silt loam

Objective

To determine the agronomic and environmental benefits of minimum tillage practices versus traditional tillage practices on residue retention, erosion potential, water conservation, and grain yield in very dry wheat-fallow cropping systems.

Treatments (abbreviated)

1. Traditional Tillage. Conventional frequency and timing of tillage practices using traditional tillage implements.

2. Minimum Tillage. Minimum tillage practices with conservation tillage implements which leave the majority of residue on the soil surface. Herbicide application will be substituted for tillage operations when practical.

Field Operations

August 15: A sweep plow was used after harvest to control Russian thistles in traditional tillage plots whereas minimum tillage plots were sprayed with a systemic herbicide. November 17: Traditional tillage plots where chiseled to a depth of 8" with chisel shanks spaced 24" apart. Minimum tillage plots were chiseled to a depth of 10" with chisel shanks spaced 6 ft apart.

Results

Fall 1993: Highly significant differences in the quantity of straw and Russian thistle residue between traditionally tilled plots (i.e. sweep and chisel) and minimum tillage plots (i.e. herbicide and wide spaced chisel) were measured following fall field operations. Thistles dislodged by sweep plowing in traditionally tilled plots were, for the most part, carried away by wind. In the minimum tillage plots, most thistles remained firmly anchored throughout the fall. In mid-November, straw and thistle residue in traditionally tilled plots was 74% and 14%, respectively, of that measured in minimum tillage plots.

Spring 1994: Over-winter fallow efficiency (i.e. the percentage of winter precipitation which is stored in the soil) was significantly greater in minimally tilled plots compared to traditional tillage. Soil water content, surface residue, surface clodiness, and wheat seedling emergence will be measured during the summer. We plan to use a newly developed "wind tunnel" on these plots after seeding to increased our understanding of the correlation between wind speed and erosion as affected by soil type and various soil surface conditions.

Fall Tillage to Improve Water Infiltration and Reduce Water Erosion During the Crop Winter

Cooperator : Harold Clinesmith
Location : Benge, Washington, 12" annual precipitation

Objective
To evaluate methods for forming tillage slots to improve water infiltration and reduce water erosion on frozen soils during the crop winter.

Treatments
1. Control - soil not disturbed after planting winter wheat.
2. Plots ripped in late fall to create open tillage channels.

Field Operations
September 22: Winter wheat seeded with HZ deep furrow drills on a 23% north-facing slope. December 13: Plots ripped with a single shank (dammer-diker type) implement on 20 ft spacings along the contour of the hill. There are 6 replications.

Results
Over-Winter Water Storage. Precipitation during the 1993-94 winter was less than average and there was little water runoff. Ripping was not effective in increasing over-winter soil water storage. The control treatment held significantly ($P = .002$) more water than the ripped treatment in the 6 ft soil profile in March 1994.

Rill Erosion. The "alutin method" was used to measure rill erosion in mid-March. There was no measurable rill erosion from ripped plots, whereas minor rill erosion (2.96 tons/acre) was measured in control plots. These differences were significant at $P = .013$. Dryland foot rot *(Fusarium)* was present near the ripped channels. Grain yield will be measured from the experiment in the summer.

AN ECONOMIC AND SOIL CONSERVATION EVALUATION OF A VARIABLE LANDSCAPE NO-TILL SYSTEM

Kathleen Painter, Roger Pennell, Douglas Young, and Roger Veseth[1]

Appropriate tillage for the highly variable, high yielding Palouse landscape differs across slope position and orientation. On the highly erodible hilltops, yield potential and residue production may be one-half or less than on the more fertile bottomland. Problems associated with too much residue are common on the bottomland, whereas on the hilltops there can be insufficient residue to effectively conserve winter precipitation and control erosion. This paper describes farming methods used by a Palouse farmer to address these different tillage needs.

Roger Pennell has been seeding no-till for 10 years as part of the production system on his farm located approximately 15 miles northeast of Colfax. For the last seven years, he has incorporated variable fall tillage methods into his no-till system. All grain crops are planted using a no-till drill. Fall grain crops are direct seeded without prior tillage. For spring grains, he fall tills the bottomland and other selected areas of the field landscape. Approximately 15% of the most fragile land on the hilltops is managed differently than the remaining 85%. The hilltops are generally left in standing stubble overwinter. The remaining land is fall chiseled following a grain crop, either with a Glencoe Soil Saver or a John Deere Mulch Tiller with a five-bar flex harrow. Areas with extremely heavy residue may be chiseled twice. The ground will then be double-harrowed in order to prepare the land for spring spraying and seeding. If there is a fall green-up, Roundup or Landmaster is applied prior to November 1. In late March or early April, 12 to 16 oz. of Roundup is applied before spring crops.

This system has excellent soil erosion control and is actively rebuilding organic matter. In time, typically low-yielding ridgetop and upper slope areas will experience yield improvement. Leaving standing stubble on hilltops will improve yields through increased water infiltration and snow trapping, and decreased run-off. Higher yields mean higher residue production for building organic matter in the soil. Use of the no-till drill with its system of fertilizer placement will also help improve yields. While standing stubble will help improve fragile land on hilltops, it can be detrimental to yields in the more fertile, less erosion-prone land on the lower slopes and bottomland. Production problems on these soils are due to excessive amounts of residue, more intensive weed and disease pressures, rodent problems, and wet, cold soils. More intensive residue incorporation, as outlined above, is needed in these areas.

In this report, Pennell's variable no-till approach has been extended to include the most common rotations used in this area. Net returns to land and management for all rotations are presented in Table 1. Conservative yields estimates were based on averages for the Central Whitman County 18"-21" rainfall zone, using the assumption that the hilltops and upper slopes (zone 1) have approximately half the grain yield potential of the lower slopes and bottomland (zone 2). Results

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[1]WSU Research Associate, Dept. of Agricultural Economics, Pullman; grower, Garfield; WSU Professor, Dept. of Agricultural Economics, Pullman; WSU/UI Extension Conservation Tillage Specialist.

are presented separately for zones 1 and 2, followed by a weighted average for the whole farm, based on 15% of the land in zone 1 and 85% in zone 2, in the last two columns of Table 1. Production costs vary by zone due to increased tillage for weed control and residue management in the less vulnerable land in zone 2 and use of chem fallow in zone 1. Based on Pennell's experience, organic matter in these poorer soils will be enhanced and higher yields can be expected over time. Given the price and yield assumptions in this study, the typical Palouse systems of wheat/lentils (Rotation 1) and wheat/barley/lentils (Rotation 2) are the most profitable. Average net returns to land and management over total production costs are $68/acre for Rotation 1 and $51/acre for Rotation 2. The third most profitable system, Rotation 5, spring wheat/spring barley/spring wheat, has net returns over total costs averaging $40/acre. If a premium price for spring wheat were obtained, the spring wheat systems would compete better with the first two rotations.

As shown in Table 2, the weighted average erosion estimate is lowest for the rotations with spring wheat, Rotations 4 and 5, at just 2.40 and 2.77 tons/acre/year for 18" rainfall and 21" rainfall respectively. Typical erosion rates for approved conventional tillage under Alternative Conservation Systems using uniform min-till practices across the landscape are approximately double the rates in this study. Except for the rotations with fallow, erosion rates for all rotations in this study are well below the soil loss tolerance factor (T) for this area, about 5.75 tons/acre/year. Erosion rates for the fallow systems, which include chem fallow on the most vulnerable land in zone 1, are in the range of approved Alternative Conservation Systems currently in use.

Pennell has observed many benefits from his current system. He feels that the high organic matter content in his soils protects yields under less than ideal growing conditions. Other benefits include 1) lack of crusting because of organic matter in soil and on the surface; 2) elimination of the "green link" associated with disease and pest problems overwintering in crop residue; 3) a firm seedbed; 4) reduced moisture loss due to tillage; 5) fewer weeds germinated due to less tillage; 6) less compaction due to fewer trips over the field; and 7) access to fields early in spring. Most importantly, he has accomplished his goals of eliminating soil erosion and lowering his costs of production while maintaining and often improving yields.

<u>Summary</u>

Many soil conservation benefits were observed from this variable landscape no-till system. Standing stubble saves soil moisture and helps stop erosion on vulnerable hilltops. Organic matter content of the soil is increased through use of no-till and standing stubble. Erosion estimates for these rotations are approximately one-half of the estimates for comparable conventional min-till rotations used uniformly across the landscape. Improving the soil had economic benefits as well, as increased organic matter content helps maintain yields during less than ideal growing conditions. Yields were also improved through proper fertilizer placement using the no-till drill. While the more conventional winter wheat/lentils and winter wheat/spring barley/lentils rotations were more profitable than the rotations with spring wheat, they were slightly more erosive. The economic competitiveness of the spring wheat systems would be improved if a higher value spring wheat variety were obtained.

Table 1: Net Returns over Variable and Total Costs of Production[1] by Crop and Rotation for Each Landscape Zone and Weighted for Whole Farm.

	ZONE 1 HILLTOPS		ZONE 2 BOTTOMLAND		WEIGHTED AVERAGE	
CROP/ ROTATION	Returns Over Var. Costs	Returns Over Total Costs	Returns Over Var. Costs	Returns Over Total Costs	Returns Over Var. Costs	Returns Over Total Costs
Rotation 1:						
Winter Wheat	29	-3	195	163	170	138
Spring Lentils	37	5	34	-4	34	-3
AVERAGE	33	1	115	80	102	68
Rotation 2:						
Winter Wheat	29	-3	195	163	170	138
Spring Barley	15	-21	64	24	57	17
Spring Lentils or	37	5	34	-4	34	-3
Summer Fallow	-68	-79	-42	-63	-46	-65
AVERAGE:						
W/B/L	27	-6	98	61	87	51
W/B/F	-8	-34	72	41	60	30
Rotation 3:						
Winter Wheat	29	-3	195	163	170	138
Summer Fallow	-68	-79	-42	-63	-46	-65
AVERAGE:	-19	-41	77	50	62	36
Rotation 4:						
Spring Wheat	-33	-65	67	30	52	15
Spring Barley	-36	-72	64	24	49	10
AVERAGE:	-35	-69	65	27	50	12
Rotation 5:						
Spring Wheat	-33	5	95	63	76	55
Spring Barley	-36	-72	64	24	49	10
Spring Wheat	-33	5	95	63	76	55
AVERAGE:	-34	-21	85	50	67	40

[1] Net returns over variable and total costs exclude land and management costs.

NOTES: Zone 1 refers to highly erodible, low yielding hilltops and consists of approximately 15% of a typical farm. Zone 2 refers to the remaining 85% of the land which is less erodible and higher yielding.

Price assumptions for this study are: $4.15/bu for wheat, including government payments; $0.16/lb. for lentils; and $102/ton for barley, including government payments. Yield assumptions for Zone 1 are: 40 bu/acre for wheat, 1 ton/acre for barley, and 1000 lb/ac for lentils. Yield assumptions for Zone 2 are: 80 bu/acre for wheat, 2 tons/acre for barley, and 1000 lb/ac for lentils.

Table 2: Erosion Calculations by Rotation Using USLE by Zone and Weighted for Whole Farm (tons/acre/year).[1]

ROTATION:	EROSION:		
	ZONE 1 HILLTOPS	ZONE 2 BOTTOMLAND	WEIGHTED AVERAGE
For 18" rainfall:			
WW/L	3.47	3.15	3.20
WW/SB/L	3.47	2.52	2.66
WW/SB/F	4.57	5.22	5.12
WW/F	5.06	6.07	5.92
SW/SB	3.47	2.21	2.40
SW/SW/SB	3.47	2.21	2.40
For 21" rainfall:			
WW/L	4.01	3.65	3.70
WW/SB/L	4.01	2.92	3.08
WW/SB/F	5.29	6.04	5.93
WW/F	5.86	7.03	6.85
SW/SB	4.01	2.55	2.77
SW/SW/SB	4.01	2.55	2.77

[1]Assumes 15% in zone 1 and 85% in zone 2.

LEGEND: WW = winter wheat, L = lentils, SB = spring barley, F = summer fallow (chem fallow in zone 1), SW = spring wheat.

NOTE: Trade names have been used to simplify information. Endorsement of named products is not intended, nor is criticism of similar products not mentioned.

RESEARCH INITIATED ON BMPs FOR CRP TAKE-OUT

Roger Veseth and Baird Miller
WSU/UI Extension Conservation Tillage Specialist
and WSU Extension Agronomist

A Washington State research and educational project on Best Management Practices (BMPs) for returning CRP land to crop production was recently approved by the national USDA-Agricultural Stabilization and Conservation Service (ASCS) office. Research which destroys CRP cover can not be conducted without national ASCS approval. Only one CRP research project can be authorized per state and it must be conducted by a bona fide research entity, such as a land grant university.

Baird Miller and Roger Veseth are serving as project leaders to coordinate this Washington State project. Other project scientists involved at this time include: Bill Schillinger, WSU Area Extension Agronomist, Adams/Lincoln Counties, Ritzville; Roland Schirman, WSU Extension Agricultural Agent, Columbia County, Dayton; Alex Ogg, USDA-ARS Weed Scientist, Pullman; Ed Donaldson, WSU Research Agronomist, Lind; and Herb Hinman, WSU Extension Agricultural Economist, Pullman. Other scientists, extension agricultural agents, SCS staff, industry representative and growers have indicated that they would like to be involved in the project.

This CRP project is designed as an umbrella project for a comprehensive "grass roots" research effort to evaluate prospective, locally-identified BMPs for specific agronomic zones in Washington. The research results should also be applicable to similar production areas in the surrounding states.

We are inviting conservation districts, SCS, the Ag service, chemical and equipment industries, county wheat grower organizations and other interested groups to actively participate in the project at the local level. We will meet with interested groups to plan and establish field trials this summer and fall.

Need and Time Frame for Developing BMPs for CRP Take-out

There are over 2.5 million acres of CRP land in the Pacific Northwest. In Washington State there is a total of 1.045 million acres of land under a total of 4,578 CRP contracts. This represents nearly 14 percent of the 7.6 million cropland acres in a 20 county area of eastern Washington. Due to Federal budget constraints and cost-benefits questions, a significant portion of the CRP land may be returned to crop production when the 10-year contracts expire, beginning in 1995.

Most of the CRP land is highly erodible by water or wind, or both. Water erosion is the primary erosion problem on approximately 70 percent of the CRP land in Washington. Wind erosion is the primary conservation problem on about 30 percent of the CRP land and a secondary problem on another 30 percent.

Air quality problems related to wind erosion are becoming an increasing issue in urban areas, such as the Tri-Cities and Spokane. Health concerns have been associated with the very small particulate matter known as PM-10 (about 1/7 the diameter of a human hair). Both of these urban areas are being considered for non-attainable air quality status by the EPA. Fugitive dust from agricultural areas is being indicated as a potential source of PM-10 emissions. Approximately 320,000 acres in CRP in Adams and Lincoln counties are currently reducing air quality problems in Spokane, and 82,000 acres in Benton and Klickitat counties benefit the Tri-Cities area.

Most growers in the lower precipitation region (less than 15 inches) in eastern Washington, where much of the CRP land is concentrated, have little or no experience with converting grassland cover to crop production under conservation systems. Serious wind and water erosion problems could result if traditional intensive tillage practices are used to return CRP land to crop production. Field research is needed now to evaluate management options before CRP contracts expire.

This project was originally proposed to start two years ago, but funding was not available and project interest was not high at that time. We hope to have at least a limited amount of management information on CRP take-out before the first Washington contracts expire September 30, 1995 (about 50,000 acres). The major project focus will be preparing for 1996 when contracts potentially expire on nearly 500,000 acres of CRP, about 45% of the CRP land and contracts. Current regulations will permit growers to begin taking out CRP grass 90 days before the contract expires to begin field preparation for crop production.

Research Project Overview

A series of replicated experiments with farm-scale equipment will be established to evaluate management practices for conversion of CRP land to crop production. The focus of the project will be to identify management strategies and practices that effectively control wind and water erosion while optimizing agronomic performance and profitability in specific agronomic areas. This research project is limited to a total of 600 acres of CRP land in the state. Most projects will probably be around 5 to 15 acres.

The research to identify management strategies for CRP take-out will focus on:

1. Evaluation of both chemical and mechanical methods and timings for killing CRP vegetation and managing residue;
2. Evaluation of tillage options for preparation of the land for crop production while maintaining adequate erosion protection following the killing of CRP vegetation cover; and
3. Evaluation of crop rotations, cultivar selections and production practices for the first crop rotation following take-out of the CRP vegetative cover.

Based on preliminary discussions with several growers groups, county agents, SCS staff and conservation district supervisors, we have tentatively narrowed the research focus to the following CRP take-out strategies:

* Fall versus spring take-out with various tillage and chemical kill options, followed by summer fallow and fall planting
* Fall versus spring take-out with various tillage and chemical kill options, followed by spring planting
* Spring planting versus fall planting
* Alternative spring crop choices to minimize pest problems

Most people felt that a summer take-out and fall planting would not be feasible due to lack of soil water, increased pest levels and other production problems.

At least two to three intensive field experiments are planned. One has already been initiated. A 18-acre experiment was established near Starbuck in Columbia County in March, 1994. Four tillage systems are being evaluated for planting spring wheat. Six spring crops are also being evaluated under two tillage systems. A second intensive research site is planned in Adams County to evaluate management practices for both spring crops and summer fallow-winter wheat after CRP. Satellite experiments with 2-3 locally-identified management treatments could be established in Douglas, Asotin, Garfield, Benton, Franklin, Walla Walla or other eastern Washington counties.

Educational Efforts - Growers, Ag support personnel and the general public will learn about the research results through tours of field research sites, meeting presentations, extension publications, articles in farm publications, newsletters and other educational opportunities.

Project Funding

Two grants have been approved through the USDA-CSRS (Cooperative States Research Service) to partially support this project. One is a 2-year grant under the tristate STEEP II Program. The other is a 2- to 3-year grant under the new Columbia Plateau Wind Erosion/PM-10 Program through WSU. Funds from these two grants, which should be available in June, 1994, will partially support a graduate student and technician, and a limited operating budget. These funds will be used primarily for the intensive research projects in Columbia and Adams Counties. Limited funds are available for coordinating the satellite studies across the state. Additional funding and in-kind support will be needed to effectively complete the statewide project.

ASCS Guidelines for CRP Research Projects

1. Research projects shall:
   - be based on objectives that are consistent with the CRP purposes;
   - provide beneficial information on economically and environmentally-sound agricultural practices;
   - not adversely affect local markets;
   - include adequate funding for completing the project from sources other than ASCS or the CCC;
   - be conducted and monitored by a bona fide research entity, such as a land grant institution;
   - be conducted on no more than 640 contiguous CRP acres.

2. The local ASCS, SCS and Cooperative Extension should be kept informed of field trial site selections and subsequent developments. The ASCS needs to place a copy of the national project approval in the CRP participant's folder, and SCS needs to modify the Conservation Plan of Operation (CPO) to show that a research project is taking place within the identified field.

3. The CRP contract participant must not receive additional compensation, monetary or otherwise, from the project. This is understood to mean: not to receive more than actual expense, if the CRP participant is hired to do some of the approved project work. In case of question, these charges and reimbursements must be justifiable. Profits from the sale of crops grown

on CRP research trials must be designated for the benefit of a state or state entity.

4. Project investigators and cooperators will meet regularly to review progress and future plans. Annual evaluation reports will be submitted to national ASCS, through the Washington ASCS State Conservation Review Group, detailing: resources allocated to the project; progress toward accomplishing objectives; copies of publications developed from the project.

5. When a research site has served its purpose and there is concern that erosion would take place before the expiration of the applicable CRP contract period, the trial area needs to be reseeded to grass at no cost to ASCS or Commodity Credit Corporation (CCC).

How to Get Involved in the CRP Project

Groups interested in satellite field trials through this project are encouraged to begin identifying potential management treatments to be compared, trial locations, cooperating growers, and equipment needed. Then contact one of us (Miller -- 509-335-2858; Veseth -- 208-885-6386) early this summer to set up a time we can meet with you to help plan and establish the trial in the field. "Satellite CRP Field Trial Proposal Forms" have been developed to help local groups in their early planning efforts. We can also provide copies of the WSU Cooperative Extension Bulletin EB1706 "On-Farm Testing: A Grower's Guide," which gives a basic overview of the principles on conducting scientific evaluations of production practices with field-scale equipment.

We are looking forward to working with other groups on this research and educational effort on BMPs for returning CRP land to crop production. Let us know if you have any questions.

ECONOMICS OF LAND USE ON EXPIRING CRP CONTRACTS

A. I. Bechtel, H. R. Hinman, and D. L. Young

There are almost 1.05 million acres of cropland enrolled in the Conservation Reserve Program in the state of Washington. The first CRP contracts will expire in 1995 with over 820,000 acres being released from contract in the years 1995-97. While some of this land might be considered for grazing or other crop uses, climatic and soil considerations make a return to winter wheat-summer fallow the option of choice for many CRP contract holders.

Farmers, Soil Conservation field staff, and Cooperative Extension workers need an easy-to-use decision aid that has modest data needs for making or predicting private decisions on post-contract CRP use. An easily-used spreadsheet has been developed to assist growers and others to determine the relative profitability of returning land to winter wheat-summer fallow versus leaving it in CRP grass with or without government payments.

The spreadsheet has been used to compute break-even yields for returning CRP acres to wheat production in Adams and Douglas counties in eastern Washington, both of which are in a winter wheat-summer fallow region with large CRP enrollments. A distribution of wheat yields on CRP parcels in these two counties was developed along with the variable cost of production. Using these data, a break-even yield for returning CRP to winter wheat-summer fallow has been calculated. This break-even yield was 33 bushels per acre in Adams county and 30 bushels per acre in Douglas county. Given the distribution of wheat yields in these two counties, 44% of Adams county CRP acres fall short of this yield and 59% of Douglas county CRP acres are below the calculated break-even yield level. These break-even yields would be even higher were it necessary to acquire additional machinery to return the CRP land to production. The break-even yield for individual parcels could be easily developed using this spreadsheet which requires only the producer's variable cost of production, expected crop prices, and level of government payments.

DEEP PHOSPHORUS PLACEMENT IN DRYLAND CEREAL PRODUCTION

W. L. Pan and M. Mohammad

The establishment of sustainable cropping systems will require fertility management practices that maximize yield and crop residue production while improving nutrient use efficiency and reducing nutrient losses, particularly N and P. Poor crop growth on eroded hilltops and sideslopes limits N recovery by crops, leaving more in the soil for leaching or buildup of residual nitrate, which can reduce yields and quality of subsequent crops. Poor crop growth also results in less residue production, which leads to greater susceptibility to erosion, contributing to a downward spiral in soil quality and productivity. Inadequate P nutrition has long been identified as an important limiting factor in soils of eastern WA. More recently, low subsoil P was identified as a factor contributing to late season P deficiency, despite conventional fertilization. Non-conventional methods are needed to enhance subsoil P availability.

Subsurface layers of eroded soils in eastern and central WA are severely deficient in available P. Grain crops are continuing to mine P from deep soil layers, without replenishing deep P reserves. Since fertilizer P is immobile in soils, it is difficult to replenish subsoil P. Conventional P placement may not be adequate for optimizing P availability, since the surface soils dry during the growing season, leaving shallow-placed P stranded. Late-season P deficiencies appears to be responsible for suboptimal grain and straw production. Deep placement to 15 inches with a paraplow (Pullman) or subsoiler (Lind) prolonged P availability in the more moist subsoil, increasing yields relative to seed placed P at Pullman and Lind, and also greater than shank banding at Pullman in 1992, due to greater head numbers and less tiller abortion. Subsoil P stimulated deeper rooting.

Phosphorus was placed with the seed, banded 5 cm below the seed, and 30 to 45 cm deep with liquid delivery tube mounted to the rear of a conventional subsoiler at Lind and a paraplow at Pullman. Tillage and N management was uniform for all treatments. All plots were subsoiled, and N was placed at all three depths in equal amounts across all treatments.

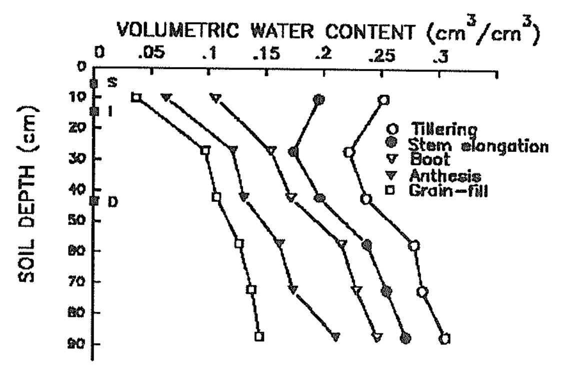

Fig. 1. Change in volumetric water content with depth and time at Lind, WA 1992

Soil water loss was greater in the surface 20 cm of soil than in deeper soil layers after stem elongation (Fig. 1). As a result, P applied in the plow layer was stranded in dry soil during the latter part of the growing season.

Intermediate and deep P placement produced higher grain yields than seed placed P at Lind (Table 1) and Pullman (Table 2), mainly due to lower tiller abortion and greater numbers of grain bearing heads per plant.

At Pullman on an eroded Palouse silt loam, deep placement with the paraplow resulted in higher grain yields than shanking P, 5 cm below the seed, due to greater kernel number per head and greater head number per plant. Deep P placement stimulated greater late-season P uptake (Mohammad, 1993), which may have promoted head and grain development.

Table 1. Winter wheat tiller densities and yield components as affected by P placement at Lind, 1992 (Mohammad, 1993).

P Placement	Tiller densities		Yield components			
30 kg P ha^{-1} total	Tillering	Anthesis	Kernel number	Kernel weight	Head number	Grain yield
	# m^{-1}	# m^{-1}	$head^{-1}$	g $kernel^{-1}$	$plant^{-1}$	kg ha^{-1}
With seed (S)	372.6a	156.4b	18.96ab	.039b	5.33b	2895b
10 cm (I)	411.3a	194.1ab	17.48ab	.041ab	7.20a	4050a
40 cm (D)	357.7a	237.1a	20.79a	.042a	6.57ab	3976a
Split P (D+S)	434.1a	229.4a	18.20ab	.041ab	7.16a	3468ab
Split P (I+S)	459.8a	240.4a	17.13ab	.041ab	6.59ab	3898a
$LSD_{0.05}$	108.2	65.7	3.4	.003	1.74	806
Contrasts						
S vs I,D	NS	*	NS	NS	NS	*
I,IS vs D,DS	NS	NS	NS	NS	NS	NS

* Means in each column designated with different letters are significantly different at the 0.05 level of probability.

Table 2. Tiller densities and yield components as affected by the P placements at Pullman, 1992 (Mohammad, 1993).

P Placement	Total tillers		Yield components			
	Late tiller	Anthesis	Kernel number	Kernel weight	Head number	Grain yield
	# m^{-1}	# m^{-1}	$head^{-1}$	g $kernel^{-1}$	$plant^{-1}$	kg ha^{-1}
With seed (S)	163.1a	73.1b	18.6b	.031a	2.4d	1708d
10 cm (I)	165.6a	79.6b	18.4b	.032a	2.6cd	2072c
30-45 cm (D)	137.3a	94.5ab	20.4a	.031a	3.3ab	2628ab
Split P (D+S)	140.5a	109.5a	21.3a	.030a	3.0bc	2567b
Split P (I+S)	157.9a	92.9ab	20.1a	.030a	3.1b	2388bc
$LSD_{0.05}$	38.6	21.7	2.0	.004	0.5	360
Contrasts						
S vs I,D	NS	NS	NS	NS	**	**
I,IS vs D,DS	NS	*	*	NS	NS	*

Means in each column that have different letters are significantly different at the 0.05 level of probability.
*, **, and NS indicate significance at the 0.05 and 0.01 levels, and nonsignificance, respectively.

These plots at Lind and Pullman have been reseeded with wheat after a summer fallow year to restore soil moisture. Residual effects of P positional availability will be evaluated in 1994.

Reference

Mohammad, M. 1993. Wheat growth and P uptake responses to mycorrhizal inoculation and deep P placement. Ph.D. Dissertation, WSU.

TEAM-DEVELOPED GUIDES FOR PEST MANAGEMENT IN CONSERVATION TILLAGE

Roger Veseth
WSU/UI Extension Conservation Tillage Specialist

Northwest producers need access to new conservation farming technologies in order to develop and maintain profitable conservation farming systems. Effective pest management strategies are particularly important. For decades, intensive tillage and residue management practices have substituted for other management options to partially control a number of crop pests in the region. As producers change to conservation tillage systems, it is critical that they are aware of potential changes in pest problems and effectively utilize other pest management options available. To assist growers in this transition to conservation tillage systems, teams of extension specialist and researchers have recently put together three management guides for important disease, insect and weed problems.

This need for effective pest management options in conservation tillage is becoming increasingly critical with the implementation of the conservation provisions of the USDA 1985 FSA (Food Security Act) and 1990 FACTA (Food, Agriculture, Conservation and Trade Act). Approved farm conservation plans on highly erodible land must be fully implemented by producers before 1995 in order to remain eligible for USDA programs.

The *Pacific Northwest Conservation Tillage Handbook Series* of publications was selected for the management guides. Since the *Handbook* was published in 1990, 18 new *Handbook Series* publications have been added. They are 3-hole punched and ready for insertion into the large 3-ring binder *Handbook*. The *Handbook* now contains 120 *Handbook Series* publications and is the major current reference on conservation farming technologies in the Northwest.

New *Handbook Series* publications are distributed through the *Pacific Northwest STEEP II Extension Conservation Farming Update*, which has been an effective method of technology transfer on new conservation farming technologies. STEEP (Solutions To Environmental and Economic Problems) and STEEP II research and educational programs have been a major source of new technologies on conservation farming systems in Washington, Oregon and Idaho. The current *Update* mailing list of nearly 2,700 includes: producers (about 1,800); applicable extension agents, conservation districts and SCS staff in the Northwest; representatives from the Ag support industries and agencies; and media.

Three new *Handbook Series* publications on pest management have been developed for distribution through the *Update* from September 1993 through June 1994. They focus on pest problems which were critical production concerns across much of the Inland Northwest in the 1993 crop year, although the pests have been chronic problems for decades. The following are a brief descriptions of the *Handbook Series* publications.

Managing Cephalosporium Stripe in Conservation Tillage Systems, *Pacific Northwest Conservation Tillage Handbook Series* No. 17 in Chapter 4, was published in September 1993. The team of coauthors include: Roger Veseth; Baird Miller, WSU Extension Agronomist; Stephen Guy, UI Extension Crop Management Specialist; Don Wysocki, OSU Extension Soil Scientist; Timothy Murray, WSU Plant Pathologist; Richard Smiley OSU Plant Pathologist; and Maury Wiese, UI Plant Pathologist.

Winter wheat yields losses from Cephalosporium stripe were particularly severe and widespread in the Inland Northwest in 1984 and again in 1993. Growers and Ag support personnel were faced with management decisions on how to reduce the potential of disease losses in future crops while staying in compliance with farm conservation plans to reduce soil erosion. This publication was developed to provide growers and grower-advisors with key management considerations. The focus was on providing a better understanding of the disease life cycle, and how environmental and management factors affect disease potential under conservation tillage.

The incidence and severity of Cephalosporium stripe depends on a number of environmental and management factors including: 1) amount of disease inoculum in the field; 2) seeding date; 3) varietal susceptibility; 4) weather conditions which influence the level of infection; 5) soil fertility/fertilizer applications; and 6) soil pH. Although these factors individually influence the amount of disease, they also interact with each other, resulting in more or less disease. The entire crop production system must be considered in order to understand how these factors influence disease potential and what combination of management practices will most effectively minimize losses from Cephalosporium stripe in the next winter wheat crop.

As with most crop pests, there is no one management choice that will provide complete control. The most effective and economical control will be achieved through the use of an integrated management approach that takes into account most applicable management options. Growers need to balance practices for disease control with other yield limitations and management considerations, such as impacts on water conservation and erosion protection.

The publication covers management options to minimize crop losses in conservation tillage systems. These include use of longer crop rotations, adjusting the seeding date, growing more tolerant varieties, controlling volunteer wheat and weeds, and utilizing protective surface residue to prevent root injury. Keep in mind that to minimize disease potential in the next winter wheat crop, management options to avoid infection can be as effective as efforts to reduce inoculum carryover in infested residue through more intensive tillage and residue management practices.

Hessian Fly Management in Conservation Tillage Systems for the Inland Pacific Northwest, *Pacific Northwest Conservation Tillage Handbook Series* No. 15 in Chapter 8, was published in September 1993. The team of coauthors included: Keith Pike, WSU Entomologist; Roger Veseth; Baird Miller, WSU Extension Agronomist; Roland Schirman, Columbia County Extension Agricultural Agent; Larry Smith, Nez Perce County Area Extension Agricultural Agent; and Hugh Homan, UI Extension Entomologist.

Significant infestations of Hessian fly have occurred in eastern Washington and north central Idaho over the past five years. Infestations were particularly extensive and severe in the 1993 crop. Growers and grower-advisors in this region were in the process of deciding how to manage infested crop residue, and what other management practices to use to reduce the potential for future crop losses from the pest under farm conservation plans. There appeared to be some confusion and misconceptions about the effectiveness of prospective management options. This publication was compiled to provide growers and grower-advisors with an integrated approach to effectively manage Hessian fly under conservation tillage.

Hessian fly is an exception to the general rule that insect pests of cereals in the Northwest are not significantly influenced by choice of tillage and residue management. Conservation tillage systems, which leave infested stubble and volunteer plants on or near the soil surface, allow greater survival of the pest than after more intensive tillage practices because few fly larvae or puparia are not buried to an adequate depth. Fortunately, the degree of fly infestation and crop loss in the subsequent wheat crop is determined more by management options for the following crops than by tillage and residue management practices after an infested crop. Therefore, Hessian fly can be effectively managed under conservation tillage systems so that growers can stay in compliance with their farm conservation plans.

After harvest of a wheat crop infested with Hessian fly, growers should not make significant changes in tillage and residue management practices. Burying infested residue at a sufficient depth to prevent emergence requires exceptionally deep plowing and should only be considered on cropland which is not highly erodible. Stubble burning is not recommended because of an inadequate reduction in fly survival in the plant crowns, and the increased potential for soil erosion. To control Hessian fly in conservation systems, growers should consider an integrated approach utilizing all feasible control options including: resistant spring wheat varieties, crop rotations with less susceptible or non-host crops, early control of volunteer wheat and host weeds, adjusted seeding dates, and management for a healthy crop. In-furrow insecticides could be considered for reducing infestation potential during seedling establishment when other control options are not feasible.

Managing Downy Brome under Conservation Tillage Systems in the Crop-Fallow Region of the Pacific Northwest, *Pacific Northwest Conservation Tillage Handbook Series* No. 15 in Chapter 5, will be published in June 1994. The team of coauthors include: Roger Veseth; Alex Ogg, Jr., USDA-ARS Weed Scientist; Donn Thill, UI Weed Scientist; Dan Ball, OSU Weed Scientist; Don Wysocki, OSU Extension Soil Scientist, Floyd Bailey, Idaho State USDA-SCS State Agronomist; Tom Gohlke, Oregon State USDA-SCS State Agronomist; and Harry Riehle, Washington State USDA-SCS State Agronomist.

Downy brome, commonly called cheatgrass, has been a major grass weed problem in winter wheat in this region for decades, particularly in the lower rainfall areas under the crop-fallow rotation. Infestations in many areas of the Inland Northwest were particularly severe in 1993. Although it is a problem regardless of tillage system used, it can be particularly troublesome in the crop-fallow rotation under tillage systems designed to retain more crop residue on the soil surface. When the seeds remain on the surface or are buried shallowly, there is a potential for rapid development of downy brome infestations in winter wheat-fallow rotations unless effective weed management strategies are implemented.

Traditional methods of controlling dense infestations of downy brome have included intensive tillage systems that deeply bury the seed, and burning to destroy seeds in the surface residue. However, high rates of soil erosion have often occurred during the subsequent fallow-winter wheat sequence following these practices. National legislation, beginning with the 1995 Food Security Act, requires producers on highly erodible cropland to effectively minimize soil erosion in order to be eligible to participate in USDA programs. These laws have limited the use of intensive tillage and burning as downy brome management tools in this production region.

Many producers have made changes in their tillage and residue management systems in recent years as part of their farm conservation plans. It is critical that producers develop an effective management strategy to minimize downy brome seed production and deplete seed populations in the soil in order to avoid dense infestations of downy brome after conversion to conservation tillage systems. This publication provides an overview of management options and considerations based on the level of weed infestation. Two management strategy situations are addressed: 1) *"Maintenance" Control Strategies* to control a light to moderate downy brome infestation which caused minimal crop yield loss; and 2) *"Reclamation" Control Strategies* to recover from a dense infestation of downy brome which caused substantial yield loss, or may reduce future yield potential to near crop failure levels.

Where to Get Copies

Copies of these three *Handbook Series* publications are available through county extension and conservation district offices in the Inland Northwest, or directly from Roger Veseth (208-885-6386). The entire *Pacific Northwest Conservation Tillage Handbook* and new updates can be purchased for $20 through county extension offices.

STRIPE RUST RESISTANCE, A MAJOR COMPONENT OF THE INTEGRATED MANAGEMENT OF WHEAT DISEASES AND A BASIS FOR SUSTAINABLE WHEAT PRODUCTION

Roland F. Line
USDA-ARS

Two important types of resistance to *Puccinia striiformis*, the cause of stripe rust of wheat, are seedling resistance and high-temperature, adult-plant resistance. Seedling resistance is characterized by race specificity and low infection types at all stages of plant growth and a wide range of temperatures. When used extensively over time or space, new races usually circumvent seedling resistance within 3-4 years after release of cultivars with the resistance. Use of seedling resistance in a multiline cultivar has provided protection for more than 10 years.

High-temperature, adult-plant resistance is characterized by a range of infection types and a shift in the range depending upon temperature and stage of plant growth. As plants with high-temperature, adult-plant resistance become older, they become more resistant at high temperatures, but they remain susceptible when grown at low temperatures. Seedlings and heads of cultivars with high-temperature, adult-plant resistance are susceptible at a wide range of temperatures. At the higher temperatures, flag leaves are most resistant. High-temperature, adult-plant resistance can be reversed by changing the temperature. High-temperature, adult-plant resistance has proven to be effective when extensively exposed to many races throughout large regions for more than 30 years. The durable high-temperature, adult-plant resistance incorporated into locally adapted cultivars has prevented major stripe rust epidemics and wide-spread losses in many regions of the world and annually prevented multi-million dollar losses in the Pacific Northwest.

The use and management of durable types of resistance to stripe rust, leaf rust and other diseases has reduced the need for fungicides, enabled more efficient use of fertilizer and water inputs, enabled use of alternative crop managerial practices to reduce wind and water erosion, and helped to sustain stable, profitable wheat production.

CONTROL OF STRIPE RUST, LEAF RUST AND STEM RUST

Roland F. Line
USDA-ARS

General Characteristics. Three rusts (stripe rust, leaf rust, and stem rust) occur on wheat in the Pacific Northwest. Stem rust also occurs on barley and stripe rust may be a problem on barley in the future. 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 larger, 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. Stem rust occurs on both wheat and barley. 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 50 percent. Since then, destructive epidemics of stripe rust that cause losses of more than 20% have occurred in fields of susceptible varieties 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 1983 and 1984. Without development of resistant varieties and emergency registration of a fungicide (Bayleton) for rust control, losses caused by stripe rust in Washington would have exceeded 50 percent in 1981 and 30 percent in 1983 and 1984.

A new strain of *Puccinia striiformis* that attacks barley (barley stripe rust) has been detected in Texas, Colorado, Arizona, California, Idaho, and Montana. Barley stripe rust looks like wheat stripe rust but is a different pathogen that is more severe on barley. There is a strong possibility that barley stripe rust will eventually get into the Pacific Northwest. When that occurs, we would expect it to damage barley in the same manner as it has damaged wheat in the past. There is already a significant effort in searching for resistance to the barley stripe rust. If it appears in the Pacific Northwest, research efforts to control barley stripe rust would have to be expanded to prevent major barley losses.

As we develop wheat varieties 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. 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.

Monitoring Rust. Races of *Puccinia striiformis*, the pathogen that causes stripe rust, are identified by the varieties that they attack, and new races of the pathogen frequently evolve to attack varieties that were previously resistant. Table 1 lists the races of *Puccinia striiformis* that have been detected in North America their virulence on differential varieties, and the year they were first detected. Fifty-three stripe rust races have been identified of which 43 have been detected in eastern Washington.

In 1993, 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-53). In addition to the wheat stripe rust races, there is at least one barley stripe rust race, BSR-24.

Most winter wheat varieties currently grown in the region are very susceptible to leaf rust. Since the current races can attack most varieties, 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 1993.

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.

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. Also, many current varieties are susceptible to races of rust that occur in the region. 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.

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 Table 2), has continued to be durable against all races in the Pacific Northwest. In contrast, the high resistance expressed in both seedling and adult plant stages at all temperatures has been effective for three years or less.

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 varieties. New information on the inheritance of race-specific 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 have been evaluated in the field and half 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 should be useful in developing more durable leaf rust resistant wheats.

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

Use of Fungicides. Resistance to all disease problems may be difficult or impossible to incorporate into a single variety, 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, RH-7592, LS86263, and BRC-519 control stripe rust, leaf rust and stem rust, especially when applied at jointing to heading stages of growth, and effectively prevented 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 varieties 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 disease. 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. 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.

Table 1. Virulence of Cereal Disease Laboratory races of *Puccinia striiformis* on North American differentials and year first detected.

CDL Race	Virulence on[a] differentials	Year detected	CDL Race	Virulence on differentials	Year detected
1	1,2		27	1,3,12,13	1983
2	1,2,5	1963	28	1,3,4,12	1983
4	1,3	1964	29	1,3,4,5	1983
5	1,3,4	1968	30	1,4,6,8,12	1983
6	1,6,8,12	1972	31	1,3,5,11	1983
7	1,3,5	1974	32	1,4	1983
8	1,3,9	1974	33	1,3,9,12,13	1984
9	1,3,6,8,12	1975	34	1,3,4,5,12	1984
10	1,2,3,9	1976	35	1,10	1985
11	1	1976	36	1,3,4,9,12	1985
12	1,5,6,12	1976	37	1,3,6,8,9,10,11,12	1987
13	1,5,6,8,12	1976	38	1,3,11	1987
14	1,8,12	1976	39	1,2,4	1987
15	1,3,6,10	1976	40	1,4,14	1989
16	1,3,9,11	1977	41	1,3,4,14	1989
17	1,2,3,9,11	1977	42	1,3,11,12	1989
18	1,3,4,9	1977	43	1,3,4,5,12,14	1990
19	1,3,6,8,10,12	1977	44	1,4,5	1990
20	1,6,8,10,12	1977	45	1,3,12,13,15	1990
21	2	1978	46	1,3,6,9,10,11	1991
22	1,3,12	1980	47	1,6,8,12,13	1992
23	1,3,6,9,10	1981	48	1,6,8,12,13,14	1992
24	1,3,5,12	1981	50	1,3,4,5,14	1992
25	1,3,6,8,9,10,12	1981	51	1,3,4,12,13	1992
26	1,3,9,12	1982	52	1,4,8,12,14	1993
			53	1,4,6,8,10,12	1993

[a] 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 and 15=Hyak.

Table 2. Seedling and adult plant resistance to stripe rust of varieties grown in the Northwestern United States[a]

Variety	Stripe Rust Seedling	Stripe Rust Adult
Soft White Winter Wheat		
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	R-MR
Hill 81	S	R-MR
Malcolm	S	R-MR
Hyslop	S	R-MR
McDermid	S	MR-MS
Nugaines	S	MR-MS
Gaines	S	MR-MS
Walladay	S	MS-S
Yamhill	S	S
Club Wheat		
WA7797	S	R
Hyak	S	
Rely	R+S	R+S
Crew	R+S	R+S
Tres	S	MS-S
Moro	S	S
Jacmar	S	S
Barbee	S	S
Paha	S	S
Tyee	S	S

Variety	Stripe Rust Seedling	Stripe Rust Adult
Hard Red Winter Wheat		
Buchanan	S	R
Blizzard	S	MR-MS
Batum	S	R
Wanser	S	MR-MS
McCall	S	MR-MS
Century	S	MS-S
Hatton	S	S
Weston	S	S
Soft White Spring Wheat		
Penewawa	S	R-MR
Edwall	S	R-MR
Waverly	S	R-MR
World Seeds 1	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

[a] R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, and R+S = resistant plants and susceptible plants (multiline). High-temperature, adult-plant resistance is expressed as a range, except for highly resistant varieties. Those varieties currently susceptible in both the seedling and adult stage are resistant to older races in both the seedling and adult stage.

BARLEY STRIPE RUST, A NEW BARLEY DISEASE IN THE PACIFIC NORTHWEST

Roland F. Line
USDA-ARS

A new barley disease, barley stripe rust, has appeared in the Pacific Northwest and could cause wide-spread damage to barley in Washington and adjacent states. If the disease becomes wide-spread on barley, losses could be 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. There is an urgent need for research aimed at preventing such a disaster.

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 70 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 1990. 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 1990. It appeared in northers Texas in 1991, in 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 central California in 1993 that were confirmed during the spring of 1994. Also, there are reports, which have not yet been confirmed, that it is in northern California, southwestern Oregon, northern Idaho, and Washington. If barley stripe rust is not in Washington at this time, it will be in the state within the near future. 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.

Little is known about the specific environmental factors that contribute to severe barley stripe rust. Based on what we know about wheat stripe rust in this region and barley stripe rust in other regions, we can postulate that the environment in the Pacific Northwest will be highly favorable for the disease. Once barley stripe rust appears in Oregon, Washington, or northern Idaho, it will spread throughout the Pacific Northwest. 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, new barley stripe rust races have been reported in Texas just as new, virulent wheat stripe rust races continue to evolve in the west. Also we do not know how similar or different the two rusts 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 species of the three wheat rusts (wheat stripe rust, wheat leaf rust, and wheat stem rust). They can also differentiate one of the wheat stripe rust races from the other wheat stripe rust races. These techniques as well as studies on pathogen virulence may be useful to differentiate the wheat and barley pathogens from one another. Rust pathogen collections will have to be tested on local cultivars and cultivars from other regions.

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 Texas and South America, and scientists in Mexico are breeding for resistance to the disease. Two genes for resistance have been identified. However, 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 very little about what type of resistance to barley stripe rust exist and how durable the resistance may be. There may 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.

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

Monitor your crop. The disease has not yet been positively detected in Washington and adjacent regions of Oregon and Idaho. Therefore, it may not develop until late in the spring, when damage is less severe. Being forewarned is half of the battle against the disease. Timely control is important. Fields should be examined frequently throughout the growing season. 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.

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. Old supplies of Bayleton may be used on barley, but new supplies will not be labeled for barley. Tilt cannot be used beyond the late jointing stage. Determine your economical benefits before using the foliar fungicide.

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. Resistant cultivars and foliar sprays are possible controls for stem rust.

MORECROP, AN EXPERT, ADVISORY SYSTEM FOR WHEAT DISEASE MANAGEMENT

Roland F. Line
USDA-ARS

An expert system for managing wheat diseases was developed for use in the Pacific Northwest and is referred to by the acronym MoreCrop (managerial Options for Reasonable Economical Control of Rusts and Other Pathogens). The purpose of MoreCrop is to present outcomes that may happen and options for control. The user evaluates the information that is provided when certain environmental conditions and managerial practices are selected and by a process of reasoning, determines the most economical control.

MoreCrop was developed using the enormous knowledge based on wheat diseases together with tools from recent technological advances in the computer industry. MoreCrop provides information, options, and suggestions to help the user make decisions regarding management of wheat diseases. It predicts diseases based on geographical regions, agronomic zones, crop managerial practices, cultivar characteristics, prevailing weather, and field and crop history. MoreCrop can also use past managerial decisions to reconstruct disease conditions, assist the user in reasoning which disease control option to select, and provide disease-related as well as cultivar-related information for teaching, research and extension. 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 for disease development must exist for the disease to damage the crop. More Crop is a management system that evolved from earlier guidelines for integrated control of rusts and was later expanded to include other diseases of wheat. The management system is based on more than 30 years of data on crop management, epidemiology, and control of diseases of wheat.

The Wheat Disease Environment. The PNW is a region of great environmental diversity. It has the greatest diversity of environmental conditions in North America. Because of this diversity, most of the known wheat diseases occur in the PNW, and at least 16 different disease groups have significantly limited yields. The occurrence and severity of diseases depend mostly on the geographical region, agronomic zone, crop managerial practices, susceptibility of wheat cultivar, prevailing weather conditions, and presence of virulent species, races, or strains of the pathogens. MoreCrop considers the environmental diversity of the PNW by giving a predictive disease output for the region and the agronomic zone where the wheat is grown.

North America can be divided into seven regions based on geographical barriers, prevailing winds and other weather, general crop management, and occurrence of specific stripe rust races. Eastern Washington and Oregon, northern Idaho, and eastern British Columbia are included in Region 1; western Montana and southern Alberta in Region 2; southern Idaho and northern Utah in Region 3; southwestern Washington, western Oregon, and northern California in Region 4; northwestern Washington and western British Columbia in Region 5; central California in Region 6; and areas east of the Rocky Mountains in Region 7.

Five agronomic zones used in MoreCrop are described based on four classes of annual precipitation, two soil depth regimes, and three categories of cumulative growing degree days (GDD). The four classes of annual precipitation were Moist (>16 in), moderately dry (14-16 in), dry (10-14 in), and very dry (< 10 in). The soil depths were deep (>40 in) and shallow (<40 in). The categories of accumulative GDD from January 1 to May 31 were cold (<700 GDD), cool (700 to 1000 GDD), and hot (>1000 GDD). Thus, Zone 1 is defined as cool to cold and moist with either deep or shallow soil. Some areas of the zone have snow cover for extended periods. Precipitation is usually adequate to support a crop every year (annual cropping); summer fallow is not required. Zone 2 is defined a cool and moderately dry with deep soil. With a well planned crop rotation and appropriate crop managerial practices, precipitation is adequate for annual cropping. In drier years, summer fallow may be necessary to conserve water, especially in the drier areas of the zone. Snow usually is not present for extended periods. Zone 3 is defined as cool and dry with shallow soil. Moderately low precipitation can recharge the shallow soil profile of this zone to support annual cropping; summer fallow is often of little advantage for water storage because of the shallow soil. Irrigation can be used to provide additional water. Zone 4 is defined as cool and dry with deep soil. Annual precipitation usually is not sufficient to fill the soil profile; therefore, summer fallow in alternate years is necessary to have enough water to grow a crop. Supplemental irrigation can be used to provide additional water. Some areas of the zone may have extended snow cover. Zone 5 is defined as hot and very dry with either deep or shallow soil. Irrigation is usually necessary to produce a wheat crop.

The weather conditions within each region and zone are further defined based on the long term historical records of temperature (cold, cool, warm, and hot) and kind and amount of precipitation (snow, wet, and dry) that occur in early fall (late August to early October), late fall (late October to early December), winter (late December to early February), early spring (late February to late April), and late spring (early May to early July). The seasonal weather, which is based on historical records for each combination of region and zone is used as a default setting. In situations when the weather in any season departs from normal, the weather setting can be changed to the one that best describes the prevailing condition.

Some Diseases of wheat in the PNW. The following is a synopsis of the wheat diseases that are important in the PNW. Stripe rust, leaf rust, and stem rust are indigenous to the PNW and are considered the most widely destructive diseases of wheat in the region. Stripe rust requires cool temperatures; leaf rust requires moderate temperatures. The environment in most areas of the PNW is favorable for stripe rust in three out of four years and leaf rust in two out of four years, but in certain specific areas of the PNW, it is always favorable for stripe rust and leaf rust. Stem rust is a warm temperature disease and is less frequently severe in the PNW. It can, however, be severe when the weather during early and late spring is warm and wet.

Common bunt, dwarf bunt, and flag smut are diseases that have been uniquely important in the PNW. Common bunt was the most important disease of wheat in the PWN for the first half of the 20th century. Dwarf bunt and flag smut are important in specific areas of the PNW. The three smuts are both seed and soil-borne and are especially problems in winter wheat. The smuts are affected by the date of planting in the fall; early planting reduces common bunt, late planting reduces flag smut, and very late or very early planting reduces dwarf bunt. Treatment of seeds with fungicides is the most effective method for control of common bunt and flag smut. Currently, there is no effective, commercially available seed treatment for control of dwarf bunt (TCK smut), and China has imposed a zero-tolerance quarantine for dwarf bunt on wheat. Dividend, a fungicide currently at the experimental stage, may be an important seed treatment for control of dwarf bunt in the future.

Cephalosporium stripe, strawbreaker foot rot (Pseudocercosporella foot rot or eyespot), dryland foot rot (Fusarium root and foot rot), Pythium root rot, Rhizoctonia root rot, and take-all are all diseases caused by soil-borne pathogens that infect underground plant parts or the basal stem (crown). These diseases are affected by crop and soil managerial practices (rotation, tillage practices, planting date, soil moisture, etc.). Most can be reduced by a 3-year rotation and tillage. Strawbreaker foot rot is controlled primarily by resistant cultivars and foliar fungicides; Cephalosporium stripe is reduced by limiting winter wheat to every third year and growing resistant cultivars; take-all and Pythium root rot may be reduced by tillage and seed treatment. The soil-borne nature of these diseases makes their previous occurrence i.e. disease history, an important aspect of disease management.

Barley yellow dwarf, powdery mildew, snow molds, and septoria occur under certain conditions in some zones and regions of the PNW, and each has its unique epidemiology and control methods. Barley yellow dwarf is common in zones where wheat is planted early in the fall or late in the spring and is transmitted by aphids. Consequently, severity of the disease is affected by aphid activity and population size. Use of insecticides to control the aphids has potential for reducing spread of the disease. Powdery mildew, which is widely distributed throughout the PNW, can be controlled by fungicides. However, powdery mildew seldom causes severe damage to wheat in the PNW. The snow molds develop during the winter especially when there is an extended period of snow cover. Conditions that favor extensive plant growth in the fall reduce potential damage from the disease. Snow molds can be controlled by growing resistant cultivars. The septoria diseases are most prevalent in Regions 4 and 5 where there are long wet periods, especially in the late spring. Crop rotation, cultivar resistance and/or foliar fungicides will control septoria.

Guidelines for managing each disease have been developed and used in the PNW. Factors considered in developing the guidelines were: 1) crop and soil managerial systems (regional and local), 2) weather conditions (seasonal, local and regional), 3) kind of diseases and their characteristics, 4) disease and pest interactions, 5) virulence of races and host susceptibility), 6) kind and degree of host resistance, 7) severity of disease at specific growth stages, 8) yield loss in relation to disease severity, 9) effectiveness of fungicides at rates and schedules, 10) potential yield, and 11) economics (costs versus benefits of control). These factors were used in developing the expert advisory system for wheat disease management.

How MoreCrop Works. Expert systems are based on a relatively new concept called artificial intelligence. Artificial intelligence is defined as the way of making computers "think" by following the process of how a human mind makes decisions in solving problems. Since artificial intelligence mimics the problem-solving process of the human mind, it exhibits characteristics such as the capacity to acquire knowledge and ability to use the knowledge. Artificial intelligence that uses knowledge from a human expert is referred to as an expert system. MoreCrop is an expert advisory system.

MoreCrop consists of a user interface, a knowledge base, a knowledge acquisition subsystem, an inference engine, a help subsystem, and a library of information. These components are functionally related to each other. The user interface of MoreCrop takes advantage of Windows environment and allows the user to interact with the system through the graphical screen and icons. The system enables the user to define a managerial scenario by selecting geographical regions, agronomic zones, crop managerial practices, wheat cultivars, weather, disease history, and disease managerial options. A mouse is used as the pointing device. Menus, control buttons, command buttons, check boxes, icons, graphics, and dynamic-link libraries are the tools that make MoreCrop easy to use.

The knowledge base of the system contains "abstract knowledge", knowledge of general application, and it develops "concrete knowledge", knowledge of a specific application. Disease susceptibility data for a cultivar is abstract knowledge. The disease that occurs on a cultivar due to a specific crop management is concrete knowledge. The abstract knowledge is permanently stored; concrete knowledge is created by inference and destroyed after use.

The knowledge acquisition subsystem is the learning mechanism of MoreCrop. It allows addition of new knowledge, rules, and data to the knowledge base in an intelligible form. The inference engine uses data and information to establish a conclusion and searches for support data and information. The library contains information on the agronomic and disease resistance characteristics of cultivars, description and distribution of stripe rust races, and maps of geographical regions and agronomic zones. Warnings, caution statements, and reminders appear in pop-out dialogue boxes for added information.

MoreCrop tells you what diseases are more likely to occur based on the selected managerial practices, cultivar, geographical region, agronomic zone, prevailing weather, and crop and disease history of the field. It provides the reasons for the disease outcome. The system has three parts called *Predictor, Controller,* and *CustomController*.

Predictor considers the classical disease triangle in predicting diseases. Thus, for a disease to occur there should be a susceptible host, a virulent pathogen, and a favorable environment for disease development. Selection of a wheat cultivar may determine the susceptibility or resistance of the host; and disease history may indicate the presence of a virulent pathogen, crop managerial practices along with the prevailing weather determine the favorability of the environment for disease development. *Predictor* provides a list of diseases that may occur and highlights those that are more likely to occur based on the region, zone, crop management, cultivar (rotation, tillage, irrigation, planting date, and fertility management), weather (early fall, late fall, winter early spring, and late spring), and crop and disease history of the field. Information related to disease control and the rationale for the disease outcome are linked to the specific diseases and are available to the user. The rationale for the disease outcome lists the reasons why a specific disease may or may not occur.

Controller makes suggestions for integrated-disease-management (IDM). It considers the diseases that are more likely to occur and evaluates the various disease control options. The options include use of seed treatment and foliar sprays in various ways. *Controller* determines the best disease control option and suggests a IDM program for control of the diseases that were predicted based on the selected crop managerial scenario.

CustomController provides an opportunity to develop your own program. It than evaluates your control program and provides a list of diseases that can and can not be controlled. The rationale for disease control or absence of disease control is also explained. *CustomController* provides an unlimited opportunity to change the managerial decisions and re-customize the disease control program.

How MoreCrop can be used. MoreCrop can be used as a decision-support system by wheat growers, extension agents, consultants, and other professionals who are involved in wheat management. The program contains up-to-date information relating to wheat cultivars and their characteristics, agronomic zones, fungicide technical information, crop managerial options, stripe rust races, distribution of stripe rust races, description of stripe rust races, and other subject matters relevant to wheat production in the PNW. MoreCrop can also be used as an educational tool for managing wheat diseases and a training and reference tool for solving problems.

The concepts of MoreCrop can be extended to include fertility management and management of other pests such as weeds and insects. Thus, MoreCrop can serve as a prototype in developing a total program for wheat management. The programming structure of MoreCrop and the visual controls as well as the concepts and principles should be easily adapted for use in managing other crops or for use in other regions of the world.

How to purchase MoreCrop. For details, 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 FAX: 509/335-7674. To purchase the manual and program, contact Washington Cooperative Extension Bulletin Office, Cooper Publication Building, WSU, Pullman, WA 99164-5912. Ask for MCP22 MoreCrop. Cost of distribution is $40. Telephone: 509/335-2857 FAX: 509/335-3006.

THE SUCCESSFUL CONTROL OF SMUTS AND BUNTS WITH SEED TREATMENTS

Roland F. Line
USDA-ARS

Control of 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.

Control of 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.

Control of 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. 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.

Control of 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 has not been controlled by the seed treatments that are 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 is expected to be registered by the summer of 1994. 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.

General Comments Regarding Seed Treatments. 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. 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. Another concern is that strains of the pathogens may evolve that are resistant to current fungicides. Therefore, there is a continual need for ongoing research on control of those diseases.

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 and *R. oryzae* 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 15 years using soil fumigation as a tool gives some idea of the importance of root diseases: The average increase in yield of winter wheat in response to soil fumigation in commercial fields has been 70, 22, and 7%, respectively, in fields cropped every year, every other year, and every third year to wheat. Besides showing the importance of root diseases, these results 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 area where the climate and soils of the region 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 (conservation tillage) is also the result of root diseases, favored by the high soil moisture typical of soil covered with straw <u>together with</u> the lack of crop rotation. Root diseases must be controlled to achieve both the high yields and the fertilizer-use efficiency possible with conservation tillage and frequent cropping to small grains.

Research done cooperatively with Drs. Richard Smiley and Alex Ogg has revealed the critical importance of eliminating the "green bridge" between harvest of winter wheat and planting of a spring grain crop (wheat or barley) directly into cereal stubble. The green bridge is volunteer wheat or barley and grass weeds that green up in the fall and carry over into the spring. This growth provides the means for root pathogens to carry over from the decomposing stubble of one crop to the young plants of the next crop. The so-call "combine row" effect commonly observed with spring grains planted directly into winter wheat stubble, and where volunteer is sprayed only 1-3 days before planting, is almost certainly the result of increased damage from root diseases favored by the concentration of volunteer and weed growth in the combine row. It is best to wait at least 7-10 days and preferably 2-3 weeks rather than only 1-3 days after spraying before planting wheat or barley into this kind of seedbed. The green bridge effect is less apparent with winter wheat after winter wheat where the stubble, being relatively fresh at the time of the next planting, provides an ample source of pathogen inoculum by itself. An exception may be winter wheat with an intervening chem fallow, where the green bridge can be important if the volunteer and weeds are not properly managed by a timely application of herbicide.

Another breakthrough has been the development of a method of planting wheat and barley directly into wheat or barley stubble in such a way as to physically loosen (till) the soil within each seed row (zone tillage) at the time of planting, <u>and</u> place fertilizer directly below the seed, all in a one-pass operation. Soil disturbance and fertilizer placement are not as critical (the shanks for fertilizer placement and loosening the soil can be up to 6 inches to one side of the seed row, with no reduction in yield) if root disease is not a factor. Our theory is that healthy roots can extend considerable distances to reach a band of fertilizer, but diseased roots need easy access to the band to perform their function. Placing fertilizer in the seed row also gives the wheat a competitive advantage over weeds in accessing nutrients. There is also evidence that Rhizoctonia root rot is amenable to some control simply by the action of loosening the soil to 2-3 inches below the seed independently of fertilizer placement.

It is now possible to grow wheat and barley without tillage other than at the time of planting, including in the intermediate and higher rainfall area, by use of the following practices:

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 grains or spring grain/fallow in the low-rainfall areas;

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; and

3) Fertilize at the time of planting such as to place the fertilizer band within easy access of the primary root system of young wheat or barley plants. 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.

We have also 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. Some strains have also shown activity against Pythium root rot. 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 some 10 large-scale field trials carried out since 1982, the average response to seed inoculation in fields of wheat following wheat (no crop rotation), and where take-all was the dominant yield-limiting factor, has been 10.4 % with a mixture of two strains having ability to produce one antibiotic and 15 % with a different single strain that by itself produces three related antibiotics. In 1993 near Almota, wheat planted no-till after 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. We are very encouraged by these results in 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%.

Future efforts will concentrate increasingly on combining our best strains of root-associated biocontrol bacteria with the cultural practices identified above to provide even better control than is possible with cultural practices or biological control alone. Our goal is to obtain yields of winter wheat in a two year rotation that now can only be obtained in three year rotations, and yields of winter wheat grown without crop rotation that now can only be obtained in a two-year crop rotation, all in combination with conservation tillage.

ADVANCEMENTS IN THE DEVELOPMENT OF SEED-APPLIED HERBICIDE SAFENERS FOR WHEAT

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Selective control measures in wheat for winter annual grass weeds such as jointed goatgrass and downy brome are difficult due to the lack of herbicides that have good selectivity between wheat and grassy weeds. The use of herbicide safeners may improve the tolerance of wheat to herbicides that control these weeds. Herbicide safeners are compounds that can be applied as seed treatments, as opposed to broadcast treatments, to maximize safening of the crop and avoid safening target weed species. We have screened several safeners for wheat in the greenhouse and field that have been used successfully in corn and sorghum. These include Concep II, Concep III, and benoxacor. CGA 185072 is a safener that has been developed for use in wheat as a foliar-applied safener, but also has shown excellent activity as a seed-applied safener. Wheat can be protected from chloroacetamide herbicides, including Dual, Frontier, and Harness, which are normally used in corn, sorghum, and soybeans to control grassy weeds. Frontier appears to have the best combination of activity on grassy weeds (especially downy brome), yet can be safened from in wheat, so further studies have focused on safening both spring and winter wheat from Frontier.

Greenhouse studies have shown that CGA 185072 and Concep III are effective safeners at relatively low rates (1.25 g/kg seed and 0.25 g/kg seed, respectively) while Concep II and benoxacor are also effective, but must be applied at rates of 5 to 10 g/kg seed for maximum safening to be achieved. In a spring-planted study in 1993, both spring and winter wheat were completely safened from Dual herbicide (at a high rate of 4 lbs/acre) with the safener benoxacor at 10 g/kg seed, while Concep II was slightly less effective. When Frontier herbicide was applied at a high rate of 3 lbs/acre, Concep II provided 90% safening and benoxacor provided 84% safening in spring wheat compared to the no herbicide - no safener control.

A field study was planted in fall, 1993 to examine the ability of two or three rates of the most effective safeners mentioned above to protect winter wheat from Frontier herbicide. Safener rates were chosen based on greenhouse results of Frontier safening in order to find the optimal safener rate in the field. The most effective safeners were Concep III at both 0.25 and 0.4 g/kg seed, CGA 185072 at 1.25 g/kg seed, Concep II at 5 g/kg seed, and benoxacor at 10 g/kg seed. These safener treatments provided 75 to 90% safening when measuring stand counts compared to the no herbicide - no safener control. Wheat will be harvested this summer and yields compared for each safener treatment to quantify safener ability to protect Madsen wheat from Frontier herbicide.

Laboratory studies have been conducted to examine the mechanism of safener action in Madsen wheat. Safeners accelerate the rate of metabolism of Frontier herbicide in treated wheat. Safeners increase the level of activity of the glutathione *S*-transferase (GST) enzymes in treated wheat. It appears that elevated levels of GSTs in safener-treated wheat enhance the ability of wheat to rapidly metabolize Frontier herbicide to non-toxic forms. Future studies will identify the initial metabolites of Frontier in unsafened and safened Madsen wheat, and purify and characterize the GST enzymes involved in the safener response. We are also screening a broad cross-section of wheat-related germplasm (in cooperation with S. Jones, USDA/ARS) to identify germplasm with high herbicide tolerance and/or strong safener responses.

HERBICIDE COST SAVINGS THROUGH VARIABLE LANDSCAPE APPLICATION

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Considerable research has focused on potential cost savings and environmental benefits of variable fertilizer application (Fiez, Miller, and Pan; Hibbard et al.; Mulla et al.; Veseth). While cost savings were achieved in some of these studies, they are relatively small compared to the costs involved, which may include soil testing, yield testing, mapping application areas, and calibrating application rates. An area with greater potential for cost savings, due to a higher relative cost, is variable herbicide application. Reducing herbicide use can also reduce the chance of crop injury from herbicides, carryover problems, and potential for groundwater contamination.

Recent research has shown that the most profitable level of herbicide use can vary by landscape position (Boerboom, Young, and Ogg). High, moderate, and minimum levels of herbicide use (90%, 75%, and 60% of full label rate) were tested on three landscape positions. On a north footslope and a south footslope, returns were maximized using the maximum level of weed management. On the summit, a moderate level of herbicide use generally resulted in the highest returns. Even though this summit was not highly eroded, as are many summits, reduced herbicide use was still most cost-effective. Some herbicide injury was observed on the summit plots, despite an organic matter content of 2.6%.

Underlying principles can explain these varying results by landscape position. Higher weed pressure on more fertile bottom land and side slopes increases herbicide needs to protect the high yield potential. Soil active herbicides are required at higher levels in soils with high organic matter because some herbicide binds to the organic matter and less is available to control weeds. Herbicides are less likely to leach in soils with higher organic matter for the same reason. On the other hand, herbicides are more available for plant uptake in low organic matter soils. As a result, marginally tolerant crops may be injured in areas of the field with low organic matter (clay knobs) from herbicides that were used at rates appropriate for the rest of the field.

Table 1 shows cost savings by crop by reducing herbicide levels by 25% and 50% from full label rates. Under reduced rates, herbicide efficacy will be more sensitive to conditions such as how easily different weed species are controlled by the herbicide, that postemergence applications are timed to treat weeds at an early stage, and that environmental conditions are favorable. Labels for soil active herbicides may also provide information on adjusting herbicide rates based on organic matter levels. A cost effective strategy would be to use reduced herbicide rates in low organic matter areas. Cost savings ranging from $3.02 to $10.62 by crop can be achieved using 75% of label rates. At 50% of label rates, savings are doubled (Table 1). Since soil areas with low organic matter are also low-yielding, reducing herbicide levels would be an appropriate management decision given these research results. Many farmers already use less than standard label rates or the lower range of recommended rates, especially for some of the more expensive chemicals. Targeting low-yielding, low organic matter land

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of the more expensive chemicals. Targeting low-yielding, low organic matter land for herbicide reduction would be a an additional strategy to economize.

Of course, variable herbicide applications, like variable fertilizer applications, would create some additional production costs. Equipment with the capability of varying rates would be needed, or different landscape zones would have to be measured and sprayed separately. Additional scouting and weed mapping would be necessary. Variable herbicide application may be cost-effective only for the more expensive chemicals. Increased risk would also be a factor, because reduced herbicide rates may not always give the required level of weed control and could expose the producer to potential yield losses. More information on economic thresholds of different weed species for various crops is needed in order to fine-tune reduced herbicide usage. Farmers experimenting with reduced rates or not applying herbicides to certain portions of the landscape are a valuable source of information in this area.

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Table 1: Cost Savings for Using Herbicides at 75% and 50% of Standard Label Rates, by Crop.

Crop	Chemical	Unit	Cost $/unit	Full Rate units/ac.	.75 Rate units/ac.	.50 Rate units/ac.	Cost Savings .75 Rate $/ac.	Cost Savings .50 Rate $/ac.
Winter Wheat, Option 1	MCPA	qt	3.55	1.00	0.75	0.50	0.89	1.78
	Harmony Extra	oz	14.20	0.60	0.45	0.30	2.13	4.26
	Hoelon	pt	8.39	2.67	2.00	1.34	5.60	11.20
							8.62	**17.24**
Winter Wheat, Option 2	Buctril (2EC)	pt	7.71	1.50	1.13	0.75	2.89	5.78
	Harmony Extra	oz	14.20	0.60	0.45	0.30	2.13	4.26
	Hoelon	pt	8.39	2.67	2.00	1.34	5.60	11.20
							10.62	**21.25**
Dry Peas	Sonalan	pt	4.93	2.00	1.50	1.00	2.47	4.93
	Metribuzin	lb	28.36	0.50	0.38	0.25	3.55	7.09
	Fargo*	qt	10.43	1.25				
							6.01	**12.02**
Spring Barley	Harmony Extra	oz	14.20	0.60	0.45	0.30	2.13	4.26
	MCPA	qt	3.55	1.00	0.75	0.50	0.89	1.78
	Fargo*	qt	10.43	1.25				
							3.02	**6.04**

*Fargo does not perform well at reduced rates, so a full rate was used in all scenarios.

NOTE: Trade names have been used to simplify information. Endorsement of named products is not intended, nor is criticism of similar products not mentioned.