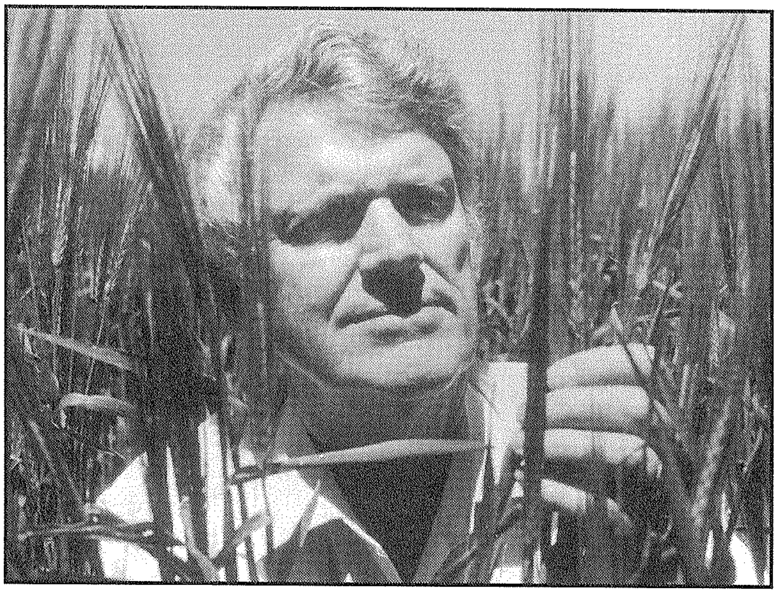
COOPERATIVE EXTENSION

Washington State University

Department of Crop and Soil Sciences

Technical Report 93-4



1993 Field Day Proceedings:

Highlights of Research Progress

Dryland Research Unit, Lind
June 17, 1993

Palouse Conservation Farm, Pullman
June 24, 1994

Spillman Farm, Pullman
July 1, 1993

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 DR. ROBERT A. NILAN

Bob Nilan's 42 plus year career started in 1951 at Washington State University, where he developed an outstanding program in barley breeding and genetics. It is nearly impossible to concisely summarize Bob's extensive career, contributions and achievements. A few major items will be highlighted here. His university education has been in areas of agronomy (B.S., University of British Columbia), agronomy, plant breeding, and genetics (M.S., University of British Columbia), and genetics (Ph.D., University of Wisconsin). His research has incorporated these three areas as well. He has garnered over 3.5 million dollars in research grant funds from diverse sources. His major research contributions have been in the areas of basic genetics and cytogenetics and applied plant breeding. His work has focused on the genetics and cytogenetics of induced mutagenesis from radiation, chemical and environmental mutagens. He has been recognized as one of the leaders in this area as documented by the numerous invitations to present symposium addresses and seminars on the topic worldwide. Although barley has been his main experimental organism, Bob has worked with and published on genetics research on ten plant, three microorganism and three animal species.

He has been extremely successful in applied plant breeding as well. "Barley Bob" is well known to the growers of Washington State. Highlights include the development and release of 'Steptoe' spring six-row, and 'Luther' and 'Kamiak' winter six-row barleys. Steptoe, released in 1973, has been the leading cultivar in the Pacific Northwest (PNW) states over the 20 years of its existence. It is easily the most successful barley cultivar ever developed in the PNW. It has also been grown extensively in other western states, Spain, and North Africa. Luther's release in 1966 was the first chemical-induced mutant cultivar developed. Kamiak, released in 1971, has been the most popular winter barley ever developed in the PNW.

Bob's research career is capped by directing and coordinating the North American Barley Genome Mapping Project (NABGMP) which involves over 40 scientists from 14 states and Canada and is funded by federal, state, and industry sources, including state barley commissions. As the director of the NABGMP, Bob also coordinates with counterparts in Europe, Asia, and Australia. NABGMP has been a model project highly recognized for its excellent organization and research accomplishments by the USDA-CSRS and ARS. It has produced the first comprehensive <u>public</u> barley genome map that integrates molecular markers and quantitative trait analyses directed at application to plant breeding.

Bob has published extensively with approximately 167 referred publications. Many journals are represented in his list of publications, including the major national and international genetics and plant breeding journals as well as prestigious scientific journals such as *Nature*, *Science*, and the *Proceedings of the National Academy of Sciences*. Further recognition has come from sabbatical awards, invited book chapters, addresses and papers, and numerous awards. Recognition has come from Washington State University, national, and international sources. Highlights include recognition by the Royal Society of London, the Danish Academy of Sciences, and the Swedish Seed Association. Perhaps the ultimate accolade for Bob was from the Washington barley growers, Washington State University and Washington State in the establishment of and appointment to the R. A. Nilan Distinguished Professorship in Barley Research and Education.

Bob has rendered considerable service to professional societies and especially the barley research community through the International Barley Genetics Committee, International Barley Genetics Symposium Organizing Committee, and the National Barley Improvement Committee.

Bob also has a considerable history of teaching formal undergraduate and graduate courses and the training of graduate and post doctorate students. His organizational skills were recognized early as he was appointed the first chairman of the WSU Program in Genetics (1965-78) and subsequently served as Acting Dean (1976 & 78) and Dean of the Division of Sciences (1979-89). While meeting the demands of the Dean's office, he remained involved in barley research and organization affairs. Upon retirement as Dean, he has returned to barley genetics research as Coordinator of the NABGMP as noted above. He continues in this role although he officially retired from WSU in December 1992.

With this dedication, the Department of Crop and Soil Sciences, salutes Bob Nilan, Professor Emeritus, Dean Emeritus, colleague, and friend.

COOPERATIVE PERSONNEL AND AREA OF ACTIVITY

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

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John Yenney	Walla Walla
Eric 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 77th 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 added in 1981. In 1957 a well that produced 340 gallons per minute was developed. In 1968 the Washington Wheat Commission provided funds for a sheath 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.

CLIMATIC DATA

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 at Dry Land Research Unit, Lind.

	1992				
	Temperature °F.		Precipitation		Precipitation
Month	Max.	Min.	1992	1993	72 yrs Av (in)
January	40	30	.97	.80	1.00
February	49	33	1.29	.51	.86
March	61	34	.26	1.27	.81
April	64	38	1.31	1.72	.70
May	79	42	.15		.78
June	85	53	.47		.81
July	84	54	.74		.26
August	88	53	.00		.35
September	75	44	.37		.55
October	64	37	.60		.85
November	43	32	2.05		1.23
December	33	19	.78		1.25
			8.99		9.45

Climatic measurements are made daily with standard U.S. 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 a continuous record of soil and air temperatures and precipitation.

Table 2. Temperature and precipitation at Palouse Conservation Field Station, Pullman, 1992-93

Month	Monthly Avg. Temperature(F) Max.	Min.	Precipitation (in) 30-Yr Avg.*	Monthly	Total Accum.	Deviation from Avg. Monthly	Accum.
1992							
January	39.0	30.0	2.89	2.07	2.07	- .82	- .82
February	48.2	33.5	2.09	2.33	4.40	+ .24	- .58
March	58.2	34.4	1.96	.45	4.85	-1.51	-2.09
April	60.2	38.5	1.58	2.58	7.43	+1.00	-1.09
May	72.2	41.8	1.52	.39	7.82	-1.13	-2.22
June	80.1	48.5	1.49	.80	8.62	- .69	-2.91
July	81.3	51.5	.53	1.11	9.73	+ .58	-2.33
August	84.3	50.8	.95	1.44	11.17	+ .49	-1.84
September	71.8	43.9	.99	1.29	12.46	+ .30	-1.54
October	62.9	39.6	1.61	.58	13.04	-1.03	-2.57
November	40.1	31.0	2.64	3.22	16.26	+ .58	-1.99
December	34.2	23.5	3.07	1.34	17.60	-1.73	-3.72
TOTAL	61.0	38.9	21.32		17.60		-3.72
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
TOTAL			8.52		8.26		- .26
1992 CROP YEAR Sept. 1991 thru June 30, 1992			19.84		14.17		-5.67

*Thirty year average for precipitation, 1951-1980

SOFT WHITE WINTER WHEAT IMPROVEMENT

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

Washington wheat growers harvested 102 million bushels of winter wheat in 1992 for an average yield per acre of 51 bushels. The growers harvested 17.6 million bushels of spring wheat for a 42 bushels per acre average. The 1991/92 winter was very mild and the wheat came through the winter in excellent condition. Below normal precipitation resulted in below average to average wheat production for most of the region. Low temperatures that occurred about the middle of May caused considerable damage over a large part of the wheat region and yields were reduced. High temperatures in June and early July and rain reduced the bushel weights of the wheats in many areas of the Washington and Idaho. The cereal pathogens stripe rust, dry land foot rot, and strawbreaker foot rot also reduced grain yields in some areas.

New Varieties:

Rod

Rod (WA007662, VH086208, Luke/Daws//Hill81) was released in 1991 and foundation was available in 1992. Rod is a high yielding, white chaffed semidwarf soft white common winter wheat. It is resistant to the local races of stripe rust, and common bunt. Rod is susceptible to leaf rust, stem rust, snow mold, dwarf bunt strawbreaker foot rot and Cephalosporium stripe. When the grain production was averaged over 38 site/years Rod produced 80 bushels per acre. This was 2.5, 2.6, and 8 percent better than Kmor, Madsen, and Stephens, respectively. Bushel weight of Rod averaged 59.0 over 28 site/years of testing. Kmor, Stephens, and Madsen had a bushel weight of 58.6, 58.2, and 59.4 respectively over these same tests. Rod is approximately 2 inches shorter than Madsen and it matures about 2 days later than Madsen. Tests conducted by the USDA-ARS Western Wheat Quality Laboratory have found that Rod equals Nugaines, Daws, and Stephens in milling score, and baking quality.

Rely

Rely (PI542401) is a semidwarf multiline soft white club winter wheat. It is a blend of 10 wheat lines which are very similar agronomically and physiologically. The lines differ mainly for resistance to stripe rust. Rely usually expresses higher field resistance to stripe rust than Crew. Rely is susceptible to dwarf bunt, Cephalosporium stripe and stem rust, and it is moderately susceptible to strawbreaker foot rot. The grain yields of Rely have generally been comparable to the other clubs. I 32 state of Washington trials Rely, Tres, Crew and Hyak had mean yields of 81.7, 82.4, 78.3, and 79.3 Bu/a, respectively. Rely is very similar to Tres and Crew for plant Height, straw strength, seedling vigor and coldhardiness. Rely has generally produced a higher test weight than Hyak. The milling and flour characteristics of Rely are equal to those of other club varieties. Rely was developed by ARS-USDA and WSU.

New Lines:

Two lines (WA007686, WA007730) that were entered in the regional nursery in 1990 and 1991 were among the best lines in the 1991/92 nurseries. Three new lines (WA007754, WA7755, and WA007756) were entered in the 1992/93 Western Regional Nursery. WA007754 is a club wheat.

Nurseries:

The WSU soft white winter wheat nurseries were grown at Pullman (early and late), Pomeroy, Walla Walla, Ritzville, Cunningham, Coulee City, and Cavendish, Idaho. Eltan (79.45 bu/a) was the best commercial cultivar when the grain yields were averaged across all locations and years (table 1) and Rod (78.12 bu/a) was second. Hyak (74.12 bu/a) was the best commercial club wheat. There was only a little over 2 bushels per acre separating the top five varieties.

The Pullman Early nursery is 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 (84.6, 87.49) was the highest yielding cultivar in both treatments and Kmor (81.3, 87.4 bu/a) was second. Hyak (78.5, 77.73 bu/a) was the highest yielding club wheat under both treatments.

The Pullman Late nursery (table 3) was sown during the first week of October. The entire nursery was fertilized before planting (60# nitrogen/a) and then one half of each plot received an additional 60# in the spring. Eltan (102.88, 100.07 bu/a) produced the most grain of the commercial cultivars across treatment and over years. Hill-81 (101.63, 99.85) was second under the both treatments. Hyak (93.32, 93.16 bu/a) was the highest yielding club wheat under both treatments. Grain production was reduced with the addition of an additional 60 pounds of nitrogen applied in the spring indicating that there was adequate nitrogen applied in the fall.

The Pomeroy nursery (table 4) is generally sown the middle of September. When the yields were averaged over years Rod (75.09 bu/a) was the highest yielding commercial cultivar and Malcolm (69.13 bu/a) was second. Hyak (65.37 bu/a) was the highest yielding club wheat.

The Walla Walla nursery (table 5) is sown about the middle of October. When the yields were averaged over years Rod (99.47 bu/a) was the highest yielding commercial cultivar and Malcolm (99.41 bu/a) was second. Hyak (91.95 bu/a) was the best club wheat. There was less than one bushel difference in the production of the top three varieties.

The Ritzville nursery (table 6) is sown the first week in September. Rod (59.87 bu/a) was the highest yielding commercial cultivar and Kmor (58.18) was second. Tres (56.79 bu/a) was the highest yielding club wheat. Lewjain was third in production but it still is able to maintain it's test weight under stress better than the other varieties.

The irrigated nursery at Cunningham (table 7) is sown around the end of September. When the yields were averaged over years MacVicar (127.75 bu/a) was the highest yielding commercial wheat and W301 (123.62) was second. Hyak (91.82 bu/a) was the highest yielding club wheat. MacVicar and W301 are new varieties that were recently released by Oregon State University. MacVicar looks very promising for production under irrigation.

The nursery at Coulee City (table 8) is sown around the end of August. When the yields were averaged over years Eltan (45.47 bu/a) was the highest yielding commercial wheat and Kmor (42.71 bu/a) was second. The grain production of Sprague averaged 39.23 bu/a. Kmor has very little resistance to snow mold.

The nursery at Cavendish, Idaho (table 9) is sown around the end of September. When the yields were averaged over years Kmor (66.82 bu/a) was the highest yielding commercial wheat and Rod (66.81 bu/a) was second. Tres (66.19 bu/a) was the highest yielding club wheat.

Table 1. Average yield data (bu/a) on 18 winter wheat varieties grown for six years (four years at Ritzville and Cunningham) at eight locations* (ten trials) in Washington and one in Idaho.

		87	88	89	90	91	92	Avg.
Eltan	PI536994	67.37	68.61	94.73	80.17	81.62	84.17	79.45
Rod	PI558510	74.50	77.03	90.36	81.01	58.96	86.87	78.12
Hill-81	CI017954	72.58	66.59	88.10	84.70	68.33	86.72	77.84
Kmor	PI536995	68.71	75.84	93.47	75.85	70.91	80.37	77.53
Madsen	PI511673	67.40	72.30	86.33	88.21	61.83	87.03	77.18
Daws	CI017419	67.13	64.33	88.31	78.89	71.94	82.81	75.57
Lewjain	CI017909	65.87	69.22	87.48	80.08	65.04	83.19	75.15
Malcolm	PI497672	69.96	61.04	81.39	85.01	59.28	78.30	72.49
W301	ORFW0301	66.72	58.92	88.68	94.34	34.18	82.17	70.83
Stephens	CI017596	74.77	58.68	82.85	91.05	34.71	82.37	70.74
Nugaines	CI013968	60.20	58.92	79.30	77.10	63.69	77.25	69.41
MacVicar	ORF75336	-	66.80	91.89	85.21	50.39	85.93	
Gene	OR830801	-	-	74.13	89.92	44.69	73.04	
Hyak	PI511674	68.63	62.47	82.36	82.11	71.59	77.56	74.12
Tres	CI017917	64.02	62.24	84.28	72.32	62.20	78.11	70.53
Crew	CI017951	60.29	58.83	79.92	82.02	62.11	78.67	70.31
Rely	PI542401	64.31	65.46	-	75.66	64.81	81.53	
Rohde	OR000855	-	-	83.51	71.53	65.59	78.80	

* Pullman Early (Foot rot, Control) ; Pullman Late (Medium nitrogen, High nitrogen) ; Ritzville ; Walla Walla ; Ritzville ; Cunningham ; Coulee City and Cavendish, ID.

Table 2. Yield data (bu/a) on 18 winter wheat varieties gown at Pullman (early), WA for six years.

Inoculated with the Strawbreaker foot rot organism (moderate infection). Grain yields also decreased by Cephalosporium stripe.

		87	88	89	90	91	92	AVG
Madsen	PI511673	66.84	78.09	102.38	91.58	38.58	130.10	84.60
Kmor	PI536995	63.13	93.00	105.13	52.73	73.72	100.35	81.34
Hill-81	CI017954	47.07	81.10	107.94	46.78	51.50	116.84	75.21
Lewjain	CI017909	49.33	68.55	105.71	53.39	58.82	108.42	74.04
Rod	PI558510	64.71	59.48	103.97	48.04	44.63	116.65	72.91
Stephens	CI017596	57.07	64.80	96.00	61.19	25.55	121.02	70.94
Daws	CI017419	37.89	83.82	100.84	42.35	34.65	115.08	69.11
Malcolm	PI497672	52.98	55.14	90.05	66.97	35.37	112.09	68.77
Eltan	PI536994	32.31	58.23	102.64	41.76	56.88	105.24	66.18
W301	ORFW0301	54.80	55.78	94.05	61.91	2.30	91.30	60.02
Nugaines	CI013968	30.64	65.75	81.57	37.01	54.03	90.68	59.95
Gene	OR830801	-	-	93.79	66.16	16.05	103.22	
MacVicar	ORF75336	-	60.94	107.91	47.26	30.28	115.29	
Hyak	PI511674	66.00	62.57	93.91	68.92	68.75	110.86	78.50
Crew	CI017951	28.89	70.15	93.55	53.42	55.52	115.95	69.58
Tres	CI017917	43.38	52.82	109.05	40.60	54.20	108.19	68.04
Rely	PI542401	40.87	64.84	-	34.96	54.10	114.72	
Rohde	OR000855	-	-	92.12	43.65	29.87	92.07	

Treated to control Strawbreaker foot rot
Grain yields decreased by Cephalosporium stripe.

		87	88	89	90	91	92	Avg.
Madsen	PI511673	76.51	82.43	101.29	101.12	39.38	124.22	87.49
Kmor	PI536995	77.71	72.61	110.23	87.27	72.93	103.67	87.40
Lewjain	CI017909	60.42	72.65	109.23	90.29	56.87	114.96	84.07
Eltan	PI536994	56.89	69.41	111.94	86.86	59.55	107.08	81.96
Rod	PI558510	66.53	70.31	98.26	108.92	37.07	108.68	81.63
Hill-81	CI017954	64.69	68.86	101.82	92.78	36.48	122.75	81.23
Daws	CI017419	47.71	65.77	117.13	81.28	38.13	112.62	77.11
Malcolm	PI497672	56.87	52.10	89.82	70.74	48.62	106.86	70.84
W301	ORFW0301	59.18	38.94	106.80	93.45	2.70	115.58	69.44
Nugaines	CI013968	42.02	61.59	80.27	83.56	54.22	94.83	69.42
Stephens	CI017596	70.31	44.54	101.11	78.13	7.03	110.18	68.55
MacVicar	ORF75336	-	52.34	111.97	81.04	31.25	116.04	
Gene	OR830801	-	-	79.82	118.98	8.35	101.58	
Hyak	PI511674	72.91	61.69	82.64	83.73	53.52	111.86	77.73
Crew	CI017951	46.87	61.33	94.82	89.05	52.93	119.27	77.38
Tres	CI017917	57.27	62.33	93.00	66.53	47.68	123.80	75.10
Rely	PI542401	52.96	76.77	-	83.39	40.63	114.02	
Rohde	OR000855	-	-	96.08	88.26	40.95	96.61	

Table 3. Yield data (bu/a) on 18 winter wheat varieties grown at Pullman (late), WA for six years.

Medium Fertility

		87	88	89	90	91	92	Avg.
Eltan	PI536994	90.32	83.18	121.59	121.60	112.63	87.97	102.88
Hill-81	CI017954	109.25	79.45	105.80	136.44	90.58	88.25	101.63
Rod	PI558510	114.63	94.08	128.81	119.18	37.27	100.17	99.02
Daws	CI017419	107.43	63.80	97.20	113.69	113.89	96.20	98.70
Kmor	PI536995	106.37	90.18	113.68	115.73	68.49	93.21	97.94
Madsen	PI511673	103.12	85.63	114.12	124.53	60.27	83.85	95.25
MacVicar	ORF75336	117.32	76.75	127.92	121.27	50.53	76.53	95.05
Malcolm	PI497672	112.95	88.00	116.17	120.58	35.50	95.98	94.86
Lewjain	CI017909	99.05	86.25	112.00	113.86	60.70	90.43	93.72
Stephens	CI017596	105.92	71.95	98.40	133.53	9.71	90.02	84.92
Nugaines	CI013968	81.22	59.17	105.48	109.68	70.32	78.85	84.12
W301	ORFW0301	75.95	78.15	109.20	132.32	14.25	71.43	80.22
Gene	OR830801	-	-	94.51	117.05	8.53	77.45	
Hyak	PI511674	94.72	72.78	108.07	121.18	92.00	71.19	93.32
Tres	CI017917	100.97	82.55	107.92	115.19	72.82	76.93	92.73
Crew	CI017951	92.03	61.97	98.39	119.64	57.04	84.63	85.62
Rely	PI542401	97.27	80.60	-	113.87	77.80	91.97	
Rohde	OR000855	-	72.25	104.93	116.78	28.90	84.95	

High Fertility

		87	88	89	90	91	92	AVG
Eltan	PI536994	107.60	84.02	115.58	88.29	116.94	87.99	100.07
Hill-81	CI017954	113.13	76.42	101.87	121.51	105.50	80.65	99.85
Rod	PI558510	111.43	93.68	123.11	113.30	48.82	95.51	97.64
Kmor	PI536995	101.72	89.72	109.80	91.04	81.17	95.24	94.78
Madsen	PI511673	92.02	81.67	104.33	110.54	77.03	87.58	92.20
MacVicar	ORF75336	116.98	75.17	115.59	118.97	41.43	75.70	90.64
Daws	CI017419	92.35	67.42	102.41	87.37	99.28	84.84	88.95
Lewjain	CI017909	96.90	76.18	103.87	85.09	77.58	76.71	86.06
Malcolm	PI497672	106.30	93.25	111.29	94.53	23.53	82.61	85.25
W301	ORFW0301	115.78	66.07	118.73	133.61	4.63	68.38	84.53
Stephens	CI017596	86.92	69.20	98.25	108.01	14.34	82.53	76.54
Nugaines	CI013968	78.90	57.83	110.04	95.32	74.86	66.15	80.52
Hyak	PI511674	90.52	75.02	102.39	109.29	100.70	81.06	93.16
Tres	CI017917	90.92	78.33	97.01	109.97	74.90	74.53	87.61
Crew	CI017951	80.40	60.07	102.14	104.39	67.16	82.57	82.79
Rely	PI542401	93.65	71.87	-	116.79	71.36	83.79	
Rohde	OR000855	-	67.83	108.37	116.35	38.79	80.73	

Table 4. Yield data (bu/a) on 18 winter wheat varieties grown at Pomeroy, WA for six years.

		87	88	89	90	91	92	Avg.
Rod	PI558510	68.39	59.74	76.33	75.27	93.26	70.83	75.09
Malcolm	PI497672	68.11	53.77	66.39	89.94	72.31	64.23	69.13
Hill-81	CI017954	67.09	49.17	70.69	71.89	92.24	62.00	68.85
Kmor	PI536995	64.97	51.09	74.00	72.39	84.21	58.79	67.58
Madsen	PI511673	59.90	52.23	63.00	85.20	81.12	60.89	67.06
Lewjain	CI017909	67.38	54.07	63.29	70.08	85.38	60.76	66.83
Eltan	PI536994	57.75	57.38	68.24	67.99	92.08	57.42	66.81
MacVicar	ORF75336	61.82	56.37	67.29	83.92	64.94	65.97	66.72
Daws	CI017419	60.80	51.29	66.35	69.48	89.73	54.29	65.32
Nugaines	CI013968	53.90	51.72	60.73	73.76	85.39	65.56	65.18
Stephens	CI017596	68.69	52.16	60.59	78.17	61.40	61.58	63.77
W301	ORFW0301	54.39	51.06	70.28	79.19	39.41	66.72	60.18
Gene	OR830801	-	-	60.67	67.48	83.96	32.61	
Hyak	PI511674	62.71	46.86	65.68	79.37	81.33	56.28	65.37
Crew	CI017951	66.51	49.89	69.34	71.42	71.84	57.35	64.39
Tres	CI017917	67.63	46.95	70.21	66.64	74.08	51.53	62.84
Rely	PI542401	67.03	50.59	-	71.66	93.12	56.03	
Rohde	OR000855	-	49.67	66.92	63.40	72.48	67.62	

Table 5. Yield date (bu/a) on 18 winter wheat varieties grown at Walla Walla, WA for six years.

		87	88	89	90	91	92	Avg.
Rod	PI558510	74.11	113.15	89.21	116.02	104.83	99.51	99.47
Malcolm	PI497672	101.95	66.51	113.93	95.47	132.54	86.05	99.41
MacVicar	ORF75336	107.43	62.97	104.41	97.76	128.11	90.73	98.57
W301	ORFW0301	85.84	61.34	94.17	101.13	130.69	88.82	93.67
Eltan	PI536994	95.26	71.43	109.46	84.99	110.58	89.65	93.56
Daws	CI017419	87.44	67.57	104.34	92.12	118.21	89.65	93.22
Kmor	PI536995	95.30	66.46	98.01	94.51	106.46	90.97	91.95
Madsen	PI511673	85.77	69.14	99.88	79.87	123.46	92.17	91.72
Hill-81	CI017954	93.41	66.93	98.90	87.25	118.32	83.33	91.36
Stephens	CI017596	92.63	61.58	91.42	87.31	130.46	81.06	90.74
Nugaines	CI013968	77.37	46.71	104.24	91.33	115.43	80.60	85.95
Lewjain	CI017909	86.94	64.79	85.95	84.54	95.07	83.45	83.46
Gene	OR830801	-	-	103.98	98.36	124.62	88.40	
Hyak	PI511674	89.19	65.49	95.22	96.34	107.82	97.64	91.95
Tres	CI017917	84.16	63.05	101.06	97.08	93.51	96.03	89.15
Crew	CI017951	88.56	61.43	89.27	91.41	107.83	89.87	88.06
Rely	PI542401	88.96	65.30	-	88.18	110.75	94.62	
Rohde	OR000855	-	65.60	101.18	92.22	135.95	87.76	

Table 6. Yield data (bu/a) on 18 winter wheat varieties grown at Ritzville, WA for four years.

		87	88	89	90	91	92	Avg.
Rod	PI558510	63.35	54.04	-	63.04	-	59.05	59.87
Kmor	PI536995	54.62	52.74	-	62.09	-	63.26	58.18
Lewjain	CI017909	57.27	52.53	-	61.11	-	60.70	57.90
Madsen	PI511673	54.74	51.30	-	64.92	-	57.38	57.09
Eltan	PI536994	46.30	49.72	-	57.26	-	63.71	54.25
W301	ORFW0301	49.58	42.58	-	60.64	-	63.97	54.19
Malcolm	PI497672	61.37	38.82	-	61.89	-	53.01	53.77
Hill-81	CI017954	54.54	43.25	-	60.14	-	55.79	53.43
Stephens	CI017596	51.91	36.70	-	63.89	-	57.17	52.42
Daws	CI017419	55.16	48.55	-	54.10	-	50.70	52.13
Nugaines	CI013968	49.88	38.62	-	53.07	-	51.07	48.16
MacVicar	ORF75336	-	37.47	-	55.18	-	56.99	
Gene	OR830801	-	60.67	-	63.39	-	48.79	
Tres	CI017917	65.93	47.81	-	60.51	-	52.90	56.79
Hyak	PI511674	49.15	43.54	-	61.78	-	57.01	52.87
Crew	CI017951	56.98	44.65	-	58.28	-	50.33	52.56
Rely	PI542401	54.42	48.38	-	-	-	61.48	
Rohde	OR000855	-	-	-	51.58	-	56.31	

Table 7. Yield data (bu/a) on 18 winter wheat varieties grown at Cunningham, WA (Irrigated) for four years.

		87	88	89	90	91	92	Avg.
MacVicar	ORF75336	112.46	108.28	-	135.30	-	154.96	127.75
W301	ORFW0301	110.19	99.87	-	139.92	-	144.51	123.62
Malcolm	PI497672	116.22	101.17	-	126.21	-	145.41	122.25
Stephens	CI017596	112.27	88.99	-	140.65	-	136.45	119.59
Rod	PI558510	95.82	104.71	-	130.73	-	136.70	116.99
Hill-81	CI017954	101.95	87.67	-	127.14	-	149.19	116.49
Madsen	PI511673	93.41	92.94	-	127.14	-	140.70	113.55
Daws	CI017419	100.47	90.49	-	118.75	-	130.79	110.13
Lewjain	CI017909	58.97	99.67	-	95.66	-	134.49	97.20
Nugaines	CI013968	84.09	89.10	-	82.11	-	119.35	93.66
Kmor	PI536995	57.89	88.88	-	104.13	-	122.10	93.25
Eltan	PI536994	61.37	90.95	-	73.34	-	120.13	86.45
Gene	OR830801	-	-	-	138.44	-	126.57	
Hyak	PI511674	77.95	80.90	-	97.95	-	110.46	91.82
Crew	CI017951	67.17	88.89	-	104.44	-	102.51	90.75
Tres	CI017951	67.97	91.52	-	82.28	-	104.26	86.51
Rely	PI542401	70.30	91.88	-	-	-	113.82	
Rohde	OR000855	-	93.24	-	112.64	-	137.92	

Table 8. Yield data (bu/a) on 23 winter wheat varieties grown at Coulee City, WA for six years.

		87	88	89	90	91	92	Avg.
Eltan	PI536994	30.81	63.85	47.57	58.75	38.50	33.32	45.47
Kmor	PI536995	39.06	60.68	43.76	53.49	27.45	31.84	42.71
Daws	CI017419	36.18	48.98	45.40	51.80	28.38	35.75	41.08
Malcolm	PI497672	26.09	53.11	44.07	60.78	26.42	35.88	41.06
John	WA006819	33.64	43.87	34.86	49.75	35.85	39.42	39.57
Lewjain	CI017909	31.89	48.30	44.41	50.72	28.09	32.22	39.27
Sprague	CI015376	40.26	49.94	36.78	44.20	28.84	35.37	39.23
Andrews	WA006820	31.23	45.22	36.18	51.31	26.35	42.68	38.83
Nugaines	CI013968	28.42	47.81	39.09	52.89	25.79	32.34	37.72
Hill-81	CI017954	32.81	42.94	39.26	51.39	24.67	32.86	37.32
Madsen	PI511673	32.20	40.31	44.62	47.50	21.47	33.61	36.62
Stephens	CI017596	27.72	54.82	35.95	52.26	11.53	34.56	36.14
Rod	PI558510	-	49.65	40.02	55.67	14.31	35.25	
MacVicar	ORF75336	-	55.28	44.87	54.61	24.37	36.45	
W301	ORFW0301	-	51.87	-	-	15.38	32.50	
Gene	OR830801	-	-	39.46	-	6.29	26.15	
Blizzard	PI512302	-	48.74	40.99	49.54	32.89	37.34	
Hyak	PI511674	39.13	50.51	38.65	45.64	25.04	24.99	37.33
Crew	CI017951	32.02	53.26	33.99	47.04	23.61	29.69	36.60
TRES	CI017917	34.56	45.08	36.61	46.32	27.78	27.75	36.35
Moro	CI013740	35.18	46.78	39.45	42.34	23.15	28.47	35.90
Rely	PI542401	-	45.23	-	51.58	24.88	35.80	

Table 9. Yield data (bu/a) on 18 winter wheat varieties grown at Cavendish, ID for six years.

		87	88	89	90	91	92	Avg.
Kmor	PI536995	52.85	67.21	83.96	74.72	58.32	63.85	66.82
Rod	PI558510	53.75	66.84	78.27	78.86	57.80	65.36	66.81
Madsen	PI511673	43.68	60.93	69.99	85.35	64.23	66.90	65.18
Eltan	PI536994	54.48	61.19	80.84	67.09	65.81	60.17	64.93
Lewjain	CI017909	55.45	63.73	74.93	70.62	58.36	58.88	63.66
Malcolm	PI497672	55.65	70.01	49.27	81.94	52.10	66.81	62.63
Hill-81	CI017954	53.22	56.84	70.62	82.11	51.71	60.90	62.57
MacVicar	ORF75336	52.62	64.38	59.44	81.21	50.07	63.77	61.92
Daws	CI017419	45.91	55.62	72.80	77.92	53.25	58.18	60.61
W301	ORFW0301	43.79	50.68	57.59	86.18	34.53	64.68	56.24
Stephens	CI017596	45.35	45.22	60.58	81.79	27.38	63.28	53.93
Nugaines	CI013968	43.03	35.07	39.93	74.25	55.54	63.67	51.92
Gene	OR830801	-	-	18.45	70.66	9.04	60.70	
Tres	CI017917	54.28	68.05	72.09	75.71	65.35	61.64	66.19
Hyak	PI511674	37.64	64.14	70.82	81.13	66.66	58.58	63.16
Crew	CI017951	43.46	36.68	57.87	81.06	60.95	54.48	55.75
Rely	PI542401	42.70	63.18	-	81.33	64.23	62.57	
Rohde	OR000855	-	59.16	61.20	80.48	56.80	54.82	

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 = Moderatly susceptible S = Susceptible

HARD WINTER WHEAT BREEDING AND TESTING

E. Donaldson, B. Sauer, S. Lyon, C.F. Morris,
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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 Plans 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 was grown at two locations in Washington and included 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. In breeding for bread baking quality the challenge is to combine high protein with flour yield and large loaf volume.

In the hard red winter wheat growing region of Washington the need for adequate straw to aid in the prevention of erosion varies from a demand for more straw than the present varieties, to a desire to have less straw to reduce the need for extra tillage. Strong emerging varieties are a necessity throughout the area. In an attempt to provide shorter wheats with good emergence, two semidwarfing genes with long coleoptiles are being used in the breeding program.

Promising Selections:
WA7679 is an awned, white-chaffed, short standard height hard white winter wheat. Grain yields during the last three years have been competitive with those of Hatton. Results thus far indicate its emergence and winterhardiness are about equal to those of Hatton. WA7679 is moderately resistant to stripe rust and dryland foot rot, and moderately susceptible to common bunt. Protein content of the grain has been slightly higher than that of Hatton. Milling and baking properties of the flour are equal to those of Hatton. Currently, release is pending results of noodle quality tests.

WA7678 is an awned, white-chaffed, short standard height hard red winter wheat. It appears to be equal to Hatton in stand establishment, but not as good as Buchanan or Blizzard. Winter survival of WA7678 is as good as Hatton, but its winter recovery is not as good. Its stripe rust resistance is probably equal to Wanser or Nugaines. Flour yield, test weight, mix-time, and mix-curve of WA7678 are equal to, or better than, those of Hatton. However, the protein content of the flour and the loaf volume when baked are less desirable than Hatton.

Yield Nurseries:
Seeding conditions were good to excellent at Connell, fair at Harrington and Waterville, poor at Lind, and very poor at Finley. The Lind dry land nurseries suffered from poor stands, wind and dust damage, and early fall frost. The winter was warm and dry. Spring weather conditions were warmer and dryer than normal. June and early July were also warmer and dryer than normal, causing drought stress which resulted in low test weights and an early harvest. Rain and cool weather shortly after the start of harvest caused extensive sprout damage in the low rainfall area, where sprout damage is usually not a problem.

Other than physiological leaf spot, disease and insect damage was minimal and probably had little, if any, effect on yield. Strawbreaker foot rot, fungal stripe, leaf rust, and stripe rust could be identified in the Connell nursery. Stripe rust showed up early in the irrigated nursery at Lind but spread slowly due to the warm temperatures.

The Hard Wheat Variety Trial grown at Lind under dry land conditions was seeded deep into minimal moisture. Emergence was slow and stands were erratic. Two windstorms which buried some plants, followed by cold temperatures near the end of October, killed some plants. Fall plant development was poor. The nursery was harvested before the July rains. Quantum Hybrid 542 had the highest yield with 29.7 bu/a. Hatton was the only variety not statistically different, with a yield of 28.3 bu/a. Seven of the cultivars in the state portion of the nursery statistically had yields not significantly different from Quantum Hybrid 542. The variety trial at Connell was seeded deep into exceptionally good moisture. Stands were good. Quantum Hybrid 542 had the highest yield (49 bu/a) of the ten entries in the extension portion of the nursery. Blizzard (48 bu/a) and Buchanan (43 bu/a) were not statistically different in yield from Quantum Hybrid 542.

The Winter Wheat Nursery at Waterville contained 69 entries. Seeding conditions were poor and stands somewhat erratic, resulting in a fairly large coefficient of variation. Weston had the highest yield in the extension part of the nursery, with 27 bu/a.

The Winter Wheat Nursery at Harrington contained ten extension entries and 62 state hard wheat cultivars. Due to stress and weathering, bushel weights were low. Yields were below normal, with whole grain protein only slightly above the usual average for the location. The highest yielding cultivars in the extension portion of the trial were Quantum Hybrid 542, Batum, Blizzard, Hatton, and Buchanan with 54, 50, 49, 49, and 47 bu/a yields, respectively.

1992 Dry land yield (bu/a) and percent whole grain protein content for six advanced hard red winter wheat cultivars at four locations.

	Lind Dry	Waterville	Connell	Harrington	Average
Hatton	28 (15.9)	23 (14.3)	42 (11.4)	49 (10.2)	35 (13.0)
Weston	22 (15.9)	27 (15.0)	45 (11.4)	44 (11.2)	35 (13.4)
Blizzard	25 (16.3)	26 (15.3)	38 (10.7)	49 (10.7)	34 (13.3)
Buchanan	25 (17.4)	22 (14.6)	43 (10.2)	47 (10.3)	34 (13.1)
Andrews	24 (16.2)	20 (15.3)	40 (11.6)	42 (11.5)	31 (13.7)
Quantum 542	30 (16.3)		49 (10.3)	44 (9.9)	
WA7678	27 (16.0)	25 (13.0)	41 (10.0)	48 (10.7)	35 (12.4)
WA7757	26 (17.7)	25 (16.1)	41 (11.3)	50 (10.4)	35 (13.9)
WA7758	21 (17.5)	25 (15.5)	43 (11.0)	49 (11.0)	34 (13.8)
WA7759	26 (17.3)	23 (15.6)	42 (11.9)	48 (10.5)	35 (13.8)
WA7760	25 (17.0)	21 (15.7)	43 (11.2)	47 (10.5)	34 (13.6)
WA7761	25 (16.6)	22 (16.0)	42 (11.5)	37 (12.2)	32 (14.1)

1992 Performance of eight cultivars in the Tri-State Irrigated Hard Red Winter Wheat Nursery at Lind.

	Plant ht.	Yield bu/A	% Protein	% Lodge
Batum	34	107	12.1	23
Andrews	34	113	12.2	5
Ute	33	104	12.8	10
WA7681	35	101	13.3	0
WA7723	32	123	12.3	0
WA7724	31	117	12.5	0
WA7725	33	113	12.1	0
WA7726	36	119	13.0	0

1992 dry land yield at four locations for five hard white winter wheat cultivars compared with hard red winter wheat checks. Average protein content over four locations is reported on an as is moisture basis.

Cultivar	Connell	Harrington	Waterville	Lind	Avg. Yield	Avg. Protein
IDHW0355	40	44	25	24	33	13.3
WA007679	37	49	24	25	34	13.7
N9000101	35	38	21	22	29	13.5
N9008011	44	48	24	26	35	13.1
WA007762	42	58	24	24	37	12.2
Hatton	42	49	23	28	35	13.0
Blizzard	38	49	26	25	34	13.3
Buchanan	43	47	22	25	34	13.1

USDA-ARS WHEAT GENETICS RESEARCH

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

Club Wheat Cultivar Development

WA7622, a club winter wheat line, has received preliminary approval allowing for breeder seed increase. WA7622 has resistance to all three rusts. It has three genes for resistance to stripe rust and it is resistant to a race capable of attacking Hyak. Like Hyak it has resistance to strawbreaker foot rot. It has higher yield potential than Hyak even under severe foot rot conditions. Because WA7622 is later than Hyak it is less vulnerable to spring frost damage. Most importantly WA7622 is a definite improvement over Hyak for club wheat flour quality. Like Hyak it has high milling quality but it is superior to Hyak in cookie bake, cake volume, absorption, viscosity and mixogram tests. If WA7622 continues to perform well, it will be considered for joint ARS/WSU release in 1994.

A new bearded club wheat, WA7752 is now in regional tests and appears to be very promising. It is a tall semidwarf derived from a Madsen/2*Tres cross. WA7752 has high resistance to stripe rust and strawbreaker foot rot and expresses moderate resistance to leaf rust and powdery mildew. Compared to existing club varieties, the yield potential of WA7752 is outstanding. It has exceeded the yields of Tres, Rely and Hyak by 30%, 20% and 7%, respectively, in trials conducted over 3 years. WA7752 has a moderately long coleoptile and fast seedling growth rate for a semidwarf. Because of this, it emerges better than our other semidwarf club wheat varieties. Like WA7622, WA7752 is also a definite improvement over Hyak for club wheat quality based on cookie diameter, absorption, AWRC, and mixogram tests.

Stripe Rust Resistance

Our program of breeding for resistance to stripe rust involves three approaches. They are: 1) Transferring resistance from wild wheat relatives to cultivated wheat. 2) Combining nonspecific resistance with specific resistance. 3) Developing multilines with genetically diverse resistance.

We have over 60 advanced club wheats that have multiple gene resistance to stripe rust in the 1993 tests. Their resistance includes a newly introduced gene from wild Emmer or *Triticum dicoccoides*. This gene conditions resistance to all of the stripe rust races it has been screened against so far. Some of these lines have 4 to 5 genes for resistance to stripe rust including 2 from Tres, 1 or 2 from Tyee and the gene from *T. dicoccoides*. Other lines also have 1 or 2 genes for adult plant resistance derived from Gaines. These lines are in preliminary trials and will be evaluated for their agronomic and quality potential this season.

We are also utilizing another exotic source of stripe rust resistance derived from *Agropyron elongatum*. This form of resistance has been transferred to several promising advanced club wheat lines. So far no stripe rust races have been detected that can attack this source of resistance. Our genetic tests indicate it is unique to all of the other types of resistance we are using. Line ARS9257 is particularly promising because it carries combined resistances to stripe rust, strawbreaker foot rot and also has high tolerance to cephalosporium stripe believed to be derived from *Ae. elongatum*. Preliminary quality tests of ARS9257 have been encouraging. Dr. Jones is using molecular genetic methods to characterize the amount of *Ae. elongatum* DNA that has been translocated into ARS9257 and several other of our advanced lines.

Other stripe rust genetic studies indicated that the new Oregon club wheat named Rohde has two race specific genes that are effective against Tres attacking races. Hyak appears to consist of a mixture of plants with either 1 or 2 genes for stripe rust resistance. We are yet uncertain as to the vulnerability of Hyak to new races of stripe rust that are virulent on it in the seedling stage. Limited results in 1992 suggested that Hyak may have some adult plant resistance after all.

Winter Wheats for Low-Rainfall Zones

The program on developing soft white winter wheat varieties specifically for the low-rainfall area has expanded. In 1992 eight ARS nonsemidwarf or tall selections were tested at Connell and Pullman. A Moro-type multiline yielded 20% higher than Moro at Connell. Two semidwarf Sava/Omar lines had yields comparable to Moro. These lines do not have shortened coleoptiles and slow seedling growth rates. Shortened coleoptiles and slow seedling growth consistently occurs with Norin 10 type semidwarfs and causes them to emerge poorly in the low-rainfall zone. We have 200 Sava semidwarf-type F_4 lines in preliminary evaluation tests in 1993. Most of them are club wheats with Omar, Tres and Moro parentage. Over 4000 nonsemidwarf F_3 head rows are being grown at Pullman. Nearly 75% of these lines are club-types. Tall nonsemidwarf plants segregate readily from crosses in which the parents differ for semidwarf genes. Populations involving semidwarf club wheats such as Hyak, Paha, Tyee, Rely and Crew crossed to Lewjain, Madsen, Stephens, Hill 81, and Luke all segregate nonsemidwarf plants because these club varieties carry a different semidwarfing gene from the common wheat varieties. Our hope is that some of these tall selections will be well adapted to the low-rainfall zones and emerge as well as Moro.

Wheats of Spring and Winter Growth Habit

We have nearly completed transferring four vernalization response genes (*Vrn*) for spring growth habit into several area winter wheats including Tres, Paha, Stephens, Luke, Nugaines, Daws, and Wanser. The main goal of this project was to develop near-isogenic lines in these various genetic backgrounds to facilitate basic research on the genetic, biochemical and physiological processes controlling vernalization. Several very practical applications should also be realized. Some of the converted winter wheats have good yield potential as spring types. In a 1992 spring sown yield trial, Penawawa yielded 93 Bu/Ac compared to the spring types of Stephens (92 Bu/Ac); Nugaines (85 Bu/Ac); Burt (85 Bu/Ac); Wanser (95 Bu/Ac) and Tyee (83 Bu/Ac). These lines were unselected except for spring habit so their yields were especially impressive. Spring habit prototypes should also speed the breeding process in our winter wheats. We plan to use spring versions of Luke and Nugaines to quickly incorporate their adult plant resistance into our winter club wheats. Because spring habit is a genetically dominant trait, multiple backcrosses can be made between spring and winter parents in a single year. After the last backcross final selection for winter growth habit will be made. These winter and spring lines should help resolve a vexing issue concerning wheat quality. Popular opinion holds that spring wheats are superior to winter wheats for bread products. For soft wheat the reverse opinion is the commonly held belief. These arguments are hotly debated between regions growing mainly spring or mainly winter wheat. spring and winter growth habit prototypes in the same variety will allow us to conclusively determine whether growth habit alone affects wheat quality. What we learn could directly impact how USA wheat is classified in the future.

Modifying Heading Date

Varieties such as Luke and Lewjain have many desirable attributes such as tolerance to dryland root rot, excellent quality, durable resistance to TCK and stripe rust, yet they remain unpopular because they head and ripen late. Using NILS that vary 8 days in heading date, we showed that it was possible to shorten heading date of Luke by 3 to 5 days without sacrificing yield potential. The milling and baking quality of several of these earlier lines is identical to Luke. Reducing the heading date of Luke by 8 days caused a yield loss of 14%.

Choice of Semidwarf Gene

No significant differences were found in the overall mean grain yields of NILS of Rht_1 versus Rht_2 semidwarfs when placed in three different winter wheat backgrounds. Without exception the highest yielding individual NIL for each genetic background possessed the Rht_1 gene. Although no direct association occurs between overall grain yield and the Rht_1 versus the Rht_2 gene, the highest yielding individual line consistently had the Rht_1 gene.

Breeding for Resistance to Pre-harvest Sprouting

Wheat varieties with red grain are generally considered to have greater dormancy than varieties with white grain. Yet exceptions occur. Using near-isolines (NILS) populations differing only for red versus white grain, developed in Nugaines, Brevor, Daws, Luke, and Paha, we showed that the red grain NILS always express greater dormancy than their white grain sibs regardless of their genetic background. The effect is greater in some backgrounds than others. The differences in dormancy between red and white grain sibs were great in Brevor and Nugaines while small in Luke and Paha. White grain sibs lost their dormancy faster than their red grain counterparts. The rate at which this occurs differed among genetic backgrounds even for those that possess the same grain color gene. To attain maximum high-temperature grain dormancy to achieve resistance to sprouting, emphasis should be placed on selecting within populations which are exclusively white grain or only among white grain progeny. In this way the masking effects caused by red grain can be avoided.

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). About 10% of the Lab's funding comes from the Washington Department of Agriculture.

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, 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 Hanan I. Malkawi; and Victor L. DeMacon and Paul Cannon.

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, R. A. Nilan, A. Kleinhofs, Z. Huang, J. J. Johnson, B. C. Miller, P. E. Reisenauer, and J. A. Froseth

The overall goal of the WSU Barley Improvement Program is to make barley a more profitable crop. The specific objectives are: 1) to develop high yielding, stiff-strawed agronomically acceptable spring and winter varieties (with emphasis on 6-row spring barley) with superior feeding and/or malting quality that are adapted to the different barley producing areas of Washington; 2) to develop and/or adapt relevant technologies that improve the efficiency and effectiveness of breeding barley; 3) to determine and understand economically important genetic traits and their inheritance, and 4) to develop and/or evaluate relevant barley management practices.

What follows is a synopsis of the various research projects within the framework of the WSU Barley Improvement Program. In some cases further detail can be found in other publications as noted.

Cultivar Development

The WSU barley breeding program has released cultivars for many decades, and WSU cultivars have traditionally dominated Washington barley production. The current cultivar giants are Steptoe among the spring types and Kamiak and Boyer among the winter types. The newest WSU winter barley release is **Hundred** which is a high yielding semi-dwarf 6-row feed type. Yield performance for Hundred and other winter cultivars can be found in Table 1. The latest barley cultivar release is **Crest** (tested as WA8771-78), which is a two-row spring type with high yield and good feed and malting quality. It has been designated a malting variety by the American Malting Barley Association. It's yield performance compared to Steptoe's can be seen in Table 2. A number of winter and spring breeding lines show promise and are in the various breeder and extension tests throughout eastern Washington. An extensive review of barley variety performance can be found in the February 12, 1993 Green Sheet issue. Carl Muir, Bob Nilan and Steve Ullrich have been major contributors to the cultivar development aspects of the program.

TABLE 1. WINTER BARLEY YIELD AVERAGES THROUGH 1992, LB/A(% of Boyer)

VARIETY	PULLMAN 9 YR	POMEROY 7 YR	WALLA[2] 8 YR	LIND IRR 4 YR	EXTENSION 58 LOC-YR
HUNDRED	5830(112)	4780(105)	4810(96)	4580(112)	4530(105)
HESK	5810(111)	4860(106)	4780(95)	4310(105)	4440(103)
BOYER	5230(100)	4570(100)	5020(100)	4090(100)	4300(100)
SHOWIN	5120(98)	4430(97)	4910(98)	4200(103)	4210(98)
KAMIAK	4690(90)	4000(88)	4390(87)	2600(63)	3920(91)

TABLE 2. SPRING BARLEY YIELD AVERAGES THROUGH 1992.

VARIETY	PULLMAN 12 YR	POMEROY 12 YR	WALLA[2] 11 YR	DAVENPORT 8 YR
		LB/A (%)		
CREST	4860(100)	3260(98)	3530(96)	2675(105)
STEPTOE	4840(100)	3340(100)	3690(100)	2555(100)
	CONNELL 8 YR	LIND 8 YR	MEAN - 59 LOC-YR	EXT MEAN 62 LOC-YR
CREST	1920(107)	1710(98)	3165(100)	3810(98)
STEPTOE	1790(100)	1745(100)	3175(100)	3875(100)

Germplasm Development

Introduction and Crossing. Crossing is the traditional approach to parent building and breeding line development. Introduced germplasm from the Midwest USA, Canada, Europe and other areas of the world primarily from the USDA Small Grants Collection and CIMMYT and ICARDA nurseries is used in our crossing program. Quality, winterhardiness, lodging resistance and pest resistance are some of the important traits sought from outside germplasm. Foreign introductions have been particularly important for Russian wheat aphid and stripe rust race 24 resistance.

An important new development is the exchange of new and advanced breeding lines among the Northwest barley breeders to facilitate specialization in cultivar development. This new program is intended to allow a concentration of breeding effort with specific programs dealing with specific barley types, eg. WA 6-row springs, OR - winters, MT - 2-row springs, ID-USDA-irrigated spring types. Evaluation of all types of barley will occur in each state as in the past.

Mutation Breeding. This technique intended to "create" new genetic variability has been a traditional approach in the WSU program. Current efforts concentrate on chemically induced mutants for lodging resistance and malting and brewing quality (proanthocyantin-free). Mutants may be used directly as new cultivars or more likely used as parents in the crossing program. Judy Cochran has been the principal person working with mutation breeding.

Variety Testing

Small Plot. Traditional small plot trials are scattered throughout eastern Washington. Winter barley breeder plot sites are located at Pullman, Pomeroy, Walla Walla, and Lind (dryland and irrigated). Extension trial sites are located lat Mayview, Dayton, St. John, Farmington, Fairfield, Dusty, Reardan, Lamont, Asotin, Bickleton and Moses Lake (irrigated). Spring breeder test sites include Pullman, Pomeroy, Lind, Reardon, and Fairfield. A reduction in breeder sites is due to budget constraints. Spring extension small plot test sites are at Farmington, St. John, Dayton, Dusty, Lamont, Bickleton and Moses Lake (irrigated). The breeder tests are coordinated by Carl Muir and Steve Ullrich and with the spring wheat program (Cal Konzak, Mike Davis and Gary Shelton). The extension tests are conducted by Baird Miller and Pat Reisenauer. Data from the small plot trials are published in various forms including Wheat Life, the Green Sheet and the Project 175 report.

On Farm Test. A spring barley genotype x environment interaction study was initiated to more efficiently select and evaluate barley lines for release. A better understanding of barley performance in relationship to eastern Washington environments should result. Procedures and trial locations for evaluation could be affected as well as recommendation domains for varieties. Four barley cultivars were produced in 40 large scale on-farm tests in 1990 in eastern Washington using commercial equipment by the cooperating grower. Five cultivars were used in 1991 in 42 on-farm tests. In addition 12 locations had 1-4 additional varieties including Russell (12), Manley (7), Excel (5) and Crystal (5).The counties involved were Adams, Columbia, Franklin, Walla Walla, Garfield, Klickitat, Lincoln, Spokane, Stevens, and Whitman. In 1992 there were 27 on-farm tests over 9 counties with 5-10 varieties. Some of the county extension agents in the above counties have been important cooperators as well. The on-farm tests have extension as well as research value. Over the three years (109 environments) Steptoe had the highest average yield at 2940 lb/a. Camelot and Harrington yielded significantly less than Steptoe, but not compared to each other at 2755 and 2710 lb/a, respectively. In 1992 the yields for Steptoe, Crest, Harrington, Russell, and Camelot were 2400, 2275, 2250, 2185, and 2175 lb/a, respectively. These data were also considered by agroclimatic zone. Other grain and grain quality data are being analyzed including test weight, kernel plumpness, protein percentage, and yield components. Jerry Johnson coordinated the on-farm test project in 1990 and 1991. Beginning with the 1992 crop year overall coordination is provided by Mary Palmer-Sullivan of the Washington Barley Commission with assistance from Chuck Goemer, WSCIA and Baird Miller and Steve Ullrich, WSU as well coordinators in each of the participating counties. A summary of the 1992 tests and two and three year averages were presented in a March 1993 Wheat Life article.

Quality Evaluations. Malting and nutritional quality are emphasized in the program. Seed of all malting barley lines in yield trials are sent to the USDA-ARS Cereal Crops Research Unit in Madison, WI for micro-malting and malt evaluation. Additional malt analyses are frequently done in industry labs as well, such as at Great Western Malting Co., Vancouver, WA. As most (70-85%) of

Washington barley is used for feed, nutritional quality is also important. The quality characteristics for malting and feed are not mutually exclusive. In general good malting varieties are good feed varieties. Advanced breeding lines are evaluated for nutritional quality through composition analyses (protein, lysine, fiber-soluble, β-glucans and insoluble, ADF, NDF) and feeding trials in cooperation with WSU animal nutritionists, John Froseth and Craig Wyatt. The new mobile nylon bag technique (for digestible energy) in pigs fitted with intestinal cannulas has been employed for the past three crop years. Large differences in feed quality have been observed. In general, spring 2-rows are better than spring 6-rows which are better than winter 6-rows. Several breeding lines have been identified as having good to excellent quality. Some composition analyses for malting and nutritional quality are performed in our lab by Janet Clancy. Work with food type barleys is proceeding with hulless (low in insoluble fiber) and waxy starch (high in β-glucans or soluble fiber) barley types. In general an understanding of fiber traits in barley is emphasized in lab and field research.

<u>Anther Culture to Produce Double Haploid Lines.</u>

We are gaining considerable experience with anther culture and are beginning to apply it to the breeding program. Although there are considerable genotype and environmental influences on anther culturability and plant regeneratability, significant success is being achieved. Many of the environmental affects are being brought under control with media and donor plant environment adjustments. We are also beginning to understand the rather complex genetics of anther culture traits. The goal of the anther culture work is to accelerate cultivar development and release by producing double haploids from F_1 plants from crosses. The doubled haploids are 'instant' homozygous lines. This can be done in essentially one generation versus five to eight generations through conventional segregation. Typically, reasonably homozygous lines occur in about the F_5 to F_8 generations depending upon the relatedness of the parents of the cross. The initial applications of anther culture to produce homozygous doubled haploid lines is in the development of Russian wheat aphid resistant and waxy hulless germplasm. Zhongxiang Huang is heading up the anther culture work. In 1992 there were about 400 doubled haploid lines from F_1's in the field for selection.

The tissue culture work in general is a prelude to genetic transformation. As we move closer to being able to transform barley, tissue and cell culture and plant regeneration will become more important.

<u>Barley Genome Mapping and QTL Analysis.</u>

Some of the WSU barley improvement team at WSU (Kleinhofs, Nilan, Ullrich, Froseth, Muir, and Clancy) is collaborating in the North American Barley Genome Mapping Project (NABGMP). It is expected that Restriction Fragment Length Polymorphism (RFLP) technology and Quantitative Trait Loci (QTL) Analysis will contribute to more directed plant breeding efforts than are currently possible. The breeder should be able to identify genes conferring specific effects on economically important traits and be able to determine the presence of desirable alleles in breeding lines. The NABGMP is currently in the RFLP mapping and trait evaluation and verification phase. One hundred and fifty double haploid Steptoe/Morex lines were planted at Pullman in 1991 and 1992 (Muir) as one of eight locations for analyses. A second mapping population from a

Harrington/TR306 cross is being analyzed in 1992 and 1993 planting. Agronomic, growth and development, and quality traits are analyzed. Genetics of the dormancy in Steptoe is one trait, we are vigorously studying. Janet Clancy is working directly in the NABGMP to transfer the genetics technology into the breeding program.

SPRING WHEAT RESULTS 1992, PROGRESS 1993

C. F. Konzak, M. A. Davis, G. Shelton
S. T. Ball, H. Zhou, Y. Zheng

The 1992 season was considerably different than the 1993 season will be, especially in the Palouse. In 1992, all the spring wheat trials were sown early; in 1993, Pullman, and Waverly were sown about the latest spring wheat trials have been sown for many years. All other sites were sown in a reasonably good time period, considering the cool wet weather which followed planting. In 1992, foliar diseases and pest damage was minimal, insufficient for gathering any useful data other than yield from the tests. However, the drought stress in the 1992 season did help the identify WA7677, as an outstanding performer, and provided strong support for the plans for its release as a cultivar, as discussed later. The early Palouse weather conditions provided a "window" usable for no-till planting of spring wheats prior to the prolonged wet, cool weather, which resulted in extensive soil erosion in the winter wheat fields, and in fields with inadequate surface residue. Unfortunately, little has yet been done to evaluate spring wheats under the early planting, no-till conditions or to develop management procedures to avoid or control the expected disease and pest problems that may be encountered. Because of the high erosion problems with wheats fall planted late and in low surface residue conditions, there is concern about the high levels of soil erosion that will drive efforts to determine if spring wheat cultivars better adapted to early wet, cool conditions (tolerant to Pythium) can be developed, and/or management methods and conditions for planting can be developed to achieve economic yields using spring wheats.

NEW RELEASES RECOMMENDED:

WA7677, named ALPOWA, a semidwarf soft white common spike spring wheat,has been recommended for cooperative release by Washington, Idaho, Oregon, and the USDA. Alpowa will provide growers with a replacement for the already too popular Penawawa, which offers not only the potential for higher yield performance, but also has quality characteristics that are superior to Penawawa. Alpowa appears to carry adult and possibly some race-specific resistance to stripe rusts, and the unusual property of a more rapid grain fill period, even though heading occurs about the same time as Penawawa. Alpowa has Walladay as a parent in 3 out of 5 combinations, but is very different in heading, maturity, and disease resistance. It should prove useful to growers, and be a good parent of future cultivars.

WUC657, named CALORWA, is a new semidwarf soft white spring club wheat, originally developed at UC Davis, California, and cooperatively evaluated by Washington, Oregon and Idaho, with some further testing in California. Tests by the USDA Western Wheat Quality Laboratory in Pullman indicate that Calorwa has typical soft white club wheat processing properties. Yields of Calorwa will not quite compete with those of Alpowa or Penawawa, but the variety will surely find a place for reseeding winter injured club wheats for which no club wheat has been available, and for spring planting to permit growers to access markets when supplies of club wheats are low due to winter kill. Calorwa appears to have moderate stripe rust and leaf rust resistance and may also have stem rust resistance because of its parentage. Calorwa will be recommended for cooperative public releases in Washington, Oregon and California. Idaho may also join.

WA7715, suggested name WADUAL 94, an improved Wadual, dual quality (bread and pastry type) likely will be released only by Washington. Because of its unique properties which need more emphasis in marketing, Wadual 94 may be a good candidate for licensing to a private organization. This possibility is being considered.

PROMISING NEW LINE

WA7712, a semidwarf soft white spring wheat with excellent processing quality properties, disease resistance and hessian fly resistance is being advanced and potential breeder stock produced for use as an improved replacement for Wakanz. The line WA7176, had been increased and readied for possible release, but was held back because extensive tests indicated it may be lower in milling yield than Wakanz and other soft white spring wheats. WA7712, corrects these weaknesses of WA7176, and has equal or better stripe rust resistance. WA7712 will be reviewed and if data continue to show it promising, will be proposed for release in 1994.

NEW DEVELOPMENTS IN ACCELERATED SPRING WHEAT BREEDING:

While efforts in the conventional spring wheat breeding program have continued at an effective pace to maintain a steady flow of improved germplasm combinations for potential cultivar development via cross-breeding and selection, the new anther culture process for dihaploid/instantly true breeding line development has been advanced and is now already contributing significantly to the numbers of lines in single row, single plot and replicated plot trials. A large number of the selected combinations have been made to introduce genes for pest resistances into the WSU spring wheat breeding program, and especially to bring both the soft white club and hard white spring wheat breeding populations to competence. In addition, new soft white and hard red spring combinations including better quality properties and pest resistance have been introduced via the dihaploid production program. The technology is still far from the level of efficiency desire. Consequently, a portion of the effort continues in technology development. One problem nearing solution is the reduction of losses of progeny because of haploidy, or failure of spontaneous chromosome doubling. While we found genotype combinations to differ markedly in the percentages of spontaneous doubling, we worked on improving methods for artificial doubling, now evaluating a method involving a short exposure of small calli to colchicine before they are regenerated. In addition, we believe we have identified an important key to increasing the yields of dihaploid green plants, and possibly to the production of dihaploids from isolated wheat microspores (prepollen). Work on these problems is continuing, with appropriate amounts of practical materials as well so as to evaluate the advances as they are made. New emphasis on techniques to evaluate traits in culture is yet needed to exploit the real potential of the new technology.

TABLE 1. CULTURAL DATA FOR 1992 SPRING WHEAT YIELD NURSERIES

LOCATION	PLANTING DATE	BASE FERTILIZER	STARTER FERTILIZER	PREVIOUS CROP	MOISTURE TOP 3′
CONNELL	2/26	8#N,12#P,9#S	6#N,8#P,6#S	FALLOW	3.90 (2/05)
LIND RESEARCH STATION	2/28	14#N,22#P,15#S	"	FALLOW	4.38 (2/05)
ROYAL SLOPE RES. STATION	3/05	180#N,110#K, 20#S	10#N,13#P,10#S	FALLOW	IRRIGATED
MAYVIEW	3/26	80#N,15#P,12#S	"	FALL WHEAT	5.23 (3/12)
PULLMAN SPILLMAN FARM	3/24	136#N,4#P,3#	"	OATS	5.37 (3/12)
FAIRFIELD	4/01	76#N,8#P,6#K,7#S	"	SPR. BARLEY	4.48 (4/01)
REARDAN	4/02	65#N	"	SPR. WHEAT	4.63 (4/02)

TABLE 2.

1992 SOFT WHITE SPRING VARIETIES (YIELD BU/AC)							
LOCATION:	LIND	FAIR-FIELD	REAR-DAN	MAY-VIEW	PULL-MAN	ROYAL SLOPE	AVE. YIELD
FIELDER	16	56	44	46	60	109	55.4
CENTENNIAL	16	53	53	52	62	109	57.6
ID000392	13	54	50	41	62	97	52.9
TREASURE	15	51	46	50	55	117	55.6
EDWALL	15	53	49	38	55	106	52.7
PENAWAWA	16	58	41	47	59	111	55.3
WAKANZ	15	54	52	44	61	109	55.9
WADUAL	16	47	39	42	63	102	51.4
WUC00657	15	53	40	37	61	91	49.5
WA007176	14	53	45	29	59	114	52.5
WA007677	16	59	53	41	66	113	58.1
WA007712	16	51	50	41	60	106	54.3
WA007715	15	52	44	42	66	108	54.5
SPRITE	16	53	50	45	60	116	56.9
NURSERY MEAN	15.2	53.4	47.0	42.7	60.7	107.9	X.. 54.5
LSD (.05) BU/AC	2.69	7.69	7.43	5.23	6.04	9.89	
C.V.	13.3	10.7	11.8	8.9	7.4	6.8	

TABLE 3.

1992 SOFT WHITE SPRING VARIETIES (TEST WT. LB/BU)							
LOCATION:	LIND	FAIR-FIELD	REAR-DAN	MAY-VIEW	PULL-MAN	ROYAL SLOPE	AVE. T.W.
FIELDER	57.5	60.0	63.4	56.6	57.4	60.2	59.2
CENTENNIAL	59.2	61.3	64.5	59.7	58.8	60.5	60.7
ID000392	60.3	61.8	64.9	59.9	60.9	60.4	61.4
TREASURE	57.5	59.8	64.1	59.0	60.0	58.5	59.8
EDWALL	55.4	57.0	61.3	53.5	53.9	57.6	56.4
PENAWAWA	56.6	60.5	63.4	55.9	54.7	59.6	58.4
WAKANZ	56.5	58.4	63.0	56.9	57.7	58.0	58.4
WADUAL	57.7	59.9	63.6	58.0	58.4	61.0	59.8
WUC00657	56.2	59.5	63.2	56.5	56.5	57.5	58.2
WA007176	54.9	58.1	63.3	53.8	56.9	58.5	57.6
WA007677	59.4	62.0	64.9	58.8	60.4	60.1	60.9
WA007712	58.7	61.0	63.4	59.1	60.3	61.8	60.7
WA007715	57.4	61.5	63.6	55.8	57.9	60.4	59.4
SPRITE	57.1	59.7	63.0	54.6	55.7	60.5	58.4
NURSERY MEAN	57.5	60.0	63.5	57.0	57.8	59.6	X.. 59.2

TABLE 4.

1992 SOFT WHITE SPRING VARIETIES (WHOLE GRAIN PROTEIN)							
LOCATION:	LIND	FAIR-FIELD	REAR-DAN	MAY-VIEW	PULL-MAN	ROYAL SLOPE	AVE. PROT.
FIELDER	14.3	13.1	12.2	12.3	12.0	12.1	12.7
CENTENNIAL	13.6	12.3	11.0	11.1	12.1	10.7	11.8
ID000392	13.3	11.5	11.1	11.7	11.4	11.5	11.7
TREASURE	13.9	13.2	12.6	11.5	11.6	11.1	12.3
EDWALL	13.9	13.1	11.6	11.8	12.2	11.2	12.3
PENAWAWA	13.9	12.0	12.4	12.0	12.5	10.9	12.3
WAKANZ	14.1	12.7	12.1	11.5	11.7	11.2	12.2
WADUAL	15.1	14.4	13.5	12.2	12.3	12.3	13.3
WUC00657	14.2	12.3	12.4	11.7	11.7	11.1	12.2
WA007176	15.1	12.6	12.8	13.7	12.1	11.0	12.9
WA007677	13.6	12.4	11.6	11.1	11.5	11.2	11.9
WA007712	14.1	12.7	13.3	12.2	12.3	11.7	12.7
WA007715	15.3	13.5	13.7	12.3	12.4	12.6	13.3
SPRITE	14.6	12.2	13.3	12.0	11.5	11.3	12.4
NURSERY MEAN	14.2	12.7	12.4	11.9	11.9	11.4	X.. 12.4

TABLE 5.

1992 EXTENSION YIELD & TEST WEIGHT DATA

	DUSTY	LAMONT	BICKLE-TON	ST. JOHN	DAYTON	FARM-INGTON	M. LAKE
CENTENNIAL	23(50.9)	28(56.1)	38(61.1)	36(58.7)	60(59.2)	72(62.4)	89(54.4)
EDWALL	22(47.7)	28(50.6)	36(59.6)	34(53.5)	59(55.5)	69(58.0)	71(49.5)
ID000392	21(51.0)	29(56.2)	34(61.3)	36(59.6)	51(57.9)	62(61.0)	105(58.2)
PENAWAWA	22(48.4)	25(52.4)	33(60.4)	29(56.2)	56(57.2)	63(60.3)	101(55.1)
SPRITE	22(47.6)	23(50.6)	28(57.7)	32(54.7)	56(55.4)	60(58.9)	67(51.4)
TREASURE	18(48.6)	24(54.7)	29(58.8)	32(58.0)	51(55.1)	62(60.1)	94(53.4)
WADUAL	16(48.5)	23(53.5)	28(60.7)	32(57.5)	54(56.5)	61(60.7)	78(54.8)
WAKANZ	16(45.8)	24(50.7)	29(57.7)	30(54.5)	54(54.7)	74(61.2)	110(54.5)
WA007176	17(46.4)	26(52.2)	30(57.9)	35(56.4)	56(54.9)	70(59.5)	77(51.7)
WA007677	21(51.2)	28(54.3)	36(60.7)	35(57.1)	65(59.1)	70(62.7)	82(53.6)
WA007715	19(49.7)	26(53.8)	31(59.6)	33(56.8)	62(57.4)	67(60.4)	80(53.5)
BZ 684-23	23(46.9)	24(49.0)	33(57.8)	33(52.8)	64(56.9)	69(59.7)	99(54.8)
KLASIC*	26(51.1)	25(56.0)	29(62.2)	30(57.1)	56(58.9)	62(60.4)	83(53.6)
WUC00657**	22(46.9)	24(52.8)	29(60.0)	34(57.3)	54(56.3)	60(60.3)	78(52.5)
BUTTE 86	19(49.5)	26(56.5)	34(62.1)	30(56.0)	56(60.0)	59(61.0)	79(56.9)
EXPRESS	20(49.1)	29(54.0)	26(59.0)	30(55.8)	59(58.6)	56(59.3)	105(54.9)
ID000420	15(45.1)	25(53.5)	28(59.7)	27(56.4)	50(57.7)	53(58.6)	103(57.0)
ORS08510	17(50.0)	21(55.1)	30(61.4)	29(56.8)	54(57.9)	57(59.7)	94(55.3)
SPILLMAN	16(44.3)	25(50.7)	25(58.0)	36(55.1)	53(55.4)	54(56.8)	84(53.6)
WAMPUM	16(47.7)	24(51.4)	27(57.8)	33(56.8)	58(57.2)	60(58.7)	84(53.6)
WA007702	20(47.4)	25(53.0)	32(59.6)	31(53.8)	55(56.8)	59(57.5)	88(53.0)
WPB 926	21(49.6)	24(55.4)	31(61.0)	31(55.1)	55(59.1)	61(60.3)	96(56.1)
WPB 986-61	19(50.1)	27(54.2)	29(60.6)	32(57.8)	57(59.0)	58(57.8)	94(57.6)
MEAN	19(47.8)	25(52.9)	30(58.8)	32(55.7)	56(56.6)	62(59.2)	89(53.7)

NUMBERS IN (..) ARE TEST WEIGHTS
* HARD WHITE
** CLUB

TABLE 6.

1992 HARD SPRING VARIETIES (YIELD BU/AC)							
LOCATION:	LIND	FAIR-FIELD	REAR-DAN	MAY-VIEW	PULL-MAN	ROYAL SLOPE	AVE. YIELD
KLASIC	16	51	37	39	55	92	48.5
WAMPUM	13	50	46	28	53	98	48.0
LEN	13	45	34	38	56	98	47.6
STOA	14	51	45	43	55	103	52.0
BUTTE 86	14	48	42	41	51	91	48.0
SPILLMAN	14	50	44	44	56	107	52.5
WA007629	17	52	42	38	52	101	50.4
WA007675	14	48	44	48	54	97	50.9
WA007676	13	46	51	45	60	94	51.6
WA007702	15	49	45	37	55	102	50.5
WPB 906R	15	50	36	39	59	90	48.3
EXPRESS	15	43	43	42	64	101	51.3
NURSERY MEAN	14.5	48.7	42.5	40.2	55.8	98.0	X.. 50.0
LSD (.05) BU/AC	2.69	7.69	7.43	5.23	6.04	9.89	
C.V.	13.3	10.7	11.8	8.9	7.4	6.8	

TABLE 7.

1992 HARD SPRING VARIETIES (TEST WT. LB/BU)							
LOCATION:	LIND	FAIR-FIELD	REAR-DAN	MAY-VIEW	PULL-MAN	ROYAL SLOPE	AVE. T.W.
KLASIC	58.5	60.2	63.0	58.0	56.6	60.7	59.5
WAMPUM	56.9	59.4	62.5	55.8	57.8	60.0	58.7
LEN	58.6	60.6	63.3	58.4	58.6	60.0	59.9
STOA	57.9	59.9	63.7	58.5	57.9	60.4	59.7
BUTTE 86	59.2	61.4	64.3	59.5	57.8	60.9	60.5
SPILLMAN	56.6	58.0	62.4	55.9	54.6	59.7	57.9
WA007629	57.5	57.6	61.4	56.5	54.1	59.7	57.8
WA007675	57.7	57.9	62.3	57.3	56.6	59.4	58.5
WA007676	56.7	58.0	62.8	57.5	58.8	58.5	58.7
WA007702	57.2	58.4	63.2	56.5	56.4	59.7	58.6
WPB 906R	58.7	59.6	62.5	58.0	57.7	60.1	59.4
EXPRESS	58.4	58.8	63.4	58.6	58.7	60.7	59.8
NURSERY MEAN	57.8	59.1	62.9	57.5	57.1	60.0	X.. 59.2

TABLE 8.

1992 HARD SPRING VARIETIES (WHOLE GRAIN PROTEIN)							
LOCATION:	LIND	FAIR-FIELD	REAR-DAN	MAY-VIEW	PULL-MAN	ROYAL SLOPE	AVE. PROT.
KLASIC	14.7	13.3	14.0	12.8	13.3	13.6	13.6
WAMPUM	15.0	13.9	13.6	13.4	13.7	12.7	13.7
LEN	16.6	15.1	14.8	14.5	14.6	14.4	15.0
STOA	15.8	15.5	14.8	13.7	15.0	14.2	14.8
BUTTE 86	15.4	14.9	14.3	14.4	14.2	14.5	14.6
SPILLMAN	16.0	14.7	14.3	13.4	14.4	13.3	14.3
WA007629	14.9	13.7	13.2	12.2	13.7	12.0	13.3
WA007675	15.8	14.4	13.8	12.9	13.7	12.1	13.8
WA007676	15.0	14.6	13.6	12.4	12.4	11.7	13.3
WA007702	14.9	14.3	13.1	12.3	12.4	12.8	13.3
WPB 906R	16.2	14.6	14.0	14.0	14.1	14.6	14.6
EXPRESS	15.0	15.0	13.9	13.1	13.6	14.4	14.2
NURSERY MEAN	15.4	14.5	13.9	13.3	13.8	13.4	X.. 14.0

TABLE 9.

SUMMARY OF YIELDS AND TEST WEIGHTS						
	HIGH YLD. LOCATIONS		MODERATE YLD. LOCATIONS		LOW YLD. LOCATIONS	
	BU/AC	LB/BU	BU/AC	LB/BU	BU/AC	LB/BU
WA007176*	97(34)	60.4(34)	47(10)	57.8(10)	25(12)	57.7(12)
PENAWAWA	96(34)	61.0(34)	48(10)	59.2(10)	25(12)	58.6(12)
WAKANZ*	97(34)	61.0(34)	49(10)	58.6(10)	27(12)	58.6(12)
WA007677	98(19)	62.4(19)	52(11)	59.7(11)	24 (6)	59.6 (6)
PENAWAWA	88(19)	60.7(19)	47(11)	57.8(11)	22 (6)	57.8 (6)
WUC00657	84 (4)	59.1 (4)	47 (6)	60.2 (6)	22 (2)	58.2 (2)
PENAWAWA	94 (4)	59.7 (4)	52 (6)	60.0 (6)	23 (2)	58.8 (2)
WA007715	91 (7)	60.9 (7)	50 (6)	60.8 (6)	22 (5)	58.8 (5)
WADUAL	91 (7)	61.2 (7)	49 (6)	61.0 (6)	22 (5)	60.0 (5)

( ) = SITE YEARS
* = HESSIAN FLY RESISTANT

TABLE 10.

1991 QUALITY DATA											
VARIETY	TWT	WPROT	FYELD	MSCOR	FPROT	CODI	TGS	CAVOL	SCSCOR	LVOL	BCRGR
WUC00657	60.9	12.0	70.9	78.8	--	8.67	--	1357	76	--	--
PENAWAWA*	60.8	12.0	70.5	76.9	--	8.56	--	1335	73	--	--
N.st.dev.	.73	.83	1.29	3.03	--	.197	--	44.8	2.13	--	--
WA007176	61.0	11.3	--	82.6	9.1	9.55+	9	1410+	74	--	--
WA007677	63.6+	10.3+	--	86.4+	8.2+	9.15	7	1450+2	81	--	--
PENAWAWA*	61.3	12.2	--	77.8	9.9	8.81	7	1355	74	--	--
N.st.dev.	1.42	.46	--	2.65	.40	.217	.7	28.1	3.59	--	--
WA007176	61.0	11.5	71.4	82.8	9.4	8.61	7	1325-	72	--	--
WA007677	63.1+	9.8+	72.6+	86.2+	8.0	8.89	7	1365	75	--	--
PENAWAWA*	62.2	11.5	70.1	78.0	9.5	8.73	7	1405	78	--	--
N.st.dev.	1.15	.64	72.6	3.06	.57	.180	1.1	38.4	2.88	--	--
WA007715	60.4	13.3	70.4	88.6	11.3	8.88	6.3	--	--	971	3.4
WADUAL*	60.8	12.8	70.8	88.8	11.1	8.89	6.9	--	--	943	4.0
N.st.dev.	1.19	1.28	1.34	1.90	1.10	.224	1.1	--	--	83.2	1.3

* = standard

TWT(test weight)
WPROT(wheat protein)
FYELD(flour yield)
MSCOR(milling score)
FPROT(flour protein)
CODI(cookie diameter)
TGS(cookie top grain score)
CAVOL(Japanese sponge cake volume)
SCSOR(sponge cake score)
LVOL(bread volume)
BCRGR(bread crumb grain rating)

TABLE 11.

VARIETY	LB/AC	YIELD	TEST WT.	PROTEIN
PENAWAWA	50	76.9	58.9	10.23
"	60	77.3	58.6	10.35
"	70	75.7	58.1	10.61
"	80	78.1	58.5	10.20
"	90	76.8	58.7	10.16
WA007677	50	84.0	62.6	9.88
"	60	83.1	62.6	9.73
"	70	81.8	62.4	10.03
"	80	83.2	62.7	9.93
"	90	80.3	62.3	10.05

Replications : 6
Previous crop : Oats 1991
Inches of moisture (top 3 ft.) : 5.37 inches
Moisture received after planting : 4.42 inches
Fertilizer in top 3 feet : 43# N, 19# P, 5# S
Base fertilizer (applied) : 136# N, 4# P, 3# S
Starter fertilizer (applied) : 10# N, 13# P, 10# S

TABLE 12.

1992 ADVANCED HARD WHITE TRIAL #69									
	YIELD BU/AC			TEST WT. LB/BU			PROTEIN		
LOC.	PL	LN	RS	PL	LN	RS	PL	LN	RS
WA7749	63	13	83	60.2	56.7	60.2	12.2	16.7	14.2
805 S10	65	16	91	58.5	57.4	59.7	11.3	15.8	13.5
805 S11	61	14	99	60.8	56.5	59.2	11.0	16.8	13.4
KLASIC	58	15	91	58.4	57.9	60.2	11.1	15.7	13.6
WPB906R	64	17	83	60.3	57.5	59.9	12.3	16.6	14.6
LSD (.05)	5.7	3.1	7.5						

TABLE 13.

1992 ADVANCED HARD RED TRIAL #86						
	YIELD BU/AC		TEST WT. LB/BU		PROTEIN	
LOCATION:	PUL	RS	PUL	RS	PUL	RS
PNG00801 S5	64	93	59.6	63.1	13.0	13.8
PNG00802 S7	63	104	60.4	62.8	11.9	13.9
PNG00806 S1	64	94	60.0	61.8	12.1	14.0
PNG00806 S5	57	99	60.6	63.1	12.0	13.8
PNG00806 S26	66	91	59.9	61.8	12.3	14.7
SPILLMAN	69	96	58.3	61.6	12.0	13.3
WPB00906R	66	85	60.2	62.1	11.9	14.0
LSD (.05)	5.1	8.0				

1992 SPRING BARLEY ON-FARM VARIETY TESTING RESULTS

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The 1992 spring barley on-farm variety testing program continued with what started out as a PhD project of Jerry Johnson. Jerry Johnson, working with Steve Ullrich and Baird Miller, conducted a 2 year research project which relied upon large unreplicated drill strips of spring barley varieties. These drill strips were seeded, managed and harvested by the farmer cooperators working with Jerry Johnson. Growers in eastern Washington were impressed with the results that were generated from these on-farm variety drill strips. As a result of the popularity and interest that this research program generated, barley producers wanted to continue the spring barley drill strip testing program.

In January 1992, interested growers met with the Washington Barley Commission and WSU Crop and Soil Science faculty to design a cost effective way to continue the spring barley on-farm variety testing program. Our objective was to decentralize the testing program down to the county level to reduce the overhead expenses. We developed the following organization to carry the program forward. Mary Palmer-Sullivan, as a Washington Barley Commission representative, was responsible for the overall coordination; Baird Miller and Steve Ullrich provided the technical support, grain sample analysis, data analysis and data summary; Chuck Goemmer with Washington State Crop Improvement Association acquired the certified seed and arranged for the seed delivery to the central location at the Ritzville Warehouse; Dave Gordon and Gary Reilly at the Ritzville Warehouse provided the storage for distributing the seed to each county; and Great Western Malting Company provided financial support.

Table 1 lists all of the participants that were the key to the success of the program. The certified seed was donated by seven seed dealers. Eleven counties identified a county coordinator that was responsible for finding farmer cooperators, acquiring the seed from Ritzville, and collecting the yield, cropping history data and grain samples from each testing site. Thirty one farmers established single replicate drill strips as participants in the program.

Five standard varieties were evaluated in all of the testing sites: Steptoe, Crest, Harrington, Camelot and Russell. Each county and farmer had the option of adding varieties. Twelve additional varieties were tested at one location or more. Great Western Malting Company provided malting varieties for interested participants.

Each farmer was asked to establish the drill strips so the strips traversed (or ran perpendicular) to the natural variability in the field. This way all of the varieties would uniformally include the variability in the field and approximate the average conditions of a particular field. It was also critical that the placement of the 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 bottomland area. The drill strips were typically wider than the combine header width and ran from 500 to 2500 feet in length. The drill strips were harvested with the farmer's combine and weighed individually by taking the grain truck to a local scale. In some cases the county had weigh wagons or truck scales to determine the yields at the testing site.

The yield and test weight results from each individual farmer is shown in table 2. A few of the testing sites are not reported because of inadvertent problems with the testing location. **It is critical to understand that each testing location represent only one replication. You should not make comparisons among varieties or make a decision about variety performance based on one replication.** The power in detecting variety differences is achieved when you combine the performance data from several locations with similar growing conditions to your own. For more details about which locations are similar to your location contact your county coordinator.

A summary of the 1992 statewide yield results is presented in Figure 1 and Table 3. Figure 1 is designed to show the performance of four spring barley varieties in comparison to Steptoe. Most farmers have very good knowledge about how well Steptoe yields under their particular growing conditions. If you choose what your typical Steptoe yield is on the lower axis, then you can determine how the other varieties would have yielded in comparison. The other valuable way to use this graph is to see where the regression lines for each variety crosses over another. For example, Camelot crosses over and begins to yield more than Harrington at 2200 lbs/acre and more than Steptoe at 1200 lbs/acre. Therefore if you have a field that typically yields 2000 lbs/acre you might consider growing Camelot instead of Steptoe.

Table 3 presents the yield data categorized by production zone. This table is designed to be used by selecting a yield range that you expect to achieve and then compare the variety yield performance within that production zone yield range. These results suggest that Steptoe, Camelot and Russell yielded similarly in a production zone of less than 1500 lbs/acre. In the production zone above 3500 lbs/acre Steptoe, Crest and Harrington yielded similarly. Finally the last three years of the on-farm variety testing yield results are shown in table 4.

The spring barley on-farm variety testing program will continue in the 1993 growing season with a few improvements. The statewide leadership will remain the same with Mary Palmer-Sullivan, Baird Miller, Steve Ullrich, and Chuck Geommer. This year Nu Chem has agreed to provide soil testing as a service to each of the participants. Great Western Malting Company will provide rain gauges for each participant in addition to the financial support contributed to WSU. The same varieties, Steptoe, Crest, Harrington, Camelot and Russell, will be grown at all location and each county or grower can test additional varieties. Great Western Malting Company will make the following malting barleys available for testing: AB1202, MT140523, Colter and Triumph.

For anyone interested in participating in the testing program please contact your county coordinator or Mary Palmer-Sullivan at the Barley Commission (456-4400).

Table 1. 1992 participants in the spring barley on-farm variety testing program.

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, Spectrum Crop Development Corp.
HARRINGTON:	Dan McKay, McKay Seed Company Fred Fleming, Reardan Seed Company
RUSSELL:	Ron Turner, Wolfkill Feed and Fertilizer
STEPTOE:	Dana Herron, Kayson Seed Company
CREST:	Jackie Tee, Fairfield Grain Growers, Inc. Kevin Anderson, Great Western Malting Company

Storage and Distribution of Seed:

Dave Gordon and Gary Reilly, Ritzville Warehouse

County Coordinators:

Adams:	Curtis Hennings
Asotin:	Gary Delaney
Columbia:	Carl Nordheim
Douglas:	Jim Kropf
Garfield:	Dave Bragg, David Ruark
Kittitas:	Tom Hoffman
Klickitat:	John Fouts
Lincoln:	Fred Fleming
Spokane/ Stevens:	Paul Peterson
Whitman:	Dan Curtis

Farmer Cooperators:

Adams:	Curtis Hennings, Eric Maier
Asotin:	Frank Johnson
Columbia:	George Wood, Ervin Ely, Juris Farms
Douglas:	Mark Thompsen
Garfield:	David Ruark, Scott Seed Farm, Roger and Mary Dye, Tom Herres
Kittitas:	Don Rhinehart, Pat Clerf
Klickitat:	Tex and Neal Brown, Mains Brothers Farm, Dean and Dale Bowdish
Lincoln:	Tom Schultz, Dale Dietrich
Spokane/ Stevens:	Dusty and Drew Eckhart, Lyle Wiltse, Maurice Piersol, David Betz, Gerald Scheele, Cliff Carstens
Whitman:	Ron and Dick Wilbourn, Colin Cook, Roy Dube, Fred Widman, Nick Henning, Mark Hall, Norm Druffel and Son

Table 2. 1992 Spring barley on-farm variety testing results.

COUNTY	COOPERATOR	Yield (lbs/acre)					Test Weight (lbs/bu)				
		STEPTOE	CAMELOT	HARRINGTON	RUSSELL	CREST	STEPTOE	CAMELOT	HARRINGTON	RUSSELL	CREST
Adams	1	1014	956	666	985	637	37.8	42.2	36.7	39.2	37.2
Adams	2	832	986	314	753	834	42.6	44.8	45.9	45.7	45.6
Columbia	1	3202	2510	2291	2444	2650	40.8	46.4	44.4	43.3	42.7
Columbia	2	2809	2349	2356	2723	2712	36.6	41.9	39.4	44.3	44.5
Columbia	3	2041	1926	2124	1550	2098	46.3	52.8	48.6	46.8	49.8
Douglas	1	1706	1627	1647	1529	1490	46.3	50.8	52.3	48.5	50.5
Garfield	1	1815	1640	1466	1606	1291	42.9	51.2	46.3	48.4	45.3
Garfield	2	2020	1822	1604	1802	1742	38.4	46.3	44.8	41.0	43.3
Garfield	3	2821	2399	2248	2572	2043	41.5	45.3	45.0	47.0	43.1
Garfield	4	1913	1891	1630	1913	1695	38.1	45.2	44.9	40.1	43.5
Kittitas	1	4235	4442	4978	4200	4527	48.0	53.8	52.2	48.2	54.8
Klickitat	1	984	882	658	1060	704	41.4	48.7	49.6	46.1	48.9
Klickitat	2	1298	1064	698	1114	856	47.7	50.1	50.4	51.0	49.5
Lincoln	1	1510	1699	1419	1851	1717	46.9	49.9	50.0	47.5	50.0
Lincoln	2	1519	1543	1226	1469	1466	48.1	48.5	49.0	47.4	48.3
Lincoln	3	1790	1754	1096	1646	1353	46.7	53.1	49.5	48.6	50.3
Spokane	1	772	1032	998	896	968	39.9	46.0	45.1	42.2	45.1
Spokane	2	1379	1291	835	1272	1010	46.4	50.8	51.5	50.8	49.6
Spokane	3	1689	1703	2027	1770	2054	46.4	50.9	49.6	48.7	49.3
Spokane	4	3068	2876	2859	2754	2541	42.3	47.4	46.0	45.8	47.9
Spokane	5	1630	1985	2409	1290	2093	50.4	54.4	53.0	54.0	52.1
Whitman	1	2648	2467	2315	2189	2035	44.6	48.1	41.4	39.4	47.3
Whitman	2	5942	4971	5257	4914	5714	45.8	53.3	49.5	48.5	53.3
Whitman	3	5481	4642	5012	4556	5185	46.2	50.4	48.3	45.1	49.6
Whitman	4	3458	3238	3040	3073	3139	48.6	52.8	51.9	51.7	54.8
Whitman	5	3567	2485	3143	3176	3274	41.1	48.6	48.4	45.8	49.9

Figure 1. 1992 spring barley on-farm variety testing yields.

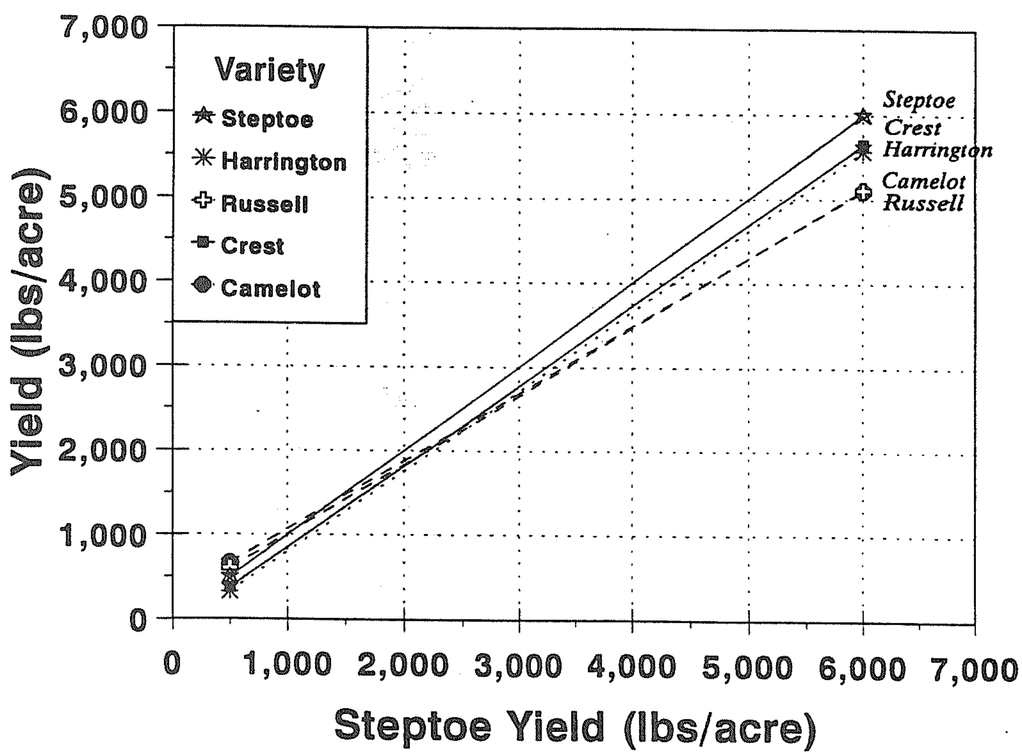

Table 3. 1992 spring barley on-farm variety testing yield performance summarized among production zones.

Variety	Production Zone (lbs/acre) <1500	1500-2500	2500-3500	>3500
	lbs/acre			
Steptoe	1114	1962	3221	5219
Camelot	1108	1901	2692	4685
Russell	1078	1793	2834	4557
Crest	928	1793	2863	5142
Harrington	771	1817	2783	5082
Average	1000	1851	2869	4937

Table 4. Three year spring barley on-farm variety testing yield performance summary.

Variety	Years (No. of Sites) 1992 (27)	1991 (42)	1990 (40)	1991-92 (69)	1990-92 (109)
	lbs/acre				
Steptoe	2400	3140	3095	2850	2940
Camelot	2175	3030	2845	2705	2755
Russell	2185	.	.	.	.
Crest	2275	2985	.	2710	.
Harrington	2250	2930	2785	2665	2710
Average	2257	3021	2908	2733	2802

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 crop 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 fern leaf structure that is typical of most chickpea cultivars currently in 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 weight 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.

LOCATING GENES ASSOCIATED WITH PREHARVEST SPROUTING IN WHEAT USING MOLECULAR MARKERS AND GENETIC MAPS

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Most soft white wheat cultivars are highly susceptible to preharvest sprouting of the grain which can cause major economic loss for wheat growers. Resistance to pre-harvest sprouting seems to be controlled by many genes. This and a strong environmental effect have limited the progress of conventional breeding programs for improvement of this trait. The combination of an important quantitative trait with lack of dramatic improvement through classical breeding techniques makes this an ideal character with which to try new approaches for trait improvement.

Consequently, the molecular tagging or identification of genes associated with this trait was used to aid in developing breeding strategies designed for its rapid improvement. Current evidence indicates that at least partial control of preharvest sprouting originates in the seed embryo and is controlled by abscisic acid (ABA) or other endogenous inhibitors. Using genetic stocks that were missing all or part of single chromosome pairs or in which alien chromosomes were substituted or added, we determined the chromosomal location in wheat and *Lophopyrum elongatum* (wheatgrass) of eight ABA responsive clones associated with seed dormancy. Mapping clones in this way located them to chromosome groups consisting of the three homoeologous chromosome pairs (e.g.. group 5 includes 5A, 5B and 5D) from the wheat genomes as well as to the long or short arms (for example group 5L or group 5S). Clones isolated from wheat hybridized to wheat and *L. elongatum* chromosome groups as follows: pMA1906, group 4; pMA1949, group 3L; pMA1951, group 5S; pMA1959, group 1L; pMA2005, group 1S; and PKABA1, group 2L. Clone pBS128, isolated from *Bromus secalinus* (cheatgrass), hybridized to wheat chromosome group 2S. The cDNA clone pcvp23 (from maize), which is required for ABA-responsiveness and the prevention of premature germination in maize embryos hybridized to chromosome groups 3L and 7 in *L. elongatum*. Four of the clones mapped previously by other researchers in barley, pMA1906, pMA1949, pMA1951 and pMA1959 were found to be on the corresponding chromosome groups in wheat.

Now that these clones have been mapped to chromosomes, the next step in fully utilizing them is the study of linkages to traits and/or other markers on the wheat map. This work would not only help to fill in the wheat genetic map but also to establish additional markers which are specific to ABA response and presumably, the problem of pre-harvest sprouting. In the hands of the breeder these markers are a powerful tool in screening for desirable genotypes and will ultimately lead to the rapid improvement of the trait.

EARLY GENERATION SELECTION FOR END-USE QUALITY USING MARKERS

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Selecting for high end-use quality in wheat can be done by analyzing a single seed for typical patterns of high-molecular weight endosperm protein. This protein combines with other classes of storage proteins to form the gluten in bread, cookies, noodles and other wheat products. This method is highly effective for early selection because it minimizes the loss of high quality genes and saves time in the breeding process by identifying acceptable lines early. It has been difficult to identify end-use quality lines in the hard white winter and club varieties used in the Pacific Northwest due to genetic dilution in the new and advanced lines, and the strong environmental effects on quality. Development of hard white winter wheats and maintenance of good quality in the club wheats is high priority in our breeding programs. These are difficult tasks because of the introgression of seed color and resistance genes into adapted cultivars. Protein analysis of the seed is a powerful tool for the selection of these lines because it allows the breeder to select for the actual genes affecting quality not just the quality trait.

Currently, 800 lines of hard white winter wheats and club types from Dr.'s Allan, Konzak, Donaldson, Zwer, Line and Peterson are being scored for their high-molecular weight proteins with regard to end-use quality. This information will be provided to the breeders to maximize efficiency in their breeding programs.

SCREENING FOR NEW GENES FROM WILD WHEATS

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In recent years considerable attention has been given to the exploitation of potentially useful alien genetic variation existing in species related to common wheat. Attempts to utilize this desirable variation have dealt mainly with the transfer of disease resistance from the genus *Aegilops*. The goat grasses, *Aegilops squarrosa*, have been reported to carry genes for resistance to leaf rust, stripe rust, powdery mildew, leaf blotch, glume blotch, eye spot, Karnal bunt, Hessian fly, greenbug, and curl spot. Another wild gene pool for disease resistance is *Haynaldia, Dassypyrum villosa*. This genus also seems to be a very important source of genes, although it has not been studied as well as *Aegilops*.

We have 290 accessions of *Aegilops* and 56 accessions of *Haynaldia* growing in our greenhouses this year. These lines are being observed to determine differences between wild species and wheat which can be used as genetic markers. We have identified 50 very early and 60 very late *Aegilops* lines, and 30 early and 26 late *Haynaldia* lines. Priority will be given to early plants as gene sources for our Northwest wheats. In addition, purple coleoptile, non-waxy foliage and brown glumes which are convenient markers for *Aegilops* lines have been identified in some accessions.

Aegilops and *Haynaldia* have been crossed to wheat to get wild and domestic wheat hybrids. Due to the difficulty in crossing wheat and these wild species, plants will be regenerated from aborted seeds when no viable seed is developed. All of the lines will be screened for stripe rust, eye spot and cephalosporium stripe resistance. Once resistant lines are determined the genes will be mapped and tagged with molecular markers, thus facilitating their transfer into wheat. The transfer will be done using the latest molecular techniques combined with classical genetics.

BREEDING FOR RESISTANCE TO ASCOCHYTA BLIGHT OF CHICKPEA

W. J. Kaiser, F. J. Muehlbauer, R. W. Short, J. L. Coker,
R. M. Hannan, and B. H. Hellier

Ascochyta blight of chickpea (*Cicer arietinum*) caused by *Ascochyta rabiei* was first observed in the USA at Pullman, Washington in 1983. By 1984, Ascochyta blight was found in over 50% of the commercial fields. In 1986, *Didmella reaiei* (syn. *Mycosphaerella rabiei)*, the teleomorph (sexual or perfect stage) of *A. rabiei* was discovered on infested chickpea debris that had overwintered on the soil surface in a field near Genesee, Idaho. The fungus is heterothallic. The teleomorph plays an important role in the epidemiology of the disease, particularly in the long distance spread of ascospores as primary inoculum. In 1987, over 4,500 hectares of 'UC-5' and 'Surutato 77' chickpeas in the Palouse region were devastated by Ascochyta blight resulting in drastically reduced yields and poor seed quality. Chickpea germplasm lines of kabuli and desi types from various sources were screened for resistance to pathotypes of the fungus that occur in the Palouse region. Resistant germplasm sources were identified; however, the resistance was associated with late maturity and medium seed size. The breeding program has incorporated blight resistance into large-seeded kabuli cultivars which are now being increased for release to producers. An integrated disease control program is needed in areas where Ascochyta blight occurs if chickpeas are to remain a viable crop in the US Pacific Northwest. The program will need to include the use of clean seed, seed treatment fungicides, crop rotation, management of infested chickpea crop debris, and resistant cultivars.

As a result of intensive breeding over the past 4 years, two selections, CA188220 and CA188359, were chosen for increase and release to growers under the proposed names 'Sanford' and 'Dwelley'. These two new varieties have good resistance to Ascochyta blight and have excellent seed quality traits.

NEW GENES FOR CEPHALOSPORIUM STRIPE RESISTANCE

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Department of Crop and Soil Sciences, WSU, Pullman, WA 99164-6420

Cephalosporium stripe of wheat is caused by a soil-borne vascular fungus, *Cephalosporium gramineum*, which can cause yield reduction in the Pacific Northwest and many areas of the world. Although it can be partially controlled by cultivation practices, the use of resistance cultivars would be the most economic and efficient approach to disease control.

Research on screening for resistance to the disease has shown that there are very limited sources of resistance in common wheat. However one of the wild species of wheat, *Agropyron elongatum*, showed high resistance to the disease, indicating that it carries resistance genes for cephalosporium stripe in its genome. In order to determine which chromosome(s) of *Agropyron elongatum* carries the resistance genes, 20 of the 21 possible disomic substitution lines of *A. elongatum* chromosomes for wheat homoeologues were utilized. Four growth chamber experiments were carried out in 1992 and 1993. Analyses of the first three experiments showed that several new sources of resistance genes have been identified. The substitution lines containing chromosome 2E nearly always showed significantly higher resistance than wheat and were superior to all other lines in all four experiments, indicating chromosome 2E of *A. elongatum* carries the major genes conferring resistance to *C. gramineum*. Some of the substitution lines containing chromosome 3E also showed significantly higher resistance than wheat and were superior to all other lines except chromosome 2E lines, indicating chromosome 3E of *A. elongatum* also carries genes for resistance to *C. gramineum*. Almost all of the substitution lines containing chromosomes 1E, 4E, 5E, 6E and 7E also showed higher resistance than wheat, but to a much lesser degree compared with DS2E and DS3E lines, indicating chromosomes 1E, 4E, 5E, 6E and 7E of *A. elongatum* probably carry minor genes for resistance to *C. gramineum*.

We have found major genes for resistance to *C. gramineum*. The next step will be to transfer them into adapted wheat cultivars by inducing homoeologous pairing. This will facilitate the development of high yielding adapted wheat cultivars resistant to *C. gramineum*, thus preventing loss of yield due to Cephalosporium stripe. Long term goals involve "stock-piling" of new resistance genes for all of the traditionally difficult to breed for diseases.

ON-FARM TESTING: A POWERFUL NEW TOOL FOR GROWERS

Stewart Wuest, WSU/UI STEEP II On-Farm Testing Coordinator
Roger Veseth, WSU/UI Extension Conservation Tillage Specialist
Baird Miller, WSU Extension Agronomist
Stephen Guy, UI Extension Crop Management Specialist

Each year growers make field comparisons of production options seeking improved production efficiency or resource conservation. This process of grower innovation and field evaluation is not new...in fact, it is as old as agriculture itself. What is "new" is the development of a more scientific approach to improve the accuracy of "on-farm testing" (OFT).

Substantial investment costs or production returns can hinge on the results of these field comparisons, thus growers need accurate testing methods in order to make reliable management choices. A tri-state STEEP II on-farm testing (OFT) project is underway to help growers accurately evaluate new technologies through field trials on their own farms.

STEEP II On-Farm Testing Project

The OFT project is part of the STEEP II (Solutions to Environmental and Economic Problems) program, an interdisciplinary research and educational effort in Idaho, Oregon and Washington to develop profitable farming systems for control of soil erosion and water quality protection. The 5-year STEEP II program, beginning in 1991, is the second phase of the original tri-state STEEP program conducted from 1975 through 1990.

The OFT project leaders include the above authors in Idaho and Washington, as well as Don Wysocki, OSU Extension Soil Scientist at Pendleton, and Russ Karow, OSU Extension Agronomist at Corvallis. At the local level, more than 13 County Extension Agricultural Agents are involved in northern Idaho, northeast Oregon and eastern Washington. Representatives from the USDA Soil Conservation Service and Agricultural Research Service, Conservation Districts, growers organizations and private industry are directly involved in many of the field trials.

The goal of the OFT project is to provide growers with the knowledge and skills they need to conduct accurate field tests of alternative crop production practices on their own farms with their own equipment. The objectives are four-fold: develop practical, accurate OFT methodologies; develop educational materials and conduct educational programs on OFT; establish local grower OFT networks; and conduct OFT trials of production/conservation practices for soil erosion control and water quality protection. The following are some brief highlights of some new developments under each objective.

OFT Methodologies

The development of OFT methodologies for this region has been a priority objective early in this 3 to 5 year project. Soil properties and production limitations can vary dramatically within and between fields in Northwest cropland. The effects of this variability on crop yield and other production considerations can be obvious at times, but is usually difficult to notice visually. Consequently, when growers conduct field evaluations of new production options, they need methods that will not mislead them into thinking a new practice caused a difference which was actually caused by natural field variability.

"Traditional" approaches to comparing a new practice with current production practices have often included 1) splitting fields, 2) making a few passes around the field using the new practice, 3) comparing a whole field with a nearby field, or 4) comparing the yield of a field using the new practice with yields from the same field in previous years. Although growers can see how the new practice "looks" with these approaches, they usually can not be sure if it results in different agronomic performance. Natural field and year-to-year variability can overshadow or exaggerate the effects of the practice itself.

As part of the STEEP II OFT project, we harvested eight side-by-side combine strips in at least two wheat or barley fields in each of the three PNW states in 1991 and 1992 to evaluate yield variability within fields. We found that the yields of side-by-side combine strip commonly varied from 1 to 9 bushels per acre due to natural variations in the field.

To help separate natural field variability from differences caused by the practices being evaluated, on-farm tests should be set up in a replicated experimental design, which means having side-by-side comparisons in three or more locations in the field. In addition to comparing yields, replicated test designs are critical for accurately evaluating practices for soil water storage, soil erosion control, pest control, response to fertilizer rates and many other management considerations.

We have just finished two years of intensive analysis of on-farm test plots, and our results are very encouraging. Replicated side-by-side harvest strips 750 feet long will produce very accurate results in most fields. In more uniform fields, plots as short as 250 feet may work also. The key to getting accurate results is replication. Four sets of side-by-side comparisons in a field is by far the best way to ensure accurate results. More replications in a carefully designed test will allow detection of a difference between practices as small as four bushels or less. Certain design principles, such as randomizing the assignment of practices to plots, help avoid mistaken conclusions.

OFT Educational Materials and Programs

An important focus of the educational objective is on developing educational materials for conducting on-farm tests, collecting data and summarizing results. Several new publications on OFT are available to help growers in their OFT efforts:

On-Farm Testing: A Grower's Guide, WSU Cooperative Extension Bulletin 1706, available for $1.00 (payable to Cooperative Extension Publications) from the Bulletin Office, Cooperative Extension, Cooperative Publications Building, WSU, Pullman, WA 99164-5912 (509-335-2857) or from County Extension offices in Washington.

How to Do an On-Farm Test, a detailed article in the December 1992 PNW STEEP II Extension Conservation Farming Update, contact Stewart Wuest (509 335-3491) or Roger Veseth (208-885-6386).

1992 Pacific Northwest On-Farm Test Results (1st annual summary of the STEEP II OFT projects), contact Stewart Wuest (509-335-3491).

Numerous workshops have been conducted around the region to teach OFT methodologies and design, and to disseminate OFT results. Field tours of the OFT sites have also been conducted.

Local Grower OFT Networks

The third project objective is to help establish grower-managed OFT groups in the three states to conduct OFT and share results. Numerous small OFT groups are now functioning at the local level across the region. They have often been facilitated by County Extension Agents who assist in establishing OFT trials, provide technical advice, and help analyze results from the OFT trials. The results of the OFT trials are summarized in annual PNW publication listed above to increase grower networking and sharing of experiences on a regional basis.

Local grower groups are being encouraged because the economic and environmental challenges which face agriculture today need to be met with timely and successful changes in how we farm. Working together can drastically reduce the number of years it will take to develop and implement the farming methods successful operators need for the future.

Conducting Local OFT Trials

The fourth project objective is to assist growers in using OFT to evaluate conservation farming practices which reduce soil erosion and/or protect water quality. During the 1992 crop year, the STEEP II OFT project helped growers with 23 on-farm tests in Idaho, Oregon and Washington. The following are a few examples of OFT topics and preliminary results.

A comparison of **seedbed preparation for winter wheat** after lentils showed that the reduced cultivation left adequate surface residue to meet conservation compliance guidelines, but did not reduce wheat yields. (Culdesac, ID, 19" Mean Annual Precipitation (MAP))

Three farmers compared their recommended **herbicide rates** with a significantly reduced rate on winter wheat, and obtained good weed control with both. Yields were variable, but statistical guidelines indicate that overall, yields were not different. More testing is necessary. (Culdesac, Reubens, and Gifford, ID, 20-23" MAP)

Conventional cultivation and planting, Haybuster no-till, and direct-seed chisel **drills were compared** for seeding winter wheat on lentil ground. Yields on the chisel-drilled plots were 10 bushels lower than the other two, but it is believed that this was not caused by the drill. The chisel-drill was used two days after the other drills, and the surface soil was frozen. The cause of the yield reduction is not known, and the comparison is being repeated. (Fairfield, WA, 23" MAP)

Chiseling to roughen a hard seedbed before no-till planting winter wheat after lentils reduced erosion without any effect on yield. (Fairfield, WA, 23" MAP)

Underseeding legumes in the spring barley of a winter wheat - spring barley - forage/green manure rotation did not affect barley yields. Several legumes are being compared for forage yield and green manure value. (Harvard, ID, 26" MAP)

Chiseling standing stubble in the fall increased the amount of soil moisture measured in the spring. (Davenport, WA, 15" MAP)

Several growers south and west of Spokane tested a **subsoiler/reservoir tillage** device called the Dammer Diker on winter wheat after planting. Where the device was not run strictly on the contour, water from outside the treated area was collected and transported through the chisel slot. Because of a lack of precipitation, we did not get a chance to test for better water infiltration. Yield reduction due to plant disturbance by the subsoiling operation was slight, if any. (Reardan, Creston, Davenport, Latah, WA, 15-21" MAP)

Tests of **boron fertilizer for spring canola** showed no response, but moisture was probably the limiting factor. (Pomeroy and Dayton WA, Craigmont ID, 22" MAP)

Biosolids (municipal sewage sludge) used in place of anhydrous ammonia produced equal wheat yields and test weights. No difference in heavy metal content of the grain was found. (Mansfield, WA, 10" MAP)

Tests continue in 1993 on most of the above topics, and many additional tests have been started including:

Effects of **subsoiling** on water retention and yield. **Nitrogen rates** for winter wheat. Comparison of **starter fertilizers**. Comparison of **foliar fertilizers**. **Gypsum** on salt affected soils. **Rotation effects** of canola. Methods of **taking out bluegrass**.

Conclusion

As farmers learn how to accurately compare farming practices, their results can become as important to the advancement of agriculture as small plot experiments at research centers. OFT benefits farmers directly, provides feedback to research and extension personnel, and enhances the public image of agriculture by addressing environmentally-oriented problems.

Most county agricultural agents can help in setting up and analyzing your on-farm tests. You can also contact Stewart Wuest (509-335-3491) or the other projects leaders for more information. We also encourage growers to contact their conservation district and other agricultural support groups and agencies to consider working together in answering questions on production practices through on-farm testing.

ALTERNATIVE AGRICULTURAL POLICY SCENARIOS: ENVIRONMENTAL AND ECONOMIC TRADE-OFFS BY POLICY

Kathleen M. Painter and Douglas L. Young

How should national agricultural policy be structured in order to encourage environmentally responsible farming practices? The performance of the current policy, the 1990 Farm Bill, is compared to four new policies in this study. The policies are applied to representative farms in two contrasting agricultural production areas, the dryland grains Palouse region of southeastern Washington and the North Carolina Coastal Plain. It is important for Pacific Northwest wheat growers to compare how policy impacts may differ regionally in order to identify policies which are favorable to their operations but which still have a chance for national support. Farm-level impacts are analyzed for farm manager returns, landlord returns, taxpayer cost, on-site and off-site soil erosion damage, and agrichemical leaching.

The performance of alternative or low-input crop choices were examined for each region. In the Washington-Idaho Palouse, winter wheat is the main cash crop. Conventional systems include a two-year rotation with dry peas or a three-year rotation with barley and dry peas. Because the Palouse is subject to severe soil erosion, alternative cropping systems emphasize saving soil. Bluegrass seed and canola rotations conserve soil relative to the conventional winter wheat systems.

In the North Carolina Coastal Plain, tobacco is the main cash crop. This area has long growing seasons, ample rainfall, level farmland, and sandy soils. A variety of other crops are raised, including corn, soybeans, small grains, wheat, cotton, peanuts and vegetables. Agrichemical leaching potential is a severe problem in this area. Alternative cropping systems include nitrogen-fixing winter cover crops followed by low-input corn. Predicted leaching of nitrate-nitrogen beyond 5 meters decreased by 58% for the low-input systems.

Methods

This study examines the impact of alternative policies when farm managers maximize profits. Computerized farm planning models were constructed for the current Farm Bill and five alternatives as described below.

1990 FARM BILL: Farmers receive deficiency payments for government farm program commodities. In return, they must "set-aside" a certain portion of their historical base acreage for these commodities. 1990 Farm Bill provisions require farmers to forgo deficiency payments on an additional 15% of their crop acreage bases ("flex acres"). They may plant program crops, oilseeds, and specified nonprogram crops on "flex acres" while preserving base and yield history. In addition, participating farmers must comply with legislated conservation provisions protecting fragile land and wetlands.

40% FLEX: In this scenario, the "flex acres" in the 1990 Farm Bill are increased to 40%. All other provisions remain identical.

ADMIN: The Administration's original proposal for the 1990 Farm Bill provided for a whole farm base called the Normal Crop Acreage (NCA), which is the sum of the farms' program crop acreage bases for food and feed grains and cotton, plus historical oilseed plantings. Deficiency payments are based on historical program crop bases and yields. Basically, this represents 100% flexibility on base acreage plantings excluding set-aside requirements which remain in effect.

RECUP: Farmers raise and sell what they wish for prevailing market prices, and collect subsidies based on specified environmental criteria. Subsidies were based on estimated soil conservation in the Palouse and on estimated leaching reductions in the Coastal Plain.

DECUP: Farmers raise and sell what they wish for prevailing market prices, and receive annual lump sum payments from the government equal to their historical levels, regardless of crop choice and farming practices.

NO PROG: In this scenario, the feed grain, food grain, and cotton programs are terminated unilaterally as in RECUP and DECUP. But farmers would receive no deficiency payments or lump sum payments for program crop production.

Quota programs (dairy, peanuts, tobacco, etc.) would be continued in all scenarios.

The local adaptation of the Universal Soil Loss Equation (USLE) is used to determine erosion by cropping system for the Washington-Idaho Palouse. Damage estimates include both on-site and off-site soil erosion. On-site damage refers to yield declines attributable to decreased soil fertility as topsoil erodes. Estimates of on-site soil erosion damage are calculated using crop-specific response functions which measure the effect of topsoil loss on productivity. In the highly erosive Palouse region, off-site damage includes siltation in roadside ditches; increased flooding problems attributed to siltation; costs of dredging hydroelectric reservoirs and navigation channels; destruction of fish habitat; declining quality of recreation areas; and making water unfit for alternative uses. The off-site soil erosion damage of $3.14 (1991 dollars) per ton of soil eroded in the Palouse is based on estimates for the Pacific region from Ribaudo.

Agrichemical leaching estimates for the Washington-Idaho Palouse and North Carolina Coastal Plain were made using an attenuation factor methodology (Khan and Liang). This approach uses data on soil, climatic and pesticide properties to estimate the relative mass of pesticide reaching the groundwater. No economic damage was assigned to agrichemical leaching in the Palouse where virtually no agrichemicals were predicted to leach beyond a depth of five meters.

In the North Carolina Coastal Plain, nitrate-nitrogen (NO_3-N) and, to a lesser extent, Banvel were likely to leach beyond a soil depth of five meters using an attenuation factor rating scale developed by Khan and Liang. Relatively high water tables, higher rainfall, and sandier soils indicate a much higher potential for water quality damage in this region. In addition, a rural population density 12 times that of the Palouse suggests greater damage from polluted groundwater. In an attempt to rank relative policy impacts for this area, a penalty of $0.50 per pound of NO_3-N predicted to move to a depth of 5 meters was assigned. This penalty was based on a level which would be sufficient to cause changes in cropping practices in the region.

Results

Economic and environmental impacts for each scenario are presented as the <u>difference</u> from the profit-maximizing solution for the 1990 Farm Bill. Total results are calculated as the sum of the changes in farm manager and landowner profit, less tax cost of the subsidies, and the change (negative or positive) in environmental damage. While this simple approach assumes equal weights for farmers, landowners, and society in general, it does allow a broader than usual view of farm policy impacts.

As shown in column (5) of Tables 1 and 2, little change in total results is generated by the various policy and rotation availability scenarios in the Palouse. However, substantial trade-offs occur among farm managers, landowners, taxpayers, and environmental damage. **Recoupling** has low total results in the Palouse due to high taxpayer cost, but returns to management are highest under this policy when alternative rotations are available. Under **No Programs**, returns to Palouse farm managers and taxpayer cost decline relative to the **1990 Farm Bill** (see Table 1). However, environmental damage does not increase relative to the **1990 Farm Bill**. This result might reflect omission of profitable, environmentally damaging cropping alternatives in the model.

In the North Carolina Coastal Plain, policy reform could achieve substantial gains. **No Programs, 1990 Administration Proposal, Recoupling**, and **Decoupling** result in positive change relative to the **1990 Farm Bill** (see Table 2). These policies increase relative farmer profit and decrease environmental damage because complete planting flexibility encourages profitable soybean production. Farmers no longer need to plant corn and wheat in order to receive government payments. Since these crops are high nitrogen users, their removal under reformed policies lessens the potential for environmental damage from nitrogen leachate.

In the Coastal Plain, **Recoupling** outperforms all other policy scenarios both with and without alternative crops in terms of total economic and environmental change (see Table 2). Low nitrogen leaching penalties are responsible for the strong performance of this policy, which subsidizes farmers for reducing nitrogen and Banvel. The **1990 Administration Proposal** performs nearly as well as **Recoupling**, however, with and without alternative crops. Complete base flexibility under this policy allowed soybean production on wheat and corn bases.

In the North Carolina Coastal Plain, landowner profit did not change in response to alternative policies, as the predominant land rental arrangement is cash rent, which is not responsive to policy and cropping changes in the short run. In the Palouse region, where crop-share arrangements are common, the decline in landlord's share under many alternative rotations may be one of the barriers to higher use of alternative rotations.

For both regions, **Decoupling** and **No Programs** perform nearly as well or better in terms of overall economic and environmental impacts as **Recoupling**. In the Palouse, the soil-conserving performance of **No Programs** may have been overestimated because the most wheat-intensive rotation in the model was wheat-peas. In the absence of government restrictions, some growers might further increase the percentage of land in relatively erosive winter wheat. In the long run, however, disease control and other agronomic factors should restrict expansion of winter wheat. In the North Carolina Coastal Plain, the most profitable crops, tobacco and soybeans, are not the worst agrichemical leachers. Thus, farm policy could be restructured to protect environmental quality without incurring undue economic hardship on farm managers in this study area.

Conclusions

Results obtained by maximizing returns to management vary greatly by production region. In the Palouse, limited crop choice diminished the potential for environmental gains using policy reform. The development of profitable, less erosive crop rotations is vital to reducing environmental damage in this region. Decoupling payments from the most profitable yet erosive winter wheat crop is important to the success of alternative crops. In the North Carolina Coastal Plain, policy reform can achieve substantial environmental improvement in agrichemical leaching due to a wide variety of crop choices. Decoupling payments from the production of corn and wheat, which are not profitable without the current government program but are high users of nitrogen, improves farm-level economic and environmental performance. This difference in regional impacts highlight the importance of detailed farm-level evaluations of national policies in different regions. Both economic and environmental impacts of policies depend greatly on site-specific land, climate, and farm structure characteristics.

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Table 1. Predicted 1990-1995 Average Change Relative to the 1990 Farm Bill in Economic and Environmental Indicators for Five Policy Scenarios, Washington-Idaho Palouse ($/ac/yr)

Policy/ Rotations Available	Returns to Management	Returns to Land	Taxpayer Cost	Total Erosion Damage	Total Econ. and Env. Results (1+2-3-4)
	(1)	(2)	(3)	(4)	(5)
1. 40% FLEX					
a. All Rotations	-4	-7	-8	-4	1
b. No Alt. Rotations	-2	-3	-7	0	2
2. ADMIN					
a. All Rotations	5	-1	5	-1	0
b. No Alt. Rotations	7	-4	5	3	-5
3. DECUP					
a. All Rotations	-1	-10	0	-9	-2
b. No Alt. Rotations	5	0	0	1	4
4. RECUP					
a. All Rotations	9	-10	13	-9	-5
b. No Alt. Rotations	1	0	0	1	0
5. NO PROG					
a. All Rotations	-15	-17	-23	-9	0
b. No Alt. Rotations	-13	-8	-23	1	1

Table 2. Predicted 1990-1995 Average Change Relative to the 1990 Farm Bill in Economic and Environmental Indicators for Five Policy Scenarios, North Carolina Coastal Plain ($/ac/yr)

Policy/ Rotations Available	Returns to Management	Returns to Land	Taxpayer Cost	Nitrate Leaching Penalty	Total Econ. and Env. Results (1+2-3-4)
	(1)	(2)	(3)	(4)	(5)
1. **40% FLEX**					
a. All Rotations	-5	0	-8	-16	4
b. No Alt. Rotations	-2	0	-16	-33	47
2. **ADMIN**					
a. All Rotations	16	0	4	-13	25
b. No Alt. Rotations	18	0	2	-42	58
3. **DECUP**					
a. All Rotations	5	0	0	-12	17
b. No Alt. Rotations	11	0	0	-42	53
4. **RECUP**					
a. All Rotations	21	0	17	-24	28
b. No Alt. Rotations	34	0	17	-42	59
5. **NO PROG**					
a. All Rotations	-21	0	-22	-12	13
b. No Alt. Rotations	-12	0	-22	-42	52

IMPACTS OF ALTERNATIVE FARM POLICY SCENARIOS: RESULTS OF A SURVEY OF PALOUSE FARMERS

Kathleen M. Painter, Douglas L. Young, and Robert L. Halvorson

During early 1990, some 246 randomly sampled farmers from Whitman County, Washington, and Latah County, Idaho, reported their views on different types of farm commodity and conservation policies as part of a joint Washington State University/University of Idaho survey. Since over 95% of Palouse farmers participate in government commodity programs, there is a strong incentive for Palouse growers to be concerned about any future changes in government conservation or commodity programs.

Survey Results

Deficit-Reducing Measures

Survey respondents evaluated three policy options for reducing farm program payments to decrease the federal deficit. The first strictly enforces production controls, limiting each farmer's production to levels which would raise market prices. As shown in Table 1, the majority of this random sample of Palouse farmers opposed this alternative, either strongly or moderately. Slightly over one-quarter favored this policy. The second policy alternative eliminates commodity payments to support farm income and crop prices, but pays farmers for conservation and environmental protection practices. This policy was opposed by 46% of Palouse survey respondents, but 39% favored it, either moderately or strongly. The third alternative policy simply eliminates all government support payments and conservation programs. This alternative was opposed by 60% of Palouse respondents, either strongly or moderately. However, nearly one-fourth of the surveyed farmers either moderately or strongly favored complete elimination of farm programs. These results confirm there was not a strong consensus among Palouse growers for any one of these three commonly publicized proposals for reducing the cost of farm programs.

Assessment of Impacts of Alternative Policies

Palouse farmers also gave their opinions on how four alternatives to the current farm policy would affect taxpayer cost, net farm income, soil erosion, crop diversity, and agrichemical use. Respondents were asked to compare the policy alternatives to the preceding four years (1986-89) of the 1985 Farm Bill. Results for policy impacts on net farm income and soil erosion as well as their overall opinion of the policy are presented here. (See Halvorson for more information on survey results.)

The first policy option (**40% BASE FLEX**) allows farmers to voluntarily plant up to 40% of wheat and barley base to any crop or use on an optional basis, without reducing future base acreage. If this option is used, however, farm program payments would not be received on the portion of base acreage that is "flexed."

The second alternative policy (**ENVIRON. RECOUPLING**) allows farmers to plant whatever they wish on 100% of their land each year. Farmers receive a government payment that would on average approximate historical government commodity program payments, with higher payments going to farmers with above average conservation and environmental protection practices and below average payments going to those with below average practices.

The third policy alternative (**STRENGTHEN CRP**) leaves the current wheat and barley program unchanged, but modifies the Conservation Reserve Program (CRP) in three ways. First, farmers do not lose base proportionate to their enrollment in CRP. Second, CRP rent would more closely approximate the land's productivity. Finally, environmentally sensitive areas would be eligible for CRP regardless of their erodibility.

The last policy option (**ENVIRON. COST SHARE**) gradually decreases wheat and barley target prices and uses the savings to provide subsidies and cost sharing for practices which save soil, reduce fertilizer and pesticide use, and promote wildlife habitat.

Table 2 reports Palouse farmers' perceptions of policy impacts on net farm income for each of these new policy proposals. ENVIRON. COST SHARE was predicted to reduce farm income by 69% of respondents. This probably can be explained by the proposed reduction in target prices under this policy. Some 45% felt 40% BASE FLEX would reduce farm income, which is interesting, as base flexibility was optional. Farmers had mixed feelings on ENVIRON. RECOUPLING, with responses evenly divided between reducing, increasing, and no change in net farm income. Since government payments would remain at historical levels on average but would be distributed based on implementation of conservation practices, payments might actually be distributed such that an equal number of farmers experienced increases, decreases, or no change in payments. Over half of respondents felt STRENGTHEN CRP would not change net farm income. Farmers may feel that there would be little difference between CRP payments and crop income, or that few Palouse growers would enroll in an improved CRP. Few farmers in the Palouse enrolled in the 1986-90 CRP program due to noncompetitive bid levels for this erosive yet highly productive region.

Palouse farmer respondents' forecasts of soil erosion by policy are presented in Table 3. Nearly three-fourths estimated STRENGTHEN CRP would reduce soil erosion. This result indicates that three-fourths of respondents felt that a revised CRP would be effective in the Palouse. ENVIRON. RECOUPLING and ENVIRON. COST SHARE are predicted to reduce soil erosion by about one-half of all respondents. Soil erosion would remain the same under 40% BASE FLEX, according to 47% of the Palouse respondents. Lack of cropping alternatives in this region for the "flex" acres may explain this response. Few farmers felt any of the four alternative policies would increase soil erosion.

Table 4 presents farmers' overall opinions of each policy. In general, the largest number of respondents (48%) opposed ENVIRON. COST SHARE, and the smallest number (19%) opposed STRENGTHEN CRP. These responses might be explained by the fact that STRENGTHEN CRP is simply an additional program which does not affect current programs, while ENVIRON. COST SHARE decreases current support programs and offers cost-shares in their place. These environmental cost-shares might not be perceived as a money-making change for many growers. A surprising 24-30% of farmers were neutral toward all four alternatives. The policy favored by the largest number of respondents (51%) was STRENGTHEN CRP. The remaining alternatives were favored, either moderately or strongly, over a range of 18% (ENVIRON. COST SHARE) to 39% (40% BASE FLEX).

Survey Response Differences by Farmer Characteristics

Four farmer characteristics were analyzed for their impacts on survey response. These characteristics were farm location by precipitation zone, age, education, and farm gross receipts.

ENVIRON. RECOUPLING had the largest number of significant relationships with these four characteristics. Opposition to this policy increased at higher precipitation levels. Both yields and deficiency payments will be higher as rainfall increases. These farmers may have more to lose with this type of change in farm policy.

Younger farmers were significantly more opposed to ENVIRON. RECOUPLING. Perhaps these farmers have higher financial burdens, and thus are opposed to policy changes they perceive as costly. As education level increases, farmers' opposition also rose. Over one-third of farmers with at least a college undergraduate degree were strongly opposed to ENVIRON. RECOUPLING. Just 8% of those with at most a high school degree were strongly opposed. Some observers might find it surprising that education does not seem to lead Palouse farmers to be more supportive of these "conservation oriented" policies.

Farm gross receipts exhibited a strong negative relationship with overall support of ENVIRON. RECOUPLING. Of those with annual receipts of $250,000 or more, 39% strongly opposed this policy. Just 12% of those with gross receipts of less than $100,000 were strongly opposed. While about 40% of the lower two receipt levels favored the policy, either greatly or slightly, only 10% of Palouse farmer respondents in the highest receipt level were favorable.

Summary and Conclusions

Nearly half of Palouse farmer respondents surveyed in 1990 opposed ENVIRON. COST SHARE, while just one-fifth opposed STRENGTHEN CRP. These responses might be explained by the fact that STRENGTHEN CRP adds a voluntary, potentially profitable program while leaving other programs intact. ENVIRON. COST SHARE, on the other hand, decreases current support programs and offers cost-share in their place. A substantial number of farmers, ranging from 24-30%, felt neutral toward all four policy alternatives. STRENGTHEN CRP was favored by half of the respondents, which was the largest favorable response. The remaining scenarios were favored, either moderately or strongly, by 39% (40% BASE FLEX), by 33% (ENVIRON. RECOUPLING) and by 18% (ENVIRON. COST SHARE).

Farmers with higher levels of gross receipts were less supportive of changing to ENVIRON. RECOUPLING. Younger farmers and those with higher levels of education also were significantly more opposed to this policy. This type of policy reform should have potential for improving the environmental and economic performance of agriculture in this country, but movement toward it is likely to be difficult if opposition from wealthier, younger, and better educated farmers observed in this Palouse survey is widespread nationally.

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TABLE 1. Farmers' Opinions of Alternative Budget-Cutting Policies (% of Respondents), n = 237

POLICY	Strongly Favor	Moder. Favor	Neutral	Moder. Oppose	Strongly Oppose
PRODUCTION CONTROLS	7	19	14	29	31
DECOUPLING/ RECOUPLING	5	33	16	31	15
ELIMINATE PROGRAMS	9	15	16	30	30

TABLE 2. Farmers' Opinions of Impact on Net Farm Income by Policy (% of respondents)

POLICY	Reduce	No Change	Increase	Don't Know	No. of Resp.
40% BASE FLEX	45	29	15	11	235
ENVIRON. RECOUPLING	29	29	29	13	235
STRENGTHEN CRP	17	55	22	6	236
ENVIRON. COST SHARE	69	19	5	7	236

TABLE 3. Farmers' Opinions of Impact on Soil Erosion by Policy (% of respondents)

POLICY	Reduce	No Change	Increase	Don't Know	No. of Resp.
40% BASE FLEX	32	47	8	13	237
ENVIRON. RECOUPLING	53	24	14	9	235
STRENGTHEN CRP	74	22	0	4	236
ENVIRON. COST SHARE	48	38	8	6	236

TABLE 4. Farmers' Overall Opinions of Each Policy (% of respondents)

POLICY	Strongly Favor	Mod. Favor	Neutral	Mod. Oppose	Strongly Oppose	Don't Know	No. of Resp.
40% BASE FLEX	11	28	26	13	12	10	236
ENVIRON. RECOUPLING	4	29	24	16	20	7	235
STRENGTHEN CRP	10	41	25	12	7	5	236
ENVIRON. COST SHARE	2	16	30	23	25	4	236

RECENT NITROGEN RESEARCH

J.L. Smith and A.C.S. Rao

Our recent work with nitrogen in soils of the Palouse region include evaluation of uptake use efficiency, the fate of NO_3 leached below the root zone and the possible causes of increased protein levels in soft white winter wheat. Currently we are conducting legume N credit experiments using a new method for following N fixed from the atmosphere by legume plants.

Our N efficiency studies over the years have shown that somewhere between 30 and 50% of the applied fertilizer is taken up by the wheat crop, be it winter or spring wheat. It is also known that fertilizer N mixes with soil N and that this mixing may cause more soil N to be taken up over the growing season, thus falsely indicating reduced fertilizer uptake. Our studies with the Palouse, Ritzville and Shano soils (organic carbon 0.4 to 1.6%) showed that some error in N use efficiency did occur due to fertilizer and soil mixing, however the error is not large enough to account for the usual 50 to 70% of the fertilizer N not being taken up by the wheat crop. Our studies on the causes of low N use efficiency by wheat in the Palouse are continuing.

We have studied the fate of NO_3-N below the root zone by coring to depths of up to 60 feet and measuring NO_3-N. Nitrogen in the 20 to 22" rainfall zone has leached to a depth of 15 to 22 feet in the last 30 years. The downward flux of NO_3-N is retarded by the action of microorganisms present in the subsurface. The potential for these organisms to convert NO_3-N to harmless N_2 gas is very high especially at bottom slope positions. These studies suggest that NO_3-N leaching is somewhat retarded by microbial activity, however will eventually reach groundwater thus we need to search for management practices that will conserve N in the root zone for plant uptake.

High protein levels in soft white winter wheat has been of increasing concern to growers of the Palouse region in the last several years. Our approach was to examine historical data of wheat protein levels, environmental factors, varieties and locations to develop relationships and causes of increasing protein levels in wheat. This study showed that environmental variables especially high temperatures during the grain filling stage are responsible for higher protein levels in wheat. There were no trends in varieties as being the cause of higher protein levels.

Contact Jeff Smith 509-335-7648 for publications on these subjects.

WHEAT SAFENER RESEARCH TARGETED FOR JOINTED GOATGRASS CONTROL

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Jointed goatgrass (*Aegilops cylindrica* Host.) is a serious weed management problem for winter wheat growers in Washington. Jointed goatgrass is a winter annual grass that is genetically related to wheat and also mimics the life cycle and growth habits of wheat (for review see Donald and Ogg, 1991). These characteristics make it very difficult to manage in winter wheat. Once established in a field jointed goatgrass can only be managed by rotating to spring crops until the seed bank is reduced to a tolerable level (Donald and Ogg, 1991). Currently, there are no registered or experimental herbicides that selectively control jointed goatgrass in winter wheat. As a result, our research objectives are to use herbicide safeners to make winter wheat tolerant to herbicides that will control jointed goatgrass. In addition to selective control of jointed goatgrass, this system will improve control of other grassy weeds such as downy brome (*Bromus tectorum* L.).

Herbicide safeners are successfully used in several grass crops, including corn, grain sorghum, and rice, to protect marginally tolerant crops against herbicides (Hatzios and Hoagland, 1989). Herbicide safeners are sometimes referred to as herbicide antidotes or crop protectants, in that they chemically increase the crop's tolerance to a particular herbicide and protect it from injury. Most safeners are applied as seed treatments to maximize uptake by the germinating crop seedling and avoid possible safening of target weed species, such as the use of Concep II treated sorghum seed to safen from Dual herbicide. Some safeners are added to the herbicide formulation and applied as a broadcast treatment. Examples include Dual II (metolachlor + safener benoxacor) in corn, and Eradicane (EPTC + safener dichlormid) in corn.

The mechanisms that chemical safeners trigger to protect crops have been widely studied and reviewed (Hatzios and Hoagland, 1989). Most cases involve increasing the amount or activity of herbicide detoxifying enzymes. These enzymes are naturally present in the crop, but need to be increased to rapidly metabolize the herbicide to prevent crop injury. Safeners must protect the crop from a high enough herbicide rate that will control the target weed species, be non-toxic to the crop, and be reliable under a wide variety of environmental conditions.

Herbicide safeners for winter wheat are being evaluated in the field and greenhouse. Several safeners that are used in sorghum and corn to protect from soil-applied grass herbicides have also shown promise in protecting Madsen winter wheat. The safeners do not significantly affect wheat growth. These safeners include benoxacor, Concep II, Concep III, MON 13900, and CGA 185072. They have been applied as seed treatments at a rate of 0.16 oz active ingredient/lb seed. The soil-applied grass herbicides that have shown complete or partial safening in Madsen wheat are Dual, Harness (acetochlor), Frontier (dimethenamid), Treflan, and Buckle. Treflan and Buckle have the added advantage that they are currently registered for use in wheat. Jointed goatgrass appears to be as or slightly less susceptible to these herbicides than Madsen wheat. Many other herbicides are also being tested to determine how well they control jointed goatgrass. If other highly effective herbicides are found, safeners will then be tested to protect winter wheat from those herbicides. Through the use of safeners, growers may be able to artificially achieve herbicide selectivity between winter wheat and jointed goatgrass. Future greenhouse and field experiments will be conducted to optimize safening of Madsen wheat from herbicides that injure jointed goatgrass, and laboratory experiments will examine the mechanism(s) of safener action.

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BIOECONOMIC MODELING FOR PROFITABLE AND ENVIRONMENTALLY SOUND WEED CONTROL IN WINTER WHEAT

D.L. Young, T. Kwon, C.M. Boerboom, and F.L. Young

Over 1985-1991, the USDA-WSU-UI IPM project identified agronomically and economically successful conservation farming systems at a research site three miles northwest of Pullman, Washington. A diversified winter wheat-spring barley-spring pea rotation, grown with a combination of no-tillage and minimum-tillage and effective weed control, increased average profitability while reducing income risk. This management system also satisfied conservation compliance.

The preceding results from the IPM project are based upon a fixed management system. However, there is evidence that further profitability and environmental gains can be achieved with a flexible system which modifies weed management each year in response to weed densities, soil conditions, and crop and herbicide prices. Over the six years of the IPM experiment, weed seed populations declined under higher levels of weed management. Higher levels of weed management also showed declining trends in weed seedling counts and subjective assessments of herbicide needs by weed scientists. Other factors supporting annually flexible weed management include a desire by growers to cut costs to improve profitability and a corresponding desire by society to use minimally necessary pesticides.

During a current three-year extension (1991/92-1993/94) of the IPM project, researchers have responded to the need for flexible weed management strategies in two ways. First, field experimentation with the successful winter wheat-spring barley-spring pea rotation is being conducted under three levels of preexisting weed seed levels and latent weed populations created by the first six years of the experiment. This research will be completed in 1994. Second, statistical analysis of the first six years data has been conducted to develop bioeconomic weed management decision models for winter wheat, spring peas, spring barley, and spring wheat under both conventional and conservation tillage. These models make use of weed seedling counts, soil moisture conditions, crop and herbicide prices, and other annual information to recommend profit maximizing herbicide treatments. Preliminary models have been developed for all four crops and the models are being field tested for selected crops during 1993. After field testing and the availability of additional information from the second phase of IPM experimental research, the models will be further refined for field use. This report focuses on the winter wheat bioeconomic model which is the most fully developed.

The bioeconomic model consists of three components: (1) weed survival functions in response to herbicides, initial weed density and tillage; (2) a crop yield function in response to aggregated surviving weed density, soil moisture, soil organic matter, tillage, and preceding crop; and (3) a profit function which is based upon predicted crop yield, crop prices, farm program participation, weed control costs and other costs.

Over 50 species of weeds were recorded in the IPM experiment over six years. For the purposes of the bioeconomic modeling, these were classified into four subgroups including spring grasses, winter grasses, spring broadleaves, and winter broadleaves. Separate survival functions were estimated for each of these

these four weed categories; however, these four weed classes were aggregated into a single biomass-based competition index for the yield response function. A total of 16 types of herbicides were used in winter wheat over the six years of the IPM experiment. These were categorized into three subgroups for the bioeconomic modeling. These included nonselective preplant herbicides, post-emergence broadleaf herbicides, and post-emergence grass herbicides.

The four estimated weed survival functions for winter wheat are presented in Table 1. All spring weed density (SWD_i) coefficients have expected positive signs and are statistically significant at the 1% level. Clearly, spring weed seedling counts appear to be a good indicator, other factors constant, of midsummer weed survival of spring annual grasses (SAG), winter annual grasses (WAG), spring annual broadleaves (SAB), and winter annual broadleaves (WAB), for winter wheat in the eastern Palouse. Nonselective preplant herbicides (H_1) were not significant at the 5% level in predicting survival of summer annual grasses, but the negative sign was consistent with expectations. H_1 significantly suppressed both broadleaf weed groups, but not winter annual grasses. Post-emergence broadleaf herbicides (H_2) significantly reduced the winter annual broad leaf weed population. Post-emergence grass herbicides (H_3) helped control both winter and summer annual grass populations, but the coefficient was not statistically significant at the 5% level for winter annual grasses. As expected, no-till (TIL_1) and chisel plowing (TIL_2) increased (relative to conventional tillage) midsummer weed populations of all weed groups in winter wheat.

The (unreported) estimated winter wheat yield response function showed increased yields with improved weed control, greater soil moisture, and increased organic matter. Conservation tillage, which was correlated with higher soil moisture, also significantly increased winter wheat yields.

The bioeconomic weed management model for winter wheat was illustrated by simulating how optimal herbicide rates responded to changes in weed seedling densities, wheat price, herbicide prices, and herbicide application constraints. On the whole, profit maximizing weed management recommendations from the model for winter wheat suggested lower and more selective use of herbicides than is common for the region. If field tests validate these results, this could be favorable for farmers and for the environment. Profits could be increased by reducing herbicides through greater use of weed counts and other information collected early in the season. The environment could benefit by net reduction in annual chemical use. Of course, the practicality of the decision model depends upon obtaining accurate weed seedling counts and other field information in the spring at reasonable cost. The model will undergo further revision after two years of field testing.

Table 1. Estimated Weed Survival Functions for Four Weed Subgroups in Winter Wheat, IPM Project, Pullman, Washington, 1986-91.

Variable[c]	Survival of Weed Subgroup[a, b]			
	SAG	WAG	SAB	WAB
Constant	8.73*	4.07	0.72	2.05*
	(4.38)	(3.76)	(0.60)	(0.94)
SWD_i	0.64**	0.23**	0.05**	
0.05**				
	(0.05)	(0.02)	(0.01)	(0.01)
H_1	-12.67	-	-4.74**	-
3.61**				
	(8.16)		(1.81)	(1.19)
H_2	-[d]	-	-	-2.17**
				(0.83)
H_3	-11.37*	-5.15	-	-
	(4.98)	(4.29)		
TIL_1 (No-till)	14.72**	7.79+	3.51**	
3.34**				
	(5.29)	(4.16)	(1.17)	(0.77)
TIL_2 (Min-till)	20.20**	17.75**	-	-
	(5.19)	(4.47)		

System weighted MSE = 0.9990 with 1708 d.f.
System weighted R^2 = 0.3083

[a]Weeds were categorized as summer annual grasses (SAG), winter annual grasses (WAG), summer annual broadleaves (SAB), and winter annual broadleaves (WAB). These variables are measured in weed plants/m^2.

[b]+, *, and ** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Standard errors are in parentheses.

[c]H_1 = nonselective herbicides; H_2 = post-emergence broadleaf herbicides; H_3 = post-emergence grass herbicides. These variables are measured in proportion of label rate. SWD_i is the spring density of weeds (plants/m^2) for the weed type in the corresponding column.

[d]These variables were not included in the wheat bioeconomic model because they showed very low statistical significance (t-values less than 1.0)

CROP RESIDUE COMPONENTS - INFLUENCE ON CONSERVATION PLANS

Don McCool, Hans Krauss, Ron McClellan, Bob Papendick

Crop residue is an important part of nearly all conservation plans. Under normal conditions on dryfarmed cropland of the Pacific Northwest, residue is the major factor controlling soil erosion. Residue is composed of a number of elements - stems, leaves, chaff and awns, or pods. It is considered by many that long straw is the main component anchoring the soil and preventing erosion. The other components would contribute to soil organic matter, and may contribute to anchoring soil particles, but these components generally disappear from sight after the first tillage operations. Only the stem component was measured on runoff plots when determining relationships between soil loss and residue cover. Hence, only the stem component should be measured when determining if a particular tillage and seeding system meets recommended residue levels of a conservation plan.

The importance of crop residue in erosion control, the wide variation in published data on residue to grain ratios, and in the partitioning of this residue into its various components, led to a major effort to determining residue-to-grain ratios and residue partitioning for a number of crops and crop varieties grown in the region.

Crop samples were clipped for two crop years, 1990 and 1992. The 1992 collection consisted of 120 separate samples of 9 different crops from scattered locations in Eastern Washington. Twenty-two of these samples were known varieties. The samples included winter wheat, spring wheat, canola, triticales, spring barley, winter barley, oats, lentils, and peas.

The 1990 collection consisted of 31 samples of five different crops from the Spillman Research Farm at Washington State University. All of these 1990 samples were known varieties and included triticales, winter wheat, spring wheat, spring barley, and winter barley.

All samples have been partitioned and statistical analysis is underway. Results will be available at the time of the Field Day.

Previous studies in the Pacific Northwest indicated about 30% of winter wheat and spring barley residue is small-sized components, primarily chaff and awn.

IMPROVEMENT OF SOIL QUALITY AND CROP PRODUCTIVITY THROUGH A GROWER DEVELOPED SYSTEM TO REDUCE EROSION AND ENHANCE MICROBIAL ACTIVITY

D. F. Bezdicek and T. A. Beaver

This project is funded through STEEP II research funds in cooperation with the McGregor Company, Progressive Farmers Inland Northwest, the Soil Conservation Service, Walla Walla County Conservation District and the Agricultural Research Service. The project was initiated by a group of Pacific Northwest wheat farmers who have been experimenting with the subsoil-ridge tiller and lime incorporation. They feel this system offers promise in reducing erosion and improving soil quality.

The subsoiler-ridge tiller tool has shanks at 36-inch intervals which penetrate the soil to a depth of 16-18 inches. Sweeps midway between the shanks mix the soil with crop residues and form a corrugated soil surface of 6- to 12-inch deep ridges and valleys over the sub-soiled region. This study was initiated to compare subsoiling or subsoiling and liming to conventional fall tillage of either moldboard plowing, chisel plowing, or disking.

One replicated trial (Quist site) and five on-farm trials were established in the fall of 1991. A second replicated site was added last fall at the Wayne Jensen farm in Genesee. The Quist and the Jensen sites compare four treatments, subsoiling alone, subsoiling with addition of lime, plowing alone and plowing with lime. The non-replicated on-farm trials compare subsoiling alone to conventional tillage alone. Tillage operations are compared in adjacent plots that run up and down the slope in order to measure and observe erosion for the entire slope. The tillage operation is done on the contour.

Objectives

The objectives for the subsoil-ridge till system research are to:

1) Evaluate the system as a substitute for fall tillage to increase water infiltration, water storage and reduce soil erosion.

2) Evaluate the potential of the system to maintain cereal residue near the soil surface to maintain adequate protection for erosion control and for optimum residue decomposition.

3) Evaluate the system, in combination with lime, for enhancing soil microbial activity and physical characteristics.

TESTS CONDUCTED:

Microbiological Tests

Soil samples were taken in the spring of 1992 and analyzed for microbial biomass, respiration, enzymes and pH. Microbial biomass tells us the weight of microorganisms in the soil. Respiration is a measure of how active these organisms are. In some cases, biomass may be high but if conditions are not right, their activity may be low. On the other hand, a small amount of biomass with all the right conditions may be a very active group. The microbial biomass is important because of the many benefits the microbes provide to the soil such as, residue decomposition, nutrient cycling, disease suppression and improved physical properties.

Physical Properties
Bulk density is the mass of soil in a given volume. So if the soil has a good structure (or lots of spaces for air and water movement), it will have a lower bulk density than a soil that has poor structure (such as compacted soil with little room for air and water movement). Soil structure is enhanced by organic matter because it binds particles into "chunks"(aggregates). It is between these "chunks" that air and water move. So the bulk density test is another method to determine if physical properties are improving due to tillage treatment.

The infiltration test is performed right in the field and tells us the rate (how fast) water moves into the soil. This is a very important parameter because the faster the water can move into the soil the less runoff there will be, and therefore, less chance of erosion. Due to the need for replication and the time involved, the bulk density and the infiltration test were only performed at the Quist site in Pullman.

Water Storage and Movement
Soil samples were taken at one foot intervals to five feet and dried in the oven to determine the percent water. In most cases gypsum blocks were also installed at these same depths to track the amount of water depletion over the season.

Potassium bromide (KBr), a tracer chemical, was applied to four plots at the Quist site and four locations at the Martin farm in Walla Walla. Soil samples from several depths were taken this fall from an area extending approximately 30 feet down from the KBr application area. Potassium Bromide moves in the soil like water, following it in the soil will tell us if there are any differences in depth of penetration due to tillage treatment.

Silt fences were installed at the bottom of four treatment plots at the Quist site and the Martin site. These fences will allow water to penetrate, while collecting any soil in the runoff. Erosion was measured at the Quist site using the Alutin method.

Residue Levels
Residue levels were taken on the Quist site in Pullman on May 6, and October 15, 1992, by SCS Soil Conservationist, David Chain, and at the Holben site in Genesee on May 8, 1992, by Dave Bezdicek and Theresa Beaver.

RESULTS

Microbiological Tests
The biomass and respiration were significantly higher for the subsoiled treatment than for the plowed treatment at the Quist site in Spring, 1992. The biomass was also significantly higher due to lime treatment alone versus no lime plots. By fall of 1992, the biomass at the Quist site was significantly greater in the limed plots only. For all other farms the biomass and respiration were very similar for both treatments.

Physical Properties
There were no significant differences between treatments for bulk density.

Water Storage and Movement
At the Quist site on April 28, 1992, prior to planting of peas, soil moisture was significantly higher in the first, fourth and fifth foot for subsoiling compared

to plowing. On August 24, 1992, after pea harvest, the amount of water was greater in the fifth foot of the subsoiled plots, and for the plowed plots, the amount of water was greater in the first foot. In the spring of 1993, there was significantly more water in the second foot of the sub-soiled plots compared to plowing. However, though the results were not significant, there was more water at every depth in the sub-soiled plots versus the plowed plots.

The only other differences in water storage were found at the Holben site in Genesee. Here the soil moisture was significantly greater for the subsoiled treatment in June, 1992, at the five foot depth.

The silt fence results were inclusive due to difficulties in interpreting the results. In the future, the fences would be installed differently. However, the Alutin method of measuring soil rill erosion showed significantly more soil loss on the plowed treatment plots with a loss of 3.74 tons/ac compared to 0.56 tons/ac lost on the subsoiled plots at the Quist. One should compare the relative differences, as this does not measure sheet erosion.

Residue levels
Barley surface residue coverage in the spring following subsoiling at the Quist site for the subsoiled treatment was 20% compared to 0.5% for fall plowing. Surface residue following peas was 24% in the subsoiled plots versus 20% in the plowed plots. At the Holben site, the surface wheat residue coverage was 46% for the subsoiled treatment compared to 31% for the chiseled treatment.

Yields
Pea yields were taken at the Quist site only. The yield for the subsoiled plots was significantly greater than the yield for the plowed plots with 2067 kg/ha (1843 lb/ac) for the subsoiled plots and 1857 kg/ha (1657 lb/ac) for the plowed treatments.

SUMMARY

Microbiological properties were improved due to subsoiling and liming. However, these improvements were only seen at the Quist site where the plots were replicated. Soil moisture in the subsoiled plots was significantly higher at the five foot depth at only two of the farms, but the trend of higher soil moisture at five feet in the subsoiled plots was seen at four of the six farms.

Residue levels were higher following subsoiling than plowing at both of the farms tested. Pea yield at the Quist site was greater for the subsoiled plots than the plowed plots by almost 200 lbs/ac.

Most of the results that showed significant differences were for the Quist site. Because the changes are subtle, the results may be harder to see unless the plots are replicated. Due to the lack of treatment differences at most of the farms, the wheat yields will be to most important measure of benefits due to treatment. Wheat yields will be taken at all farms in 1993.

CONTROL OF ERGOT IN BLUEGRASS SEED FIELDS USING FUNGICIDES AND WETTING AGENTS, 1992 FIELD TRIALS

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INTRODUCTION

Kentucky bluegrass (*Poa pratensis* L.) seed production is an important component in the agriculture of the Pacific northwest. In 1991, there were 34,000 acres of bluegrass grown for seed in Washington with a yield of 540 lb./acre and a crop value of $7.7 million.

Currently, there are no fungicides registered for the control of ergot caused by the fungus *Claviceps purpurea* in bluegrass seed fields. The only recognized method of control is open-field burning following harvest. This practice is controversial and may be limited in the future, thus leaving growers with no means of controlling ergot in grass seed fields.

MATERIALS AND METHODS

Fungicide trials were conducted in a commercial Kentucky bluegrass seed production field near Post Falls, Idaho. Individual treatment plots were 10 x 20 feet with four replications in a randomized complete-block design. Three fungicides, Punch at 8 oz. a.i./acre, Folicur at 7.2 oz. a.i./acre, or Tilt at 3.4 oz. a.i./acre, were applied alone and in combination with two wetting agents, Penaturf and Sylgard, at 34, 338, and 676 oz./acre. Treatments were applied with a CO_2 pressurized boom sprayer at 40 psi using a 28 gal/acre carrier rate on 28 May (early anthesis of the Kentucky bluegrass). Plots were rated for disease severity and phytotoxicity on 26 June by visually observing the amount of sclerotia and seedhead exudate (honeydew) on the panicles. On 26 June, 30 to 50 panicles were harvested by hand from each plot. Mean weight of clean seed and sclerotia per panicle were determined.

RESULTS AND DISCUSSION

Warm, dry spring weather and a short bluegrass flowering period in eastern Washington and northern Idaho during 1992 was not conducive for ergot development. Consequently, disease severity was low in all plots and only small differences in disease control were observed among treatments. Disease control was not significantly different between fungicide and fungicide-wetting agent combinations except when using 676 oz. of Sylgard. Phytotoxicity was observed when fungicides were used in combination with 338 or 676 oz. of Sylgard. Phytotoxicity was not observed with any other treatment. Seed yield per panicle was relatively high among all treatments except those combined with the high rates of Sylgard. The highest seed yield per panicle was observed when each fungicide was combined with the lowest rate (34 oz.) of Sylgard, although they were not significantly higher than the nontreated control. Sclerotia yield per panicle was reduced by all treatments compared to the nontreated control. Seed germination was reduced by Folicur when used in combination with the two high rates of Penaturf or Sylgard.

Product	Manufacture	Composition
Punch 25 EC	Dupont de Nemours	Flusilazole (25%)
Folicur 3.6 F	Mobay Chemical	Terbutrazole (38%)
Tilt 3.6 E	Ciba Geigy	Propiconazole (42%)
Penaturf	Chas. H. Lilly Co.	Sodium dodecylbenzene sulfonate (20%) nine mole ethoxylated C_{11} - C_{15} alcohol (5%)
Sylgard 309	Dupont de Nemours	2-(3 hydrozypropyl)-heptamethyltrisiloxane, ethoxylated acetate, allyloxy polyethylene glycol monoallyl acetate, polyethylene glycol diacetate (100%)

SUMMARY AND CONCLUSIONS

Since 1990, our research program on ergot control in Kentucky bluegrass has shown that ergot causes loss of yield and reduced seed quality. We have identified fungicides, rates, and time of application to control ergot. We have successfully used wetting agents to mitigate honeydew and secondary infection of the disease and wetting agent-fungicide combinations to lower the application rate of fungicides. Grower implementation of these findings will improve the yield, quality, and market for northwest Kentucky bluegrass seed.

GUIDES TO MANAGING THE "GREEN BRIDGE" FOR ENHANCED SPRING CROP YIELDS UNDER CONSERVATION TILLAGE

Roger Veseth , WSU/UI Extension Conservation Tillage Specialist

An important management consideration in the shift from conventional tillage to conservation tillage has been control of root diseases. When spring cereals are planted after cereals in the Northwest, a common practice with no-till seeding has been to spray volunteer grain and weeds with a non-selective herbicide, such as glyphosate, shortly before seeding. Although volunteer and weeds were controlled with this spray timing, crop yields were often lower than expected, thus limiting the use of spring no-till seeding. Root diseases recently have been identified as a major cause of the yield reductions. Fortunately, a research breakthrough in management of these diseases through early "green bridge" control now makes conservation tillage seeding of spring crops an attractive production option. A new Extension video and publication are available to provide growers and the agricultural service industry with management guides on this topic.

What is the "Green Bridge?"

Pacific Northwest research has shown that volunteer grain and weeds growing between cereal harvest and spring planting can serve as a "green bridge" host for build up of some root diseases. Research on green bridge management from 1987 through 1992 has been part of the tristate STEEP (Solutions to Environmental and Economic Problems) program, as well as other related PNW research projects supported by grants from commodity commissions and the USDA Agricultural Research Service. Key researchers included R. James Cook and Alex Ogg, USDA Agricultural Research Service plant pathologist and plant physiologist, respectively, in Pullman, WA, and Richard Smiley, Oregon State University plant pathologist in Pendleton, OR.

The researchers have found that the typical 1- to 3-day time interval between spraying and seeding greatly increases the level of some root diseases, particularly Rhizoctonia root rot, Pythium root rot and take-all. They explain that as the plants begin to die from a glyphosate application, the natural disease resistance of healthy living roots slowly breaks down. Root pathogens, that are already on and in the roots of these dying plants, have a major initial advantage in taking possession of these roots as a food source first, compared to nonpathogenic soil microbes involved in organic matter decomposition. Their populations rise sharply and commonly peak within a few day after application, and then begin to decline as organic matter decomposition continues. Planting when the pathogen level is high can result in significant yield losses from root diseases.

Management Strategy

Now for the new management breakthrough! The researchers found that if volunteer and weeds were sprayed earlier ahead of seeding, the root disease problem associated with the green bridge can largely be eliminated. Spraying glyphosate at least 2-3 weeks before seeding commonly increased yields of direct-seeded spring cereals after cereals by 20 to 50 percent compared to spraying 1-3 days before seeding. When extensive germination and growth of volunteer and weeds occur in the fall, the researchers point out that control

before winter can further reduce root disease levels by lengthening the "host-free" period between susceptible crops.
The researchers put together a schematic (Fig. 1) to help illustrate how timing of green bridge control before seeding spring grains can affect root disease potential, using Rhizoctonia root rot as an example. After winter wheat harvest, pathogen inoculum levels in the soil tend to decrease slowly because of the combination of dry soil conditions, that limit activity of beneficial decomposing microbes, and lack of growing roots of host plants. Pathogen inoculum levels begin to increase again when volunteer grain and weeds emerge after fall rains. If glyphosate is applied in the fall after most of the volunteer and weed seeds have emerged, pathogen inoculum levels would rise sharply for a short time and then decline to a relatively low level by spring seeding time, assuming few additional volunteer and weeds emerged.

If volunteer and weeds are not controlled in the fall, the pathogen inoculum level would continue to increase over the winter and into the spring as plant populations and root mass increased. If glyphosate is applied in early spring (at least 2-3 weeks before seeding), the pathogen inoculum level would temporarily increase sharply and then decline again to a relatively low level by seeding time. However, if the application was delayed until just 1 to 3 days before seeding, inoculum level would still be high during crop germination and early growth stages, and could result in significant crop damage. The key then, is early control, beginning in the fall if possible.

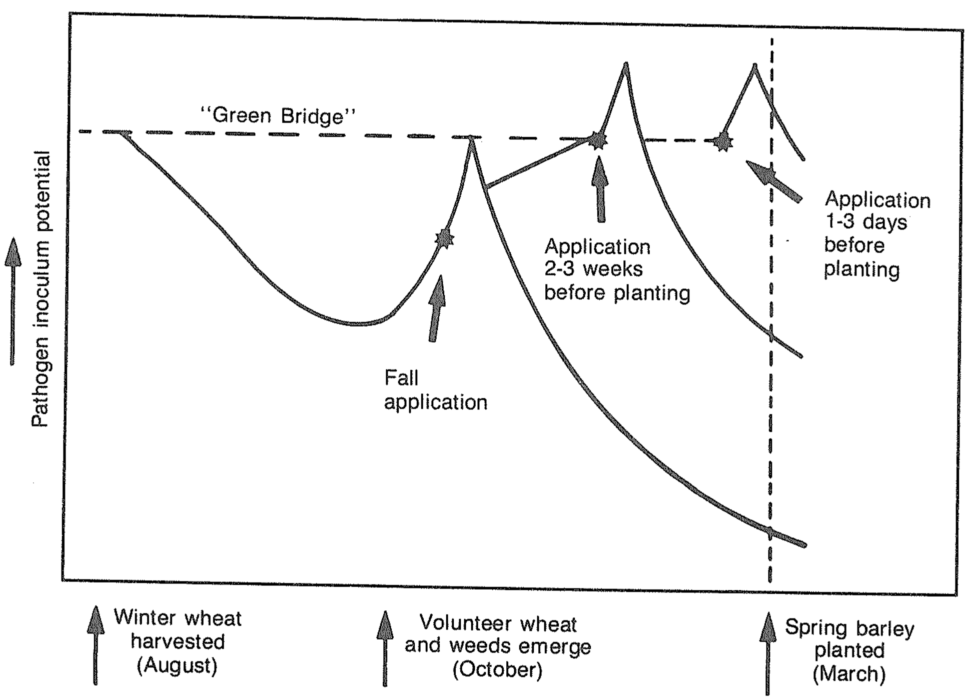

Fig. 1. Schematic representation of the effects of the "green bridge" and timing of glyphosate application before direct seeding spring barley after winter wheat on pathogen inoculum potential for Rhizoctonia root rot (from "Green Bridge Key to Root Disease Control," *PNW Conservation Tillage Handbook Series* No. 16, Chap. 4, July 1992)

Interactions with Other Management Choices

Crop Rotation Interactions

Problems encountered with root diseases in spring cereals under conservation tillage systems are not due to the lack of tillage as much as to the lack of crop rotation. The most effective way to control cereal root diseases in conservation tillage systems is through crop rotation, allowing the soil to sanitize between susceptible crops. In most rotations, the crops most vulnerable to root diseases associated with the green bridge are spring cereals after cereals -- spring barley and spring wheat seeded after wheat or barley -- because they are susceptible to some of the same root diseases. This is where early green bridge control is most important in the rotation.

In addition to the preceding crop, other related rotation factors include the population of volunteer grain and weeds, and when they are eliminated before the next planting. The higher the population and the longer they are allowed to grow, the greater the potential for disease.

Tillage and Surface Residue Interactions

Tillage and planting system choice can influence green bridge impact on root diseases in recropped cereals, and the need for early application of glyphosate. Like early control with a herbicide, use of tillage can also minimize the build up of root diseases associated with the green bridge. Tillage accelerates root death in volunteer and weeds so that the roots are comparatively more accessible to residue decomposing microbes, thereby limiting root pathogen activity. The tradeoffs with more intensive tillage, on the other hand, include lower yield potentials from reduced soil water storage -- increased evaporation and runoff -- and increased soil erosion potential. With early green bridge control to reduce root diseases, crops seeded with no-till or minimum tillage can take advantage of this higher water storage-yield potential. The researchers found that early control of the green bridge before direct seeding of spring cereals after cereals resulted in yields that were as good as and often better than where tillage was used prior to seeding.

The effects of surface residue on root disease potential in spring cereals has often been a point of confusion over the years. The major effect of surface residue on root disease potential is that by protecting the soil from evaporation, it can create a cool, moist environment favorable to root diseases. With early elimination of the green bridge, and other appropriate pest management strategies, surface residues can increase yield potential by increasing soil water storage. Crop residue is not the major source of the root disease problem in spring crops under conservation tillage. It is the roots of the volunteer grain and weeds, particularly grassy weeds.

Volunteer grain and weeds concentrated in combine chaff rows have often result in thin stands and stunted, late-maturing plants in no-till spring cereal crops after cereals. The so-called "combine-row effect" is now believed to be largely a "volunteer-row effect" because of the green bridge enhancement of root diseases.

Green Bridge Video and Publication

Two new references provide more details on how to manage the green bridge to reduce root disease problems in spring crops under conservation tillage. A colorful and fast-moving video titled "*Managing the Green Bridge: Root Disease Control in Conservation Tillage*" was completed in January 1993 through Washington State University Cooperative Extension. The 17-minute video includes a series of animated graphics to clearly explain how the green bridge can increase root diseases and how it can be managed with early control. It features ARS scientists Cook and Ogg explaining actual field trials comparing early versus late green bridge control for spring barley after winter wheat under no-till and conventional tillage. Two Washington farmers also share their experiences of how early green bridge control has increased the profitability of spring crops through the use of conservation tillage. The video, VT0040, is available for $15 (payable to WSU Cooperative Extension Publications) from the Bulletin Office, WSU Cooperative Extension, Cooper Publications Bldg., Pullman, WA 99164-5912 or call (509) 335-2857.

A publication titled "*Green Bridge Key to Root Disease Control*" summarizes five years of field research in the Pacific Northwest. It is *PNW Conservation Tillage Handbook Series* No. 16 in Chapter 4 of the *Handbook*. This Series publication was distributed through the Summer 1992 issue of the *PNW STEEP II Extension Conservation Farming Update* publication which is supported by grants from the Wheat Commissions in Idaho, Oregon and Washington. For a copy of the publication, contact Roger Veseth, Extension Conservation Tillage Specialist, at the Plant, Soil and Entomological. Sci. Dept., University of Idaho, Moscow 83844-2339, (208) 885-6386.

Conclusions and Implications

Early green bridge control can increase the success of spring crops and the feasibility of using conservation tillage in spring crop production. More profitable spring cropping, in turn, permits longer crop rotations which reduce crop losses from root diseases, winter annual grassy weeds and other pest problems for all crops in the rotation under conservation tillage. The best part about the green bridge-disease management tool is that there are little or no additional costs -- it is only a matter of timing.

MORECROP, AN EXPERT, ADVISORY SYSTEM FOR WHEAT DISEASE MANAGEMENT

Roland F. Line

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 PNW 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 dialog 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.

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 their importance. The average increase in yield of winter wheat in response to soil fumigation in commercial fields in the higher rainfall areas has been 70, 22, and 7%, respectively, in fields cropped every year, every other year, and every third year to wheat.

In addition to the disappointing yields, root diseases prevent crops from taking full advantage of nitrogen applied as fertilizer. Again, using soil fumigation, we have shown that crops with healthy roots do better at using available nitrogen, whereas crops with diseased roots leave considerable nitrogen unused in the soil profile.

Damage from root diseases also accounts for much of the poor performance of wheat and barley planted into wheat or barley residue (conservation tillage). The high potential for root diseases created by planting cereals after cereals is one factor. The moist soil conditions associated with straw mulches and surface residues is a second factor. The pathogens responsible for these root diseases are greatly favored in their ability to attack the roots of wheat and barley by cool, moist soil conditions typical of conservation tillage systems. The additional water available to wheat and barley in conservation tillage systems should lead to higher rather than lower yields of wheat and barley, but unfortunately root disease and not water becomes the limiting factor to yields of wheat and barley managed in this way.

Soil fumigation is not an option for root disease control, but neither is clean tillage or open-field burning. The 3-year rotation is currently the most acceptable environmentally, and much can be done to make this rotation more acceptable economically. However, 3-year rotations typically mean that two-thirds of the land is in spring crops or fallow. The spring of 1993 revealed the disadvantages of having two thirds of the land in spring crops, when rainy conditions greatly delayed spring work, yet will contribute significantly to high yields of winter wheat provided diseases can be controlled.

Our program has two practical goals:

1. For the intermediate and lower rainfall areas--to develop root disease controls necessary to permit planting spring barley directly (no-till) into standing stubble of winter wheat, as a means to increase to yield potential and hence economic attractiveness of spring barley as a rotation crop in these areas;

2. For the intermediate and high rainfall areas--to develop root disease controls necessary to achieve the same yield for winter wheat in two year

rotations, using conservation tillage, that currently are only possible for winter wheat in three year rotations using clean tillage.

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 winter wheat stubble. The green bridge is volunteer wheat or barley and grass weeds that green up in the fall and carry over into the spring. These plants provide the means for root pathogens to carry over from the decomposing stubble of one crop to the young plants of the next crop. 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 in these kinds of management systems. This allows time for the soil to "sanitize itself" of the root pathogens hosted by the young roots of these weedy plants.

Early elimination of the green bridge, including in the previous fall if practical, could have a major influence on successful cropping spring barley planted directly into the stubble of winter wheat in the intermediate and lower rainfall areas. The advantages would be higher yield potential of spring barley because a) more water is saved for the crop, b) two years out of three with cereal stubble means more residue for erosion control (the third year being conventional fallow) and c) the yield potential of winter wheat is higher because of the rotational benefits of spring barley/fallow rather than just fallow prior to planting winter wheat.

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. Results to date show that the 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 diseased roots need easy access to fertilizer to perform their function. Placing fertilizer within easy reach of roots cannot compensate entirely for the lack of healthy roots, but apparently it can make a big difference to the productivity of the crop. Placement of fertilizer is especially critical for phosphorus, because of its immobility in soil and the fact that roots must go to the phosphorus because the phosphorus moves very slowly towards the roots. Our results indicate that phosphorus with the seed is as good as phosphorus directly below the seed. Of course, banded nitrogen must be placed below or to one side of the seed to avoid injury to the germinating seeds. Nitrogen and phosphorus banded together is best placed below the seed.

There is also evidence that Rhizoctonia root rot and take-all are amenable to some control simply by the action of loosening the soil to 2-3 inches below the seed independently of fertilizer placement.

The use of zone tillage and fertilizer banding below the seed (or phosphorus with the seed) increases even more the prospects for reaching the high yield potential of winter wheat planted after peas or lentils (two-year rotations) with no-till or reduced tillage systems. This approach has also proven effective for spring barley planted directly into stubble of winter wheat in the intermediate rainfall areas, especially when combined with early elimination of the green bridge. Future work will test this system for spring barley in the lower rainfall areas.

Ultimately, it will be necessary to use a genetics/biological approach to manage these root diseases. We have identified a great diversity of microorganisms naturally associated with roots of wheat and that have the ability to produce antibiotics inhibitory to one or more of these wheat root pathogens. In a sense, we have found the equivalent of genetic "resistance" to take-all in strains of bacteria. These bacteria become naturally associated with roots of wheat after several successive outbreaks of the disease. We must find ways to derive disease-control benefits from them but without waiting through several years of destructive disease for this biological control to develop naturally. Some strains have also shown activity against Pythium root rot. The reservoir of potentially useful microbial germplasm in some soils is virtually unlimited.

Research during the past year has confirmed that our microorganisms selected originally from roots of wheat can be "genetically engineered" to express a desirable trait such as ability to inhibit one or more root pathogens. 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.

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.

CEPHALOSPORIUM STRIPE AND STRAWBREAKER FOOT ROT RESEARCH

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Strawbreaker foot rot and Cephalosporium stripe are two of the most important diseases of winter wheat in the Inland Pacific Northwest. These diseases are most common in the high rainfall areas (more than 18" annual precip.), but also cause significant losses in the lower rainfall areas. Both diseases are most severe on early-seeded winter wheat, especially when planted following summer fallow, and for both diseases, the yield in fields where disease is severe may be only half of that where disease is not a problem.

Cephalosporium is currently controlled by modifying cultural practices such as delaying seeding in fields seeded early, increasing the length of crop rotation so that winter wheat is grown one year in three, and by increasing tillage to promote decomposition of crop residue. None of these practices completely controls the disease, and all may have undesirable consequences such as increased soil erosion potential or decreased yield potential. Our previous work indicated that raising soil pH with lime could reduce Cephalosporium stripe. Whether lime applications were generally useful or effective for all varieties was not known, and thus, studies on the interaction of seeding date, variety, and rate of lime application were begun. Prilled lime was applied to soil with an initial pH of 4.8 at the rate of 0, 1.5, or 3.0 tons/acre in June 1991. Soil pH 18 months after lime application was 5.1, 5.6, and 6.1 for the 0, 1.5, and 3.0 ton/acre lime treatments, respectively. The varieties Hill 81, Madsen, and Stephens were then seeded on September 10, 20, and 30, 1991. Lime did not reduce disease incidence or severity in the first crop year after application, however, there were large differences among seeding dates and varieties. As expected, delaying seeding reduced disease and increased yield. Unexpected was the fact that both Hill 81 and Madsen had significantly higher yields than Stephens, but about the same amounts of disease. In other words, Madsen and Hill 81 were better able to tolerate the disease than Stephens, which resulted in a higher yield.

Growing disease resistant varieties offers the most reliable method of controlling Cephalosporium stripe, however, varieties with high levels that are adapted to the Inland Pacific Northwest are not available. Although some wheat varieties grown in Montana and Kansas have resistance to Cephalosporium stripe, the level of resistance is low and it is difficult to identify varieties with resistance in field plots. Better sources of resistance to Cephalosporium have been found in *Agropyron elongatum*, including some that were immune to the disease. The location and number of genes in *Agropyron* conferring resistance to the disease is not known, however. Along with Dr. S. Jones, we have obtained several of the best *Agropyron* lines and screened them for resistance to Cephalosporium stripe in the growth chamber. We have identified one of the *Agropyron* chromosomes that carries at least one resistance gene, and are now trying to move that gene into wheat without the other negative traits from *Agropyron*. Ultimately, we want to develop molecular markers for these resistance genes in order to accelerate the development of Cephalosporium stripe resistant varieties. Molecular markers are like "tags" placed on the actual resistance genes that allow us to follow them in crosses and determine which progeny plants have the resistance genes. This approach eliminates the need to continually screen for disease resistance in field plots.

From about 1978 to 1989, strawbreaker foot rot was successfully controlled with a fungicide application in the spring before jointing began. In 1989 and 1990, resistance to these fungicides (Benlate, Mertect, and Topsin-M) in the foot rot fungus was discovered in 20% of the 225 commercial winter wheat fields surveyed in Washington, Oregon, and Idaho. Fungicide application was not effective in controlling disease or providing a yield increase in many of the fields where fungicide resistance was found. Due to the fact that all of the fungicides listed above have the same mode of action, once resistant, the fungus becomes it is resistant to all three fungicides; a phenomenon known as "cross-resistance." Methods other than fungicides are now needed to control Strawbreaker foot rot.

The use of disease resistant varieties, and/or fungicides with different modes of action, are two areas being investigated for foot rot control. Madsen and Hyak were the first two varieties released with high levels of resistance to foot rot. It is important to know that foot rot will still develop on these varieties, however, in most years it will not be severe enough to require fungicide application. All future varieties must have resistance to foot rot equal or greater than Madsen and Hyak.

Improving methods of screening wheat genotypes for resistance to Strawbreaker foot rot is a high priority. Currently, recognizing breeding lines or varieties with resistance is time-consuming and not completely accurate. We are trying to measure the amount of fungus in seedlings inoculated with the foot rot fungus as a way of identifying resistant plants. When tested under the same conditions, plants with resistance should have less fungus present than susceptible plants. Put another way, the foot rot fungus grows unimpeded in susceptible plants, but meets with many roadblocks in resistant plants. Robert de la Peña, a graduate student, is using a commercial immunodiagnostic kit and a genetically marked strain of the foot rot fungus to specifically and quantitatively measure growth of the foot rot fungus, *P. herpotrichoides*, in plants. Once the foot rot resistant plants are identified, we can then develop molecular markers to identify disease resistance genes, which should hasten the development of strawbreaker foot rot resistant varieties with greater accuracy than is now possible in the field. Cooperating on this work is Dr. S. Jones, USDA-ARS wheat geneticist.

Occasionally, fungicides are needed even with the current resistant varieties, and for that reason we continue to test new fungicides. Results of an experiment with Cashup wheat in a field near Garfield, WA are summarized in Table 1. Treatments are listed in the order of best to worst disease control. Disease incidence is the percentage of stems with foot rot at the watery-ripe stage and ranges from 0 to 100%. Disease severity is on a 1-4 scale, where 1=a minor lesion and 4=a severe lesion that will or has killed the stem. In this experiment, the untreated control had a high percentage of infected stems, but the severity was only 2.3. Under most conditions, yield losses become apparent only when disease severity is greater than 2.0. Approximately 25% of the foot rot fungus isolates in this field were resistant to the fungicides Benlate, Mertect, and Topsin-M in the laboratory. A significant level of fungicide resistance was present in this field, and was revealed by the lack of disease control and yield improvement with the 'standard' fungicide treatments Benlate and Mertect. Currently, Tilt is the only fungicide registered for foot rot control having a different mode of action than the standard materials. Tilt can be applied with a half rate of one of the other three foot rot fungicides. Several of the experimental fungicide treatments look very promising as potential replacements for the current treatments and we are again testing several of them for disease control and yield increase.

Table 1. Strawbreaker foot rot Fungicide Trial, Pfaff Farm, Garfield, WA 1991-1992.

Treatment, rate a.i./Ac.	% Infected Stems	Disease Severity	Yield, bu/Ac	Test Wt., lbs/bu
Tilt 3.6E + Benlate WP 2.5 oz + 0.28 lb	79.9	2.0	112.2	57.2
RH7592 + Benlate +Triton CS7, 4.0 oz + 0.28 lb + 2 pts/100 gal	81.6	1.8	114.2	57.2
Punch 25EC + Benlate, 4.5 oz + 0.11 lb	82.0	2.0	120.4	58.4
Punch 25EC, 3.0 oz	82.9	2.1	108.5	57.3
RH7592 + Triton CS7, 2.0 oz + 2 pts/100 gal	84.0	2.0	98.0	55.8
Punch 25EC + Benlate WP, 3.0 oz + 0.07 lb	85.3	1.9	109.8	57.1
Benlate WP, 0.57 lb	85.8	2.1	96.5	56.4
Punch 25EC, 2.0 oz	86.3	2.3	99.2	56.1
Tilt 3.6E, 1.7 oz	88.4	2.2	101.2	56.6
RH7592 + Triton CS7, 4.0 oz + 2 pts/100 gal	88.6	2.1	98.8	56.2
RH7592 + Benlate + Triton CS7, 2.0 oz + 0.28 lb + 2 pts/100 gal	89.7	2.1	104.4	56.9
Untreated control	90.9	2.3	91.9	55.9
Mertect DF, 0.76 lb	91.3	2.2	102.7	55.9
LSD **(P=0.05)	11.1	0.2	11.3	1.1

* -Treatments currently registered for strawbreaker control are indicated in **bold**.

** -LSD= the least significant difference; Two numbers in the same column must differ by this amount to be considered statistically different.

CONTROL OF STRIPE RUST, LEAF RUST AND STEM RUST

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General Characteristics. Three rusts (stripe rust, leaf rust, and stem rust) occur on wheat in the Pacific Northwest. Stripe rust appears as golden-yellow, long, narrow stripes on the leaf surface and glumes; leaf rust appears as small, red pustules on the leaf surface and leaf sheath; and stem rust appears on the stems and as 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 wheat 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 have occurred in fields of susceptible varieties in three out of four years. 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, and Arizona. It is currently (1993) causing major damage to barley in Arizona. 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.

As we develop 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 15% in one out of two years since 1974. In irrigated fields, leaf rust can cause 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.

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-one stripe rust races have been identified of which 42 have been detected in eastern Washington.

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

[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.

In 1992, 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-51).

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 1992.

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 barberry.

Effect of Weather. The rusts are obligate parasites and must have a living host to grow on. The continual presence of living wheat plants 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 winter and spring temperatures has proved to be reliable since 1979. When that information is used with precipitation data, 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 35,000 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, and LS86263 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. 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 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.