Washington State University

Department of Crop and Soil Sciences

Technical Report 92-1

1992 Field Day Proceedings:

Highlights of Research Progress

Dryland Research Unit, Lind
June 18, 1992

Palouse Conservation Farm, Pullman
June 25, 1992

Spillman Farm, Pullman
July 1, 1992

Baird Miller, Editor

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

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A DEDICATION TO

DR. CARL F. ENGLE

Dr. Carl F. Engle, Professor of Soil Science, retired on April 1, 1992 after 28 years of professional service. He started at Washington State University in 1970 and served as Extension Soil Specialist in the Crop and Soil Sciences department for the past 21 years. His major responsibilities at Washington State University centered around soil management problems in eastern Washington, Oregon and northern Idaho for erosion and soil sediment control in dryland cropping systems. His work focused on the effects of conventional and conservation tillage upon water quality and the conversion of crop lands into the federal conservation reserve program (CRP). He was heavily involved with the SCS, STEEP and other programs in the Pacific Northwest where he did much to make soil management and water conservation an active component of the extension program at WSU. He was part of the STEEP program from its beginning in 1970 and for a number of years as the only extension participant promoting STEEP.

Before coming to WSU Dr. Engle was on the faculty at West Virginia University from 1964 until 1967, where he taught courses and conducted research in soil fertility and soil physics. In 1967 he was appointed to an extension position in soil fertility and soil test correlations until 1970, when he left to assume a new position at WSU.

While at Washington State University Carl played a significant role in the adaptation of conservation and no-till technology for Washington. He coordinated the Palouse Conservation Research Field Day for many years, which annually showed the results of tillage and residue research efforts for the Palouse and similar cropping areas. Carl worked closely with the SCS and several State Conservation Districts on various aspects of the 1990 Farm Bill.

In 1957 Dr. Engle helped establish the first university-based state soil characterization lab at Penn State with the late Roy P. Matelski, Professor of Soil Technology. This statewide soil database has been invaluable for use to this current day in GIS (Geographic Information Systems).

Carl is a member of the American Society of Agronomy, Soil Conservation Society of America and many other organizations. He received the professional service award in 1985 from the Washington Association of Conservation Districts for outstanding service in support of soil and water conservation. He received the blue ribbon award for his extension publication series from the American Society of Agricultural Engineers in 1984 and 1988. Carl was presented a certificate of appreciation from the Cooperative Extension System in recognition of his creativity, contributions and efforts on behalf of the National Extension Task Force on Conservation and Management of Natural Resources in 1988.

Carl and his wife Christine plan to remain in Pullman, Washington, and spend more time with their four children and numerous grandchildren. He also likes to play golf. Dr. Engle commented at his retirement party that he has many fond memories of his career at Washington State University, but would probably miss working with growers on land problems more than anything else. We wish Carl and Christine the very best in the years ahead and hope they will drop by to see us often when they can find the time.

A DEDICATION TO

DR. ROGER L. WILSON

Dr. Roger Wilson retired this spring after serving the past 13 years as Area Director for Tennessee Valley Authority, while stationed at Pullman, WA. His thirty years of professional endeavors are marked by distinguished service in facilitating improvements in crop and soil management in the western U.S. Roger has devoted much of his career to solving agronomic and agribusiness related problems. He has promoted best management practices in fertilizer technology and management for improving crop yields, profitability, while minimizing effects on water quality.

Dr. Wilson began his formal agronomic training in Utah, where he earned a B.S. in Agronomy at Utah State University. He then moved to Philipsburg, Montana where he worked as a soil scientist for the Soil Conservation Service. At the same time, he enrolled at Montana State University, earning an M.S. in Agronomy in 1962. Roger then became a county agent with the Cooperative Extension Service at Bozeman, while he pursued his Ph.D. degree at Montana State University. Upon receipt of his degree in 1970, he accepted a position as Extension Soil Scientist, remaining in Bozeman until 1979. He authored several fertilizer guides on nutrient management of agronomic crops.

Dr. Wilson then moved to Pullman, WA, where he has served as Area Director for the National Environmental and Fertilizer Research Center, a branch of Tennessee Valley Authority (TVA). Roger has promoted TVA sponsored programs in fertilizer technology and nutrient management in six western states. He has also administered TVA funding for numerous soil fertility related research projects in Washington, Idaho, Oregon, Montana, Hawaii, and Alaska. These projects have helped to determine proper fertilizer rates, timing, and methodologies of application on a wide range of agronomic crops. In addition, he has supported fundamental research designed to help us better understand rotation and residue management effects on crop growth and development, and nutrient cycling.

Not only has Dr. Wilson collaborated with university researchers, but he has also devoted much of his time to working with the fertilizer industry and with individual growers. He has been the extension arm of Tennessee Valley Authority, providing technical information and advice to the industry on such matters as fertilizer developments at TVA and on-farm fertilizer management practices. Most recently, Roger has worked closely with fertilizer dealers in helping them to 1) better understand the issues of fertilizer containment in relation to environmental protection, 2) anticipate and prepare for pending governmental regulations on fertilizer handling, and 3) extend TVA expertise in establishing proper on-site facilities for fertilizer handling, waste storage, and containment. He recently worked with a local fertilizer dealer in constructing a new fertilizer plant facility that is now cited as a national model for safe handling of agrichemicals.

While in Pullman, Roger and his wife Orma have been active in numerous civic club and church activities. From all who know and have worked with Roger and Orma over the past years, we wish them the very best as they move to Colorado to begin the next chapter in their lives.

COOPERATIVE PERSONNEL AND AREA OF ACTIVITY

Samuel Smith..........................President, Washington State University
L. E. Schrader.................Dean, College of Agriculture & Home Economics
J. J. Zuiches...........Director of Research, College of Ag. & Home Economics
L. G. James.......................Interim Director of Cooperative Extension
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Cereal Breeding, Genetics and Physiology

R.E. Allan, J.A. Pritchett, L.M. Little, USDA.................Wheat Genetics
E. Donaldson, B. Sauer, Dry Land Res. Unit, Lind......................................HRW, HWW Wheat Breeding
C.F. Konzak, M.A. Davis, Gary Shelton.........................Spring Wheat Breeding & Genetics
S.E. Ullrich, C.E. Muir, J.A. Clancy, J.S. Cochran, J.B. Davis....................Barley Breeding & Genetics
R.A. Nilan..Barley Genetics
A. Kleinhofs, C.M. Stiff, V. McCamant.......................Barley Genetics
C.J. Peterson, D.F. Moser, V.L.DeMacon...................SWW Wheat Breeding
R.L. Warner, A. Kleinhofs......................Barley Evaluation Laboratory
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M.K. Walker-Simmons, R.J. Anderberg, J. Curry, L. Holappa, J. Ried, USDA..................Cereal Physiology
P. Chevalier...Cereal Physiology
J.D. Maguire...Seed Physiology

U.S.D.A. Western Wheat Quality Laboratory

C.F. Morris............................Research Cereal Chemist and Director
H.C. Jeffers...................................Research Food Technologist
A.D. Bettge, D. Engle, M.A. Baldridge, D.Smith, R. Ader..Technicians
G.E. King, B. Davis...................................Early Generation Testing

Cereal Diseases

S.D. Wyatt, T.D. Murray...........Cereal Viruses, Foot Rots & Other Diseases
R.J. Cook, D. Weller, L. Thomashow, Coop. USDA.............Soilborne Diseases
R.F. Line, Cooperative USDA...................Rusts, Smuts, Foliar Diseases

Breeding and Culture of Dry Peas, Lentils and Chickpeas

F.J. Muehlbauer, J.L. Coker, R. Short, S. Spaeth, and C.J. Simon, USDA

Weed Management

A.G. Ogg, F.L. Young, and D.R. Gealy, USDA, E.P. Fuerst, C. Boerboom

Fertility Management and Conservation Systems

W.L. Pan, D. Granatstein, R.I. Papendick, D. McCool, K. Saxton, and J. Smith, USDA

Soil Microbiology

D.F. Bezdicek, A.C. Kennedy, A. Ogram

Soil Physics

G.S. Campbell

Agricultural Economics
D. Young

Animal Nutrition
J. Froseth, D.C. Honeyfield, C.L. Wyatt

Foundation Seed Service
Greg Vollmer

Plant Germplasm Introduction and Testing
Clarence Kelly, Manager, and Richard Johnson

Spillman Farm Manager
D.A. Deerkop

Dry Land Research Unit Farm Manager
Dick Hoffman

ACKNOWLEDGEMENT OF CONTRIBUTORS IN SUPPORT OF 1991-92 RESEARCH

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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WA Barley Commission
WA State Dept. of Agriculture

Dry Land Unit, Palouse Conservation Station and Spillman Farm Field Days Contributors

American Malting Barley Assn.
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Palouse Conservation District
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Fletcher Brothers	Dayton
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Juris Farms	Dayton
Ray Kamerrer	Pullman
Koller Farms	Mayview
Jerry Krause	Creston
Dale Lyon	Pullman
Steve/Dan Mader	Pullman
Eric Maier	Ritzville

Farmer Cooperators

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Mac Mills	St. John
Don/Steve/Dan Moore	Dusty
Maurice Piersol	Rosalia *
Dick Reid	Craigmont ID
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Bryce Stephenson	Lacrosse
Elmo/Larry/Jerry Tanneberg	Coulee City
Mark Thompsen	Waterville
T16 Ranch	Lind
Reggie Waldher	Pomeroy
Don/John Wellsandt	Ritzville
Fred Widman	Fairfield
Bob Wigen	Dusty
Ron/Dick Wilbourn	Pullman
Lyle Wiltse	Deer Park
George Wood	Dayton

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 76th 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.

	Temperature °F.		Precipitation		Precipitation
Month	Max.	Min.	1991	1992	71 yrs Av (in)
January	34	22	.65	.97	1.00
February	42	24	.53	1.29	.86
March	53	32	1.79	.26	.82
April	63	35	.50	1.31	.69
May	72	42	.85		.79
June	83	45	1.01		.81
July	90	52	.12		.25
August	90	50	.25		.36
September	79	45	.17		.55
October	65	38	.47		.85
November	47	29	2.14		1.23
December	37	26	.48		1.25
			8.96		9.46

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, 1991-92

Month	Monthly Avg. Temperature(F)		Precipitation (in)				
	Max.	Min.	30-Yr Avg.*	Monthly	Total Accum.	Deviation from Avg. Monthly	Deviation from Avg. Accum.
1991							
January	34.5	23.3	2.89	2.01	2.01	- .88	- .88
February	49.8	33.9	2.09	.84	2.85	-1.25	-2.13
March	46.2	30.4	1.96	2.61	5.46	+ .65	- .48
April	56.7	34.6	1.58	1.35	6.81	- .23	-1.71
May	60.5	39.5	1.52	3.28	10.09	+1.76	- .06
June	66.0	43.7	1.49	1.94	12.03	+ .45	+ .50
July	82.8	48.8	.53	.24	12.27	- .29	+ .21
August	85.9	51.3	.95	.43	12.70	- .52	- .31
September	78.9	42.5	.99	.03	12.73	- .96	-1.27
October	61.7	34.0	1.61	.78	13.51	- .83	-2.10
November	42.8	32.1	2.64	3.57	17.08	+ .93	-1.17
December	41.2	30.4	3.07	1.17	18.25	-1.90	-3.07
TOTAL	58.9	37.0	21.32		18.25		-3.07
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
TOTAL			8.52		7.43		-1.09
1991 CROP YEAR Sept. 1990 thru June 30, 1991			19.84		20.7		+ .33

*Thirty year average for precipitation, 1951-1980

SOFT WHITE WINTER WHEAT IMPROVEMENT

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

Washington wheat growers harvested 40.6 million bushels of winter wheat in 1991 for an average yield per acre of 58 bushels. Approximately 58.0 million bushels of spring wheat was harvested for a 40 bushels per acre average. The winter was very severe and Approximately 70 percent of the winter wheat was killed. The spring was cool and fairly wet which help produce some good to excellent yields. The diseases that reduced yields in some areas were Cephalosporium stripe, dryland foot rot, take all, stem rust and leaf rust.

Rod (WA007662, VH086208, Luke/Daws//Hill81) was released in 1991 and foundation will be 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.

Kmor and Eltan performed quite well in 1990/91. Eltan continued to express good winter hardiness. Kmor did not respond as well as it did in 1988/89. Kmor was no better than Lewjain. Both Eltan and Kmor are quite susceptible to stem rust which was prevalent in 1990/91 because the nurseries were slow to ripen.

ELTAN is a semidwarf soft white winter wheat that is resistant to snow mold, dwarf bunt, and common bunt. It has an awned, lax spike with white glumes. Eltan has good winter hardiness, moderately weak straw, and is late in heading. It is moderately susceptible to the local races of stripe rust, and is susceptible to leaf, and stem rust. When the grain production was averaged over 47 site years Eltan produced 1.3, 2.3, 4.4, and 11.4 percent more grain per ha than Lewjain, Madsen, Daws and Stephens, respectively. It is approximately 2.5 cm taller than Daws. Straw strength of Eltan is similar to that of Lewjain and better than that of Sprague. It is similar to Lewjain in maturity. Volume weight of Eltan is equal to that of Daws and the grain protein of Eltan is equal to or lower than that of Daws. Tests conducted by the USDA-ARS Western Wheat Quality Laboratory have found that Eltan has satisfactory milling and baking quality. Eltan was named in honor of Elmo Tannenberg, a wheat producer from Douglas county. Mr. Tannenberg has been an excellent supporter of the wheat research program and has work to improve wheat production in Washington. Foundation seed will be available in 1991. Eltan was developed by WSU and ARS-USDA.

KMOR has the same winter hardiness as Lewjain and will emerge better than Daws. It has an awned lax spike with white glumes. Kmor moderately weak straw, and is medium to late in heading. It is resistant to the local races of stripe rust and is susceptible to snow mold, leaf rust, and stem rust. Kmor is moderately resistant to Cephalosporium stripe, strawbreaker foot rot, common bunt, and dwarf smut. When the grain production was averaged over 47 site years Kmor produced 5, 6, 8.5, and 18.6 percent more grain per ha than Lewjain, Madsen, Daws and Stephens, respectively. Kmor is approximately 8 cm taller than Daws and it matures about 2 days later than Daws. Volume weight of Kmor averaged 2% below that of Daws and the grain protein of Kmor is equal to or lower than that of Daws. Tests conducted by the USDA-ARS Western Wheat Quality Laboratory have found that Kmor has satisfactory milling and baking quality. Kmor was named in honor of the former Extension Agronomist, at Washington State University, Dr. K.J. Morrison. Foundation seed will be available in 1991.

Two lines (WA007686, WA007687) that were entered in the regional nursery in 1990 were among the best lines in the 1990/91 nurseries. Two new lines (WA007729, and WA0077730) were entered in the 1991/92 Western Regional Nursery. WA007729 is a club wheat.

Nurseries.

The WSU soft white winter wheat nurseries were grown at Pullman (early and late), Pomeroy, Walla Walla, Coulee City, and Cavendish, Idaho. Ritzville and Cunningham nurseries were killed by the cold weather. Kmor (76.9 bu/a) was the best commercial cultivar when the grain yields were averaged across all locations and years (table 1) and Eltan (74.66 bu/a) was second. Hyak (72.57 bu/a) was the best commercial club wheat.

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 was reduced over the years by both strawbreaker foot rot and Cephalosporium stripe. Kmor (76.3, 82.9) was the highest yielding cultivar in both treatments. Madsen (74.1 bu/a) was second when inoculated with Cercosporella foot rot and Lewjain (79.1 bu/a) was second in the control plots. Hyak (71.3, 70.4 bu/a) was the highest yielding club wheat under both treatments.

The Pullman Late nursery (table 3) is 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 (95.9, 92.5 bu/a) produced the most grain of the commercial cultivars across treatment and over years. Madsen (92.9) was second under the medium nitrogen treatment and Hill 81 was second under the high nitrogen treatment. Hyak (91.6, 86.6 bu/a) was the highest yielding club wheat under both treatments.

The Pomeroy nursery (table 4) is generally sown the middle of September. When the yields were averaged over years Kmor (70.3 bu/a) was the highest yielding commercial cultivar and Eltan (66.5 bu/a) was second. Hyak (65.4 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 Malcolm (97.4 bu/a) was the highest yielding commercial cultivar and Eltan (93.4 bu/a) was second. Hyak (93.4 bu/a) was the best club wheat.

The Ritzville nursery (table 5) is sown the first week in September. The 1990/91 nursery was killed by the cold weather. Kmor (59.50 bu/a) was the highest yielding commercial cultivar and Lewjain (58.17) was second. Tres (57.50 bu/a) was the highest yielding club wheat.

The irrigated nursery at Cunningham (table 6) is sown around the end of September. When the yields were averaged over years Malcolm (113.33 bu/a) was the highest yielding commercial wheat and Daws (108.5) was second. Crew (96.2 bu/a) was the highest yielding club wheat.

The nursery at Coulee City (table 7) is sown around the end of August. When the yields were averaged over years Eltan (49 bu/a) was the highest yielding commercial wheat and Kmor (46 bu/a) was second. The grain production of Sprague averaged 39.8 bu/a. Kmor has very little resistance to snow mold.

Table 1. Average yield data (bu/a) on 13 winter wheat varieties grown for eight years (1984-91) (six years at Ritzville and Cunningham) at seven locations in Washington and one in Idaho.

	WA01	WA01	WA02	WA02	WA14	WA15	WA17	WA53	WA54	ID22	Average
Nugaines	55	64	76	75	62	81	47	88	73	48	67
Stephens	59	56	77	72	58	92	43	104	37	50	65
Daws	65	69	89	83	65	92	55	109	42	55	72
Dusty	61	72	92	88	64	92	53	103	43	59	73
Lewjain	71	79	87	82	65	87	58	101	43	58	73
Hill81	66	73	92	92	66	92	51	105	39	55	73
Malcolm	56	60	83	80	66	98	48	113	41	56	70
Madsen	74	76	93	88	66	93	55	105	36	58	74
Crew	62	70	81	79	64	88	55	96	40	54	69
Tres	58	69	86	83	62	89	58	93	42	61	70
Hyak	71	70	92	87	65	93	56	95	37	59	73
Kmor	76	83	92	89	70	94	60	99	46	60	77
Eltan	63	78	96	93	67	95	56	92	49	60	75

WA01 = Pullman Early, WA02 = Pullman Late, WA14 = Ritzville, WA15 = Walla Walla, WA17 = Ritzville, WA53 = Cunningham, WA54 = Coulee City and ID22 = Cavendish,ID.

Table 2. Yield data (bu/a) on 15 winter wheat varieties gown at Pullman (early), WA for eight years.

Inoculated with the Strawbreaker foot rot organism.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Nugaines	46	57	65	31	66	80	37	54	54.5
Stephens	19	48	73	57	65	101	61	44	58.5
Daws	51	64	90	38	84	117	42	35	65.1
Dusty	50	59	58	38	77	112	44	53	61.4
Lewjain	61	72	92	49	69	109	53	59	70.5
Hill81	54	63	80	47	81	102	47	52	65.8
Malcolm	20	53	70	53	55	90	67	36	55.5
Madsen	54	81	81	67	78	101	92	39	74.1
Crew	53	72	67	29	70	95	53	56	61.9
Tres	49	66	67	43	53	93	41	54	58.3
Hyak	47	78	95	66	63	83	69	69	71.3
Kmor	52	70	95	63	93	110	53	74	76.3
Eltan	69	65	70	32	58	112	42	57	63.1
Rod				65	60	98	48	45	
Rely				41	65		35	54	

Treated to control Strawbreaker foot rot

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Nugaines	46	70	73	42	62	82	84	54.0	64.1
Stephens	25	53	77	70	45	96	78	7.0	56.4
Daws	53	74	92	48	66	101	81	38.0	69.1
Dusty	50	70	97	62	52	110	94	44.0	72.4
Lewjain	67	79	101	60	73	106	90	57.0	79.1
Hill81	57	70	88	65	69	108	93	36.0	73.3
Malcolm	21	58	81	57	52	90	71	49.0	59.9
Madsen	48	73	85	77	82	102	101	39.0	75.9
Crew	51	80	82	47	61	94	89	53.0	69.6
Tres	50	74	82	57	62	109	67	48.0	68.6
Hyak	42	74	80	73	62	94	84	54.0	70.4
Kmor	57	75	115	78	73	105	87	73.0	82.9
Eltan	74	77	93	57	69	103	87	60.0	77.5
Rod				67	70	104	109	37.0	77.4
Rely				53	77		83	41.0	

Table 3. Yield data (bu/a) on 15 winter wheat varieties grown at Pullman (late), WA for eight years.

Medium Fertility

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Nugaines	71	54	57	81	59	106	110	70	76.0
Stephens	82	48	62	106	72	98	134	10	76.5
Daws	84	49	85	107	64	97	114	114	89.3
Dusty	97	61	86	106	83	108	120	71	91.5
Lewjain	76	54	92	99	86	112	114	61	86.8
Hill81	84	54	74	109	79	106	136	91	91.6
Malcolm	67	52	69	113	88	116	121	36	82.8
Madsen	98	69	88	103	86	114	125	60	92.9
Crew	86	54	78	92	62	98	120	57	80.9
Tres	83	60	68	101	83	108	115	73	86.4
Hyak	106	60	78	95	73	108	121	92	91.6
Kmor	86	61	94	106	90	114	116	68	91.9
Eltan	93	66	78	90	83	122	122	113	95.9
Rod				115	94	129	119	37	
Rely				97	81		114		

High Fertility

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Nugaines	70	49	62	79	58	110	95	75	74.8
Stephens	82	50	69	87	69	98	108	14	72.1
Daws	82	54	77	92	67	102	87	99	82.5
Dusty	90	58	83	100	84	117	112	62	88.3
Lewjain	80	53	85	97	76	104	85	78	82.3
Hill81	87	57	70	113	76	102	122	106	91.6
Malcolm	78	55	79	106	93	111	95	24	80.1
Madsen	91	63	82	92	82	104	111	77	87.8
Crew	93	49	73	80	60	102	104	67	78.5
Tres	84	59	73	91	78	97	110	75	83.4
Hyak	95	54	66	91	75	102	109	101	86.6
Kmor	88	58	94	102	90	110	91	81	89.3
Eltan	79	69	79	108	84	116	88	117	92.5
Rod				111	94	123	113	49	
Rely				94	72		117		

Table 4. Yield data (bu/a) on 15 winter wheat varieties grown at Pomeroy, WA for eight years.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Nugaines	57	51	54	59	52	61	74	85	61.6
Stephens	38	36	69	69	52	61	78	61	58.0
Daws	67	40	73	61	51	66	69	90	64.6
Dusty	66	45	77	63	44	67	69	77	63.5
Lewjain	69	41	72	67	54	64	70	85	65.3
Hill81	73	38	64	67	49	71	72	92	65.8
Malcolm	65	46	65	68	54	66	90	72	65.8
Madsen	73	45	70	60	52	63	85	81	66.1
Crew	73	38	70	67	50	69	71	72	63.8
Tres	55	42	75	68	47	70	67	74	62.3
Hyak	76	43	68	63	47	66	79	81	65.4
Kmor	93	48	75	65	51	74	72	84	70.3
Eltan	80	48	61	58	57	68	68	92	66.5
Rod				68	60	76	75	93	
Rely				67	51		72		

Table 5. Yield date (bu/a) on 15 winter wheat varieties grown at Walla Walla, WA for eight years.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Nugaines	89	54	70	77	47	104	91	115	80.9
Stephens	131	58	86	93	62	91	87	130	92.3
Daws	120	59	84	87	68	104	92	118	91.5
Dusty	137	76	92	89	64	96	89	93	92.0
Lewjain	123	68	85	87	65	86	85	95	86.8
Hill81	120	66	85	93	67	99	87	118	91.9
Malcolm	109	64	96	102	67	114	95	133	97.5
Madsen	128	65	90	86	69	100	80	123	92.6
Crew	113	59	92	89	61	89	91	108	87.8
Tres	118	64	94	84	63	101	97	94	89.4
Hyak	140	66	88	89	65	95	96	108	93.4
Kmor	132	70	88	95	66	98	95	106	93.8
Eltan	134	71	81	95	71	109	85	111	94.6
Rod				100	74	113	89	116	
Rely				89	65		88		

Table 6. Yield data (bu/a) on 14 winter wheat varieties grown at Ritzville, WA for six years.

	83/84	84/85	85/86	86/87	87/88	89/90	Average
Stephens	29	36	42	52	37	64	43.33
Daws	81	38	55	55	49	54	55.33
Dusty	60	47	49	58	48	56	53.00
Lewjain	78	46	54	57	53	61	58.17
Hill81	63	40	44	55	43	60	50.83
Malcolm	49	40	39	61	39	62	48.33
Madsen	68	41	51	55	51	65	55.17
Crew	74	43	51	57	48	58	55.17
Tres	71	49	54	66	44	61	57.50
Hyak	74	46	51	49	53	62	55.83
Kmor	77	51	59	55	53	62	59.50
Eltan	78	52	51	46	50	57	55.67
Rely				54	48	61	
Rod				63	54	63	

Table 7. Yield data (bu/a) on 14 winter wheat varieties grown at Cunningham, WA (Irrigated) for six years.

	83/84	84/85	85/86	86/87	87/88	89/90	Average
Stephens	82	96	105	112	89	141	104.17
Daws	120	100	122	100	90	119	108.50
Dusty	85	120	110	80	100	124	103.17
Lewjain	121	116	113	59	100	96	100.83
Hill81	103	92	118	102	88	127	105.00
Malcolm	93	121	123	116	101	126	113.33
Madsen	109	111	95	93	93	127	104.67
Crew	89	106	122	67	89	104	96.17
Tres	82	112	121	68	92	82	92.83
Hyak	85	113	113	78	81	98	94.67
Kmor	106	119	117	58	89	104	98.83
Eltan	108	112	107	61	91	73	92.00
Rely						114	
ROD				96	105	131	

Table 8. Yield data (bu/a) on 19 winter wheat varieties grown at Coulee City, WA for eight years.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Nugaines	65	28	55	28	48	39	53	26	42.8
Stephens	47	29	39	29	55	36	52	12	37.4
Daws	42	40	46	36	49	45	52	28	42.3
Dusty	57	35	39	39	52	38	55	27	42.8
Lewjain	67	31	41	32	48	44	51	28	42.8
Hill81	50	34	33	33	43	39	51	25	38.5
Malcolm	47	27	47	26	53	44	61	26	41.4
Madsen		29	37	32	40	45	48	21	
Crew	64	34	35	32	53	34	47	24	40.4
Tres	60	40	42	35	45	37	46	28	41.6
Hyak		30	42	29	51	39	46	25	
Kmor	59	44	42	39	61	44	53	27	46.1
Eltan	60	45	45	31	64	48	59	39	48.9
Rod				24	50	40	56	14	
John	44	38	37	34	44	35	50	36	39.8
Sprague	36	38	44	40	50	37	44	29	39.8
Andrews	50	36	34	31	45	36	51	26	38.6
Weston	38	36	31	33	46	40	39		
Rely					45		52		

Table 9. Yield data (bu/a) on 14 winter wheat varieties grown at Cavendish, ID.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	Average
Nugaines	52	43	38	43	35	40	74	56	47.6
Stephens	45	49	42	45	45	61	82	27	49.5
Daws	43	44	48	46	56	73	78	53	55.1
Dusty	46	64	50	44	57	75	67	70	59.1
Lewjain	43	55	50	55	64	71	71	58	58.4
Hill81	45	52	47	53	57	49	82	52	54.6
Malcolm	40	57	38	56	70	50	85	52	56.0
Madsen	46	57	40	44	61	70	85	64	58.4
Crew	51	56	47	43	37	58	81	61	54.3
Tres	43	66	46	54	68	72	76	65	61.3
Hyak	56	55	41	38	64	71	81	67	59.1
Kmor	50	59	35	53	67	84	75	58	60.1
Eltan	42	58	50	54	61	81	67	66	59.9
Rod				54	67	78	79	58	
Rely				43	63		81		

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

USDA-ARS WHEAT GENETICS RESEARCH

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

Club and Common Wheat Winter Wheats for Low-Rainfall Zones

Wheat varieties with semidwarf growth habit have had little impact in the low-rainfall zones of the Pacific Northwest. Stand establishment is the main varietal adaptive requirement for this region. All of the varieties having the most widely used semidwarf genes (*Rht_1* and *Rht_2*) have less than adequate stand establishment characteristics. Moro remains the most important club variety produced in the low rainfall zone because it has excellent stand establishment properties. All soft white winter (SWW) common wheat varieties are either *Rht_1* or *Rht_2* semidwarfs. Hence the growers generally must grow either Moro or hard red winter varieties, which generally have low yield potential. Moro also has low yield potential, weak straw and not the best club wheat quality. Moro is also susceptible to some of the newer races of stripe rust.

A project has been initiated to develop suitable club and common white winter replacements for Moro. One short-term strategy is to convert some well-adapted semidwarf club and common SWW varieties to nonsemidwarf types. Fortunately we have been conducting a genetics study on the effect of semidwarf genes on the adaptation of several wheat varieties and we already had available several backcross populations in which we have produced nonsemidwarf versions of Tres, Daws, Nugaines and Stephens. These standard height selections have been placed in a yield trial near Connell.

Using semidwarf sources that do not adversely affect stand establishment is another strategy that we will use. Wheat breeders of eastern European countries utilized the *Rht_8* and *Rht_9* semidwarf genes in their programs and claim that these genes do no adversely effect emergence. So far our results using the *Rht_8* gene have been mixed. Field seedling vigor tests last summer suggested that *Rht_8* semidwarfs derived from early backcross populations of several regionally adapted varieties did not emerge notably better than Lewjain and Stephens. However, laboratory tests revealed that the *Rht_8* semidwarf gene did not reduce coleoptile length or impede seedling growth rate as occurs with the *Rht_1* and *Rht_2* genes. Field emergence tests on backcross derived PNW wheats with *Rht_8* gene should tell us whether this gene has adaptive value for the low-rainfall areas of the PNW.

Breeding for Stripe Rust Resistance and Other Foliar Diseases of Club Wheats

Rely, a club wheat multiline variety was released in 1991 and is intended to replace Crew. Rely is a mixture of 10 components. Each component has 1 or more different genes for resistance to stripe rust. This mixed form of resistance offers partial yet effective resistance to the stripe rust pathogen and should reduce club wheat production losses caused by the newer races attacking Tres and Hyak. Rely also has mixed resistance to leaf rust and powdery mildew. Rely has very good club wheat milling and baking quality. It is a definite improvement over Hyak for Japanese sponge cake quality and low flour viscosity.

Transferring unique genes for stripe rust resistance from the wild and weedy relatives of wheat into cultivated wheat is an important objective of our research. Research Assistant, Brett Sowers has studied the resistance derived from *Triticum dicoccoides*, which is a wild emmer form of wheat. He discovered that its resistance is explained by a single dominant gene that differs from all of the other genes that we are currently using in the USDA-ARS club wheat breeding program. A number of club wheat lines have been selected that have a high probability of possessing the new gene from *T. dicoccoides* as well as combined resistance from Tyee and Tres. Other lines from crosses involving Gaines have potential for carrying both the gene from *T. dicoccoides* and genes for adult plant resistance from Gaines. Mr. Sowers also showed that our advanced club wheat line WA7437 has a single gene for stripe rust resistance presumably derived from slender wheat grass. This gene has given durable resistance to stripe rust for over 12 years.

Exploiting adult plant resistance (HTAP) to stripe rust is now receiving the top priority in our club wheat breeding program. Germplasm selected by R.F. Line has HTAP resistance derived from Daws, Luke and Stephens. Numerous crosses have been made between Dr. Line's material and our better club lines with race specific resistance to combine these two different types of resistance. We are also testing advanced club wheat lines that have potential for adult resistance contributed by several northern European varieties including Cappelle, Bersee, Druchamp and Flenor.

Partial or incomplete resistance is often a good indicator of durable resistance to stripe rust. We selected over 800 lines from the USDA-ARS wheat collection for this trait. In 1991 we confirmed that 340 lines exhibited partial resistance and harvested 200 that also showed agronomic potential. These lines will be checked for seedling resistance to a composite of several races of stripe rust. Those that lack seedling resistance will be used as additional sources of durable resistance.

Modifying Wheat Growth and Development to Improve its Adaptation.

Nearly everyone knows how important the development of semidwarf wheats has been toward increasing wheat production in the Pacific Northwest, and throughout the world. Primarily by breeding in a single gene from Norin 10/Brevor, the yields of wheat were increased by 25%. We are attempting to favorably exploit other gene systems that modify the growth and development of wheat.

Our efforts are concentrating on genes that control: 1) spring vs. winter growth habit, 2) response to day length and 3) plant growth traits controlled by the cytoplasm.

<u>Spring vs. winter growth habit</u>

The Pacific Northwest is one of the only wheat producing regions in the world that can economically produce spring and winter wheat. This allows for greater flexibility in wheat market classes, their end product uses, crop management systems and distribution of inputs. We have nearly completed transferring four different vernalization (*Vrn*) response genes for spring growth habit into several of our winter wheats including Tres, Paha, Luke, Stephens, Nugaines and Wanser. Introducing these genes into adapted winter wheats could have immediate practical value. Currently there are no adapted club wheat varieties with spring growth habit. The severe winter killing of the 1991 wheat crop especially jeopardized club wheat production in the PNW. The option of planting spring or winter forms for club wheats and other market classes would be highly desirable and help to insure adequate supplies to customers of PNW wheat. Developing wheat varieties or germplasm with both spring and winter wheat growth habit also greatly facilitates wheat breeding. Many of the traits that we need to transfer into our winter wheats are controlled by only one or two genes. For example, the resistances to Russian aphid and to strawbreaker foot rot are controlled by single genes. We could greatly speed up developing a variety such as Luke that would have resistance to these two pests by transferring the trait by backcrossing several times to a spring habit Luke line and finally to normal Luke. Winter wheats that have been converted to spring forms will be on display at the 1992 Spillman Farm Field Day.

Daylength response

There are several different genes controlling daylength response. Daylength response greatly influences heading date and maturity. Global change, the current drought, and the reoccurrence of El Nino already have begun to adversely affect wheat production in the Pacific Northwest. Modifying heading date and maturity may be necessary to adapt wheat to our changing environment. We have nearly completed transferring 1 to 3 genes that control response to daylength into several SWW club, common and HRW wheat varieties. These genetic stocks should have considerable value as tools for both applied and basic wheat research. For example, our results show that under irrigation at Walla Walla the yields of Nugaines and Luke can be increased 5 to 15% by shortening their heading dates by 5 to 7 days. Shortening days to heading often increases kernel weight, which usually enhances milling score but may adversely affect kernel texture and cookie spread. As with vernalization response genes, the introduction of short daylength genes will expedite wheat breeding. By combining both short daylength with spring growth habit, we should be able to make 4 to 5 backcrosses per year versus 1 to 2 backcrosses for long-daylength winter wheat varieties.

From the standpoint of basic research, genetic stocks differing for spring vs. winter growth habit and for daylength response will help us determine how these processes are regulated. Plant growth substances are believed to regulate these systems. By having closely related lines differing only for the genes controlling spring vs. winter habit and for short vs. long daylength response plant biochemists should be able to learn the exact role plant hormones have in regulating these processes.

Cytoplasmically controlled traits

Because wheat has three diverse gene pools made up of numerous wild and weedy species the potential for exploiting traits controlled by diverse cytoplasms is impressive. There are over 16 different cytoplasms based on their variation in chloroplast and mitochondrial DNA. By transferring various nuclear genes of cultivated wheat into various cytoplasms useful variability can be obtained for several wheat growth traits. These include annual vs. perennial growth habit, heading date, spring vs. winter habit, cold hardiness, male sterility, seed dormancy and tillering capacity.

We recently completed a 3 year study involving 49 wheats with alien cytoplasms. Traits such as grain yield, kernel weight, harvest index, tillering capacity and test weight were favorably altered in 5% of the comparisons. Exploiting diverse cytoplasms had more potential in some varieties than others. Three different cytoplasms enhanced several traits of Tyee club wheat. By blending together Tyee lines having these three different cytoplasms, we should be able to increase its grain yield, bioyield, kernel weight and number of kernels per spike. In contrast alien cytoplasms seldom caused favorable changes in Luke.

SPRING WHEAT RESULTS 1991, PROGRESS 1992

Cal Konzak, Mike Davis, Gary Shelton, Mohamad Akram,
Shane Ball, Huaping Zhou, YuanMing Zheng

Based on WSU experimental results and reports from growers, yields of spring wheats in 1991 were generally good to exceptional. Penawawa and Edwall were the dominant SWS varieties, while Wakanz production, except that grown for seed was concentrated in the Lewiston, ID area because of its protection against the hessian fly. Seed of Wakanz produced in 1991 was sufficient for the Eastern Washington needs, thus Wakanz has displaced some of the Penawawa in 1992 plantings. Wampum retained its lead among the hard reds in 1991, possibly because of its greater availability and taller straw for the dry areas. However, Butte 86 was introduced in near record amounts, and reports from growers indicate considerable satisfaction with its earliness, yielding capacity, grain protein content, and moderately tall straw height. Butte 86 should continue to be useful to dry land wheat growers in the next years, and the variety has been planted extensively also in spring 1992. Among the semidwarfs, Spillman continued its good yield performance in experimental plots, and while its grain protein continues to be higher than Wampum at comparable yield levels, it did not outperform the privately bred cultivars, Express and WPB906R (or WPB926) in 1991 (Tables 1,2). Seed of Spillman is still in short supply. Spillman, nevertheless, continues to show good straw strength snd disease resistances. Other NDak cultivars, Stoa and Len appear to have promise, based on the 1991 data, and may merit wider evaluation by growers.

Management of WSU Breeder Regional Research Trials: Growers often have expressed interest in knowing the details of the management practices applied in the WSU Breeder Trials as evolved over the years. All fertilizer practices are based on prior soil test analyses (Table 3). The 1991 soil tests showed higher than usual soil moisture levels in the top 3 feet, but the values ranged widely depending on the area and previous cropping history. Sometimes, as is often the case at Lind, because of winter-kill crop losses in a prior season, the residual N level is high, and the P level may be considered adequate. Even so, we have found it beneficial to apply a starter fertilizer with the seed. The starter fertilizer must include 20-25 lb/a P2O5 and 7-10 lbs N appears useful. Seeding is usually completed as early as soil and weather conditions permit, i. e. it is never too cold or unpleasant to plant, if the soil conditions are right for proper tillage to be done. Because we grow wheats varying widely in rates of early development, we do not use systemic herbicides if avoidable, and have recently used a mix of Harmony and Buctril. On occasion, if russian thistle or other tough weeds are a problem, we sometimes will apply a mix of Bronate and Buctril, or under the worst conditions, only Bronate. Growers have wider choices of herbicides, because they will plant a single cultivar in a field and apply the herbicide at an appropriate growth stage for the whole crop, which we cannot do in our trials. We harvest the plots with an experimental combine, record yields when possible at the test site, or transport the samples to Pullman, and complete the recording of data. Most usually, one replicate of the harvested grain is saved for additional analyses and test weight determinations on recleaned grain, and for protein, milling and baking tests. We have found over the years also that spring wheats should be seeded in narrow (6-7") rows, irrespective of the location. We feel that the major soil moisture loss is from the soil surface, and by using narrow rows, the surface soil is covered more quickly, if at all, than is possible with wide row spacing. Young seedlings compete for nutrition and moisture very early in their development, and if seeds are too closely spaced in a row, there is a considerable loss of stand, and the consequent waste of water and nutrients that could be better exploited by plants that survive. We feel that we are now showing at least a 10% overall yield gain from the narrow row spacing, and will be selecting new cultivars best adapted to the limits, if any, placed upon them by this practice.

Possible new releases: As indicated above, hessian fly resistant lines of WA7176 will be increased and proposed for release in 1993 as a replacement for Wakanz. Its yield performance, quality properties, agronomic characteristics are similar to Wakanz, but it has a higher type of stripe rust resistance, hopefully, both adult plant and race specific resistances (Table 4). Breeder seed of WA7715 is being increased as a more uniform replacement for Wadual. WA7715 is a subline of Wadual, but has an improved combination of the brad and pastry-making quality properties, and is otherwise equal in other characteristics. An unusually widely adapted SWS line, WA7677 was approved for breeder seed increase as a possible replacement for Penawawa, Edwall and other standard soft white spring wheats. WA7677 stands out as the highest overall performing SWS wheat selected in the history of the WSU spring wheat program. It also has the record among SWS wheats for grain test weight. Unfortunately, WA7677 does not carry hessian fly resistance, and in 1992, a possible new race of stripe rust was found to attack it at Mount Vernon on the Pacific Coast. That may not be an important problem, because races at Mount Vernon able to attack Dirkwin and Owens have not moved to Eastern Washington. A new spring club wheat, WUC657 (W added because UC657 designates another line in CA), was approved for preliminary breeder seed increase, expecting that with another year's regional data, and more extensive pastry quality analyses, it can be released to growers. WUC657 appears to carry adult stripe rust resistance, as well as leaf and stem rust resistance. Some tests indicated WUC657 may have outstanding club quality, an exceptional advance in terms of a combination of desirable traits. One test milling suggested a possible bolting problem, which needs to be rechecked. Its yield performance is slightly below that of standard SWS wheats, but close enough, considering its earliness, that growers will use it in reseeding club wheats and for supplementing production when winter-killing reduces supplies. WUC657 was bred at UC Davis, CA. The breeder has agreed to make the material available to WSU and OSU who likely will cooperate in the release, and appears willing to assist with the production of Foundation seed. CA would likely join in the release.

Hessian fly: The 1991 fly infestations may have expanded in area due to the production of susceptible varieties either near or in conservation tillage situations. Any time residue remains on the soil surface from previous wheat (sometimes also barley) crops, hessian fly pupae can survive, emerge in the spring as adults, mate, and infest young wheat seedlings in the spring. Later than usual spring planting often will increase hessian fly infestations, especially after mild winters, as was the case preceding the 1992 spring. The hessian fly infestations appeared lower in 1991 than in 1990, because of the severe winter, but the insect remains a threat to spring wheat, and to some extent winter wheat production in Eastern Washington, Northern Idaho, and Northeastern Oregon. Fortunately, Wakanz continues to perform well over a wide area (Table 4), certified seed increases in 1991 were sufficient to meet the needs of most Southeastern Washington growers. Wakanz resistance to stipe rust seems primarily of the adult plant type, thus can be infected to a greater extent than Penawawa under cool temperature conditions, and under heavy inoculum load. The cultivar also may not be uniform for hessian fly resistance, because the breeder seed lines were never tested individually for resistance. Because of these two limitations, a sister line of Wakanz, WA7176, was continued in the testing program because it had a higher type of resistance to stripe rust and was originally found resistant to the hessian fly. During 1991, a preliminary breeder seed increase of individual sublines of WA7176 was made. All lines were harvested separately, and submitted for hessian fly tests by DR. J. H. Hatchett at the USDA-ARS Laboratory, Kansas State University, Manhattan, KS. The population was found to be mixed for resistance. Consequently, only the resistant lines are being increased separately for use in the breeder seed after further observations in the field in 1992.

Among the HRS wheats, WPB906R and WPB926 are the only cultivars currently known to carry resistance to the hessian fly. The resistance may have a different basis from that in Wakanz and WA7176.

Russian Wheat Aphid: Although the weather conditions over the past two years have not favored the survival and early build-up of RWA populations, it is not prudent to become complacent about this insect, because its existence in the area represents a potentially serious threat to wheat producers. Integrated Pest Management (IPM) programs in the area continue to develop and release predator insects to control the RWA, but these predators offer no protection to the crop itself other than hopefully reducing the RWA population. WSU spring wheat research efforts have focused on the use of anther culture methods to rapidly develop lines carrying resistance to the RWA. Germplasm stocks of unadapted wheats obtained from South Africa have been used in crosses with local SWS and HRS wheats. Dihaploid, true-breeding progeny from these crosses were screened for reaction to the RWA in the greenhouse, and the best lines increased in the field in 1991. Many of the selections proved unfit for a variety of reasons, including susceptibility to stem, stripe or leaf rust, weak straw, etc. However, from among the several hundred lines evaluated, 12 had agronomic characteristics suitable for advancement and use in further crosses. None of the lines recovered adequate quality, thus are being used for further crosses to recover the desired quality in combination with other traits, as hessian fly resistance and disease resistances. New crosses were made with another RWA resistance source also identified by South African scientists, and progeny of these crosses will be evaluated in 1992. Most important, however, we have identified a previously unrecognized form of resistance of potentially greatest value for protecting the wheat crop while interacting favorably with the IPM programs. Genetic resistance to the RWA toxin has been isolated in some of the lines selected from the RWA resistance crosses. This toxin resistance protects the wheat from trait which distinguishes the RWA effects on plants from those of other aphids. The RWA feed normally on the toxin resistant lines, but the leaves of the plants do not curl and the effects of the RWA are not different from those of the grain aphids. We expect that this type of resistance will be durable, since there is no selection effect on the RWA, yet the RWA will be as vulnerable to predators as any other aphid, as well as being as sensitive to the non-systemic pesticides. At this point, we know that the trait is inherited independently from the antibiosis types of resistances to the RWA, and we suspect that the trait may be recessively inherited. The toxin resistance trait probably was overlooked by other workers because they placed more emphasis on the ability of the RWA to feed on plants. A combination of antibiosis and toxin resistance could also be achieved, as was most likely present in the original germplasm stocks. However, the combined resistance would tend to select for aphids able to circumvent the antibiosis, while providing no support for maintaining the preditors.

New developments in Soft White Spring Wheats: In addition to those SWS wheats mentioned above, it should be noted that another hessian fly resistant SWS wheat is now in regional tests, as a further back-up to WA7176. WA7712 may have a different basis for stripe, leaf and stem rust resistance than WA7176 and Wakanz, and quality tests have shown it to be exceptional. WA7712 is being used in further crosses to introduce Russian wheat aphid resistance into SWS wheats via dihaploid production. WA7712, like WA7677, has the capacity to produce grain of high test weight (Tables 4,5). The improvements in grain test weight are a further indication of the progress made by the WSU spring wheat research program. These improvements have been made in wheats of the same maturity class as Edwall. The high test weight of Centennial grain may be related to its earliness, a factor which some growers may wish to consider in 1992. However, caution is advisable in areas where hessian fly infestation is likely, because of the extreme susceptibility of Centennial to that insect. Spring club WUC657, is now intensively being used in crosses to develop a hessian fly, RWA resistant, higher yielding, more club-like grain spring club. WUC657 was identified as showing unusual promise from among a set of spring habit clubs made available to us for evaluation by Dr. Pam Zwer, OSU, Pendleton. The lines were developed by Dr. Cal Qualset at Davis CA, as part of a genetics study. After the first year's tests at Pullman and Royal Slope, WUC657 was singled out as showing excellent club-type processing properties, the only one among the 12 lines initially tested. Impressively, WUC657 appears to carry adult plant stripe rust resistance, as well as stem and leaf rust resistances recovered from its HRS wheat parent. WUC657 is especially early in maturity, and a semidwarf. Protein electrophoresis tests by Dr. Steven Jones USDA-ARS, Pullman indicate that it has the proteins desired for weakest mixing properties, confirming the initial quality tests by the Western Wheat Quality Laboratory. Further support came from Dr. Qualset, who provided data indicating that WUC657 has the lowest SDS sedimentation (a simple measure of protein strength) value of any of the test wheats, including Wakanz and Treasure. The results all add up to indicate that a spring club, even with a higher protein content, can maintain highest club-type processing properties of our club wheats. WUC657 appears to be somewhat lower yielding than most SWS wheats, but this may be related to its earliness. Newer, highest-ever quality SWS wheats are just entering State regional tests, providing a strong back-up for the cultivars already in release channels.

New Developments in HRS and HWS Wheats: WSCIA sponsored regional spring wheat trials in WA in 1992 include new HWS wheats from ID and OR that are being advanced into breeder seed production. The WSU program has entered its first high quality HWS dihaploid line into TriState Regional trials in 1992, in only the third season ater the initial cross was made. This line and two HRS sister lines also in the tests was derived from the cross of Spillman and WPB906R. These lines show the greatest advances yet made at WSU toward improving grain protein content and baking quality, while apparently maintaining or increasing yield potential and disease resistance. "Apparently" is used because seed of the lines was increased at Pullman, but not in replicated trials, and observations made to eliminate disease susceptible selections. The better selections were analysed for quality by the USDA-ARS Western Wheat Quality Laboratory.

New Developments in Double Haploid Breeding (see poster): Because SWS wheats, such as Edwall produce abundant calli in anther cultures, but few green plants can be regenerated from them, crosses and reciprocal backcrosses have been made with high green plant, but low to medium callus-producers, such as Spillman to produce dihaploid derivative SWS and HRS wheats with genetically higher culturability. Since the culturability traits seem either dominant or codominant, the derivative lines should prove efficient as parents for developing new wheats via dihaploid methods. The club wheats appear to respond poorly to culture, much like the SWS wheats, thus, must likewise be improved by genetic recombination. Results already obtained demonstrate fairly simple codominance of the culturability traits. Cytoplasm genetic differences were not detected between Spillman and Edwall or Yecora Rojo and Edwall, but within cultivar differences in culturability were identified, indicating that it may be desirable to test parental lines intended for use in crosses to improve their effectiveness for dihaploid production. Earlier studies showed highly significant cytoplasm-related effects on culturability and nuclear gene x cytoplasm genetic interactions, indicating there also was potential to improve culturability by recombining desirable nuclear genes in a favorable cytoplasm.

What now appears to be a major new discovery has just been made for increasing the efficiency of the double haploid system for practical wheat breeding. Part of a graduate research study, the discovery results in a considerable increase in the number of calli and probably plants from the anther culture system. Once confirmed, the method will be introduced as a routine for the production of double haploids in the practical part of the anther culture project. We feel the new technology will be equally applicable to winter and spring wheats.

Progress in Research to Manage Effects of Soil Spatial Variability: As part of the graduate research completed by Dr. Shane Ball, aerial infrared photographs were taken of the WSU spring wheat research plot areas at several sites in 1990 and 1991. After digitizing the photographic information for computer processing the remotely sensed data were subjected to a number of analyses. The analyses conducted to date indicate that the soil spatial trends, either large or small, can be identified. Differences among wheats for maturity, effects of stresses and other features were readily distinguishable. It appears possible to use the digitized photos to more accurately count individual plants infected by some diseases, as dry land foot rot or take all, and lodged grain was visible as well. Equally important, some new procedures involving new methods in spatial statistics were developed which may have wide application to improve the efficiency by which genotype differences in yield performance can be obtained. These results alone could bring about a marked improvement in the rate of improvement by breeding by allowing earlier recognition of both superior and inferior lines.

TABLE 1.

1991 HARD SPRING VARIETIES (YIELD BU/AC)								
LOCATION:	LIND	WAVE-RLY	DAVEN-PORT	MAY-VIEW	WALLA WALLA	PULL-MAN	ROYAL SLOPE	AVE. YIELD
KLASIC	27	59	58	57	63	85	104	64.7
WAMPUM	29	52	50	46	55	81	123	62.3
LEN	28	50	49	50	53	80	100	58.6
STOA	29	52	49	45	58	77	105	59.3
BUTTE 86	29	51	52	49	57	73	95	58.0
SPILLMAN	30	54	56	55	63	88	115	65.9
WA007629	31	57	58	57	69	92	112	68.0
WA007702	30	56	59	56	64	87	113	66.4
WPB 906R	29	58	55	56	69	84	110	65.9
EXPRESS	29	54	53	58	66	80	114	64.9

1991 HARD SPRING VARIETIES (TEST WT.LB/BU)								
LOCATION:	LIND	WAVE-RLY	DAVEN-PORT	MAY-VIEW	WALLA WALLA	PULL-MAN	ROYAL SLOPE	AVE. T.W.
KLASIC	60.9	63.0	63.2	61.5	60.9	64.1	62.9	62.4
WAMPUM	58.7	60.7	58.4	60.5	60.3	61.0	61.7	60.2
LEN	61.5	61.2	62.3	59.5	61.6	63.5	62.3	61.7
STOA	59.4	61.5	60.6	61.8	61.0	63.0	61.9	61.3
BUTTE 86	60.4	62.4	62.4	60.3	61.0	63.0	61.9	61.6
SPILLMAN	59.5	60.7	59.9	59.0	58.3	62.0	61.4	60.1
WA007629	60.0	60.5	59.1	59.0	60.8	61.3	62.0	60.4
WA007702	60.5	61.0	59.1	60.5	60.9	60.1	62.1	60.6
WPB 906R	61.4	61.3	60.0	59.6	60.2	61.6	61.2	60.8
EXPRESS	60.3	61.0	61.1	61.2	60.7	61.6	61.8	61.1

TABLE 2.

1991 HARD SPRING VARIETIES (WHOLE GRAIN PROTEIN)								
LOCATION:	LIND	WAVE-RLY	DAVEN-PORT	MAY-VIEW	WALLA WALLA	PULL-MAN	ROYAL SLOPE	AVE. PROT.
KLASIC	15.0	12.2	12.7	12.7	12.8	12.0	13.3	13.0
WAMPUM	14.2	12.6	13.3	11.1	13.0	12.0	13.1	12.8
LEN	16.1	14.8	14.4	12.6	15.3	14.5	15.4	14.7
STOA	15.5	14.8	14.7	11.2	16.1	14.5	16.1	14.7
BUTTE 86	15.7	14.3	13.9	12.6	16.0	14.8	16.2	14.8
SPILLMAN	15.9	12.7	13.2	11.8	14.2	13.6	14.0	13.6
WA007629	13.6	12.5	12.9	10.5	12.8	12.7	13.1	12.6
WA007702	14.0	11.9	13.6	10.5	12.9	13.2	13.9	12.9
WPB 906R	15.8	13.9	14.3	12.0	15.4	14.1	15.1	14.4
EXPRESS	15.5	13.7	13.8	12.8	15.6	14.3	15.4	14.4

TABLE 3.

CULTURAL DATA FOR 1991 SPRING WHEAT YIELD NURSERIES

LOCATION	PLANTING DATE	BASE FERTILIZER	STARTER FERTILIZER	PREVIOUS CROP	MOISTURE TOP 3'
LIND RESEARCH STATION	3/09	00#N	6#N,8#P,6#S	FALLOW	3.06
ROYAL SLOPE RES. STATION	3/14	240#N,1#BORON 30#S	"	FALLOW	4.69
WALLA WALLA	3/22	84#N	"	SPR. WHEAT	7.58
MAYVIEW	4/15	80#N,15#S	"	FALL WHEAT	5.56
PULLMAN SPILLMAN FARM	4/16	87#N	"	PEAS	5.88
DAVENPORT	4/23	110#N	"	FALL WHEAT	5.31
WAVERLY	4/30	126#N	"	FALL WHEAT	6.04

TABLE 4.

1991 SOFT WHITE SPRING VARIETIES (YIELD BU/AC)								
LOCATION:	LIND	WAVE-RLY	DAVEN-PORT	MAY-VIEW	WALLA WALLA	PULL-MAN	ROYAL SLOPE	AVE. YIELD
FIELDER	31	54	58	48	61	88	113	64.7
FLS 22	28	50	48	47	64	80	96	59.0
CENTENNIAL	33	63	53	60	71	89	114	69.0
EDWALL	33	58	56	57	66	94	116	68.6
TREASURE	31	58	47	58	72	91	113	67.1
PENAWAWA	30	57	57	56	68	90	121	68.4
WAKANZ	32	60	56	60	62	94	114	68.3
WADUAL	29	57	53	57	61	89	113	65.6
UC000657	30	52	51	53	55	80	105	60.9
WA007176	30	63	60	53	65	90	124	69.3
WA007715	27	55	54	52	66	87	103	63.4
WA007677	33	58	62	65	78	93	123	73.1
WA007712	33	63	55	59	73	93	108	69.1
SPRITE	32	58	56	57	59	95	122	68.4

TABLE 5.

1991 SOFT WHITE SPRING VARIETIES (TEST WT. LB/BU)								
LOCATION:	LIND	WAVE-RLY	DAVEN-PORT	MAY-VIEW	WALLA WALLA	PULL-MAN	ROYAL SLOPE	AVE. T.W.
FIELDER	60.1	61.0	60.4	56.4	60.5	61.3	62.8	60.4
FLS 22	59.6	61.4	60.0	60.4	61.7	62.2	63.0	61.2
CENTENNIAL	60.5	62.5	61.0	60.4	62.3	62.4	62.4	61.6
EDWALL	57.8	57.9	55.7	56.0	59.1	60.4	60.5	58.2
TREASURE	60.2	60.9	58.3	59.3	60.5	61.7	60.5	60.2
PENAWAWA	60.0	61.4	60.0	59.2	61.1	62.2	62.6	60.9
WAKANZ	58.5	60.4	59.0	59.7	60.0	62.1	61.4	60.2
WADUAL	59.5	62.4	60.7	61.5	60.8	62.1	62.8	61.4
UC000657	60.2	62.2	60.4	59.8	61.5	61.7	60.7	60.9
WA007176	58.2	59.7	58.9	57.8	58.7	60.3	61.5	59.3
WA007715	58.9	62.2	61.1	61.1	59.4	61.9	63.3	61.1
WA007677	60.0	61.8	61.0	61.2	62.7	61.0	63.7	61.6
WA007712	60.4	62.1	60.9	61.5	62.3	61.6	63.4	61.7
SPRITE	58.7	60.0	58.3	57.3	57.7	60.3	62.3	59.2

1991 SOFT WHITE SPRING VARIETIES (WHOLE GRAIN PROTEIN)								
LOCATION:	LIND	WAVE-RLY	DAVEN-PORT	MAY-VIEW	WALLA WALLA	PULL-MAN	ROYAL SLOPE	AVE. PROT.
FIELDER	13.3	12.3	11.4	10.9	13.3	11.3	12.1	12.1
FLS 22	14.5	12.8	13.4	12.7	12.9	13.0	13.0	13.2
CENTENNIAL	14.0	11.5	12.1	10.6	12.2	11.9	11.4	11.9
EDWALL	13.4	11.9	12.8	11.5	11.9	10.8	12.1	12.1
TREASURE	14.4	11.8	12.6	10.3	12.2	11.4	12.0	12.1
PENAWAWA	13.1	11.6	12.5	12.2	12.6	11.6	12.7	12.3
WAKANZ	14.5	11.7	13.3	9.9	12.4	12.3	12.4	12.4
WADUAL	15.4	11.7	13.5	11.2	12.8	13.0	13.6	13.0
UC000657	14.0	11.2	13.3	11.9	12.8	12.7	11.8	12.5
WA007176	14.3	11.6	12.7	10.5	12.2	12.0	11.9	12.2
WA007715	15.8	12.4	13.3	11.6	13.8	12.9	13.9	13.4
WA007677	13.3	12.4	12.2	9.8	11.4	12.3	11.2	11.8
WA007712	13.8	11.4	12.3	11.1	12.5	12.3	11.3	12.1
SPRITE	14.3	11.6	13.1	11.2	13.4	13.0	12.2	12.7

HARD RED WINTER WHEAT BREEDING AND TESTING

E. Donaldson, B. Sauer, C. F. Morris, B. C. Miller, and
P. E. Reisenauer

In the fall of 1990 seed zone moisture in hard red winter wheat producing areas varied from excellent at Lind, Harrington and Waterville to poor at Connell and the Horse Heaven Hills. Many areas received heavy rains in August, allowing relatively shallow seeding. In these areas excellent stands were established and good fall growth was attained. Unfortunately, most of the winter wheat was destroyed by several days of sub-zero temperatures and high winds which desiccated the entire plant. The harsh winter weather resulted in a large percentage of the winter wheat acreage in the state being reseeded to spring grain.

Because early spring reseeding of winter wheats in a winterkill year is an accepted practice to avoid conflicting classes of wheat when marketed, the ability of a winter cultivar to produce a competitive yield from spring seeding is important. The response of winter cultivars to spring seeding has varied in the last three years. In 1989, spring seeding could not be accomplished before March 20. No winter cultivar was competitive with the spring wheat checks, but Weston had the highest yield of the winter wheats. In 1990, the March 20 planting was not harvested due to lack of vernalization in all winter cultivars. From the March 8 planting in 1991, Hatton was the highest yielding cultivar with the highest test weight, outyielding the spring wheat checks. The newer cultivars released by this project--Batum, Andrews and Buchanan--are poorly adapted to spring planting. WA7679, the cultivar proposed for release, yielded equal to the spring wheat Klasic and less than Spillman, having lower test weight than either spring wheat.

The hard red winter wheat breeding and testing program in Washington is partially funded by the Washington Wheat Commission, and is conducted from the Dry Land Research Unit at Lind. The primary objective is to provide Washington hard red winter wheat producers with good quality, consistently high-yielding, disease-resistant through varietal development and testing of advanced selections and varieties developed elsewhere. The Great Plains yield nurseries, which include selections from Texas to Canada, from both public and private breeders, are grown at Lind. The Western Regional Hard Red Winter Wheat nursery, which includes selections from Oregon, Idaho, Utah, Montana, and Washington, is grown at five locations in 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.

To obtain the desirable characteristics, new germplasm must be constantly introduced into the program. Currently material from Hungary is being used to widen the genetic base. This material is adapted to high production, has good quality characteristics, and offers new sources of disease resistance.

Promising selection:
WA7679 is an awned, white chaffed, short standard height hard white winter wheat. Grain yields during the last two years have been competitive with those of Hatton. Results thus far indicate that 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 noodle quality tests.

Nurseries:
Due to winterkill, the only nurseries harvested were those at Waterville, Harrington and Lind Irrigated. The nursery at Finley was destroyed by hail. Yields were low in general with some exceptions at Lind Irrigated. Harvest dates were late due to erratic ripening.

Hard Red Winter Wheat 1991 Yield Results in Bu/Ac

	Waterville	Harrington	Lind Irrig	Lind Pre-Irrig
Hatton	23	24	102	32
Weston	19	13	65	25
Blizzard	22	25	106	39
Batum	15	2	37	34
Andrews	17	9	49	28
Buchanan	16	11	56	33
WA7679*	20	20	93	32

*Hard white

Hard Red Winter Wheat 1991 Test Weight Results in Lbs/Bu

	Waterville	Harrington	Lind Irrig	Lind Pre-Irrig
Hatton	62.3	58.9	62.7	63.8
Weston	60.1	57.1	61.6	63.2
Blizzard	61.3	57.4	61.9	62.4
Batum	57.8	0	58.6	61.5
Andrews	57.1	54.7	50.9	61.4
Buchanan	58.4	55.1	58.0	61.7
WA7679*	58.9	54.5	60.7	62.1

*Hard White

Hard Red Winter Wheat 1991 Percent Survival Following 1990-91 winter

	Waterville	Harrington	Lind Irrig	Lind Pre-Irrig
Hatton	33	13	45	68
Weston	18	8	13	55
Blizzard	40	25	35	55
Batum	5	0	0	53
Andrews	17	3	13	65
Buchanan	10	0	10	63
WA7679*	30	28	43	78

*Hard White

BARLEY IMPROVEMENT RESEARCH

S. E. Ullrich, C. E. Muir, J. A. Clancy, J. S. Cochran, R. A. Nilan, A. Kleinhofs, L. Hou, 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 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 along with other spring cultivars 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 1992 Wheat Life 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 1991, LB/A(% of Boyer)

VARIETY	PULLMAN 8YR	POMEROY 6YR	WALLA[2] 7YR	LIND IRR 4YR	EXTENSION 58 LOC-YR
HUNDRED	5620(112)	4730(107)	4720(97)	4580(112)	4530(105)
HESK	5460(109)	4840(109)	4660(95)	4310(105)	4440(103)
BOYER	5010(100)	4430(100)	4880(100)	4090(100)	4300(100)
SHOWIN	4900(98)	4300(97)	4720(97)	4200(103)	4210(98)
KAMIAK	4440(89)	4110(93)	4160(85)	2600(63)	3920(91)

TABLE 2. SPRING BARLEY YIELD AVERAGES THROUGH 1991.

VARIETY	ROW TYPE	EXTENSION MEAN 55 LOC-YR	STATE NURSERIES			
			PULLMAN 11 YR	POMEROY 11 YR	WALLA[2] 11 YR	MEAN 33 LOC-YR
		- - - - - - - - - - -	LB/A (%)	- - - - - - - - - - -		
STEPTOE	6	4010(100)	4980(100)	3310(100)	3690(100)	3990(100)
CREST	2	3920(98)	5010(101)	3230(98)	3530(96)	3920(98)
COUGBAR	6	3785(94)	4890(98)	2910(88)	3600(98)	3800(95)
KLAGES	2	-	4720(95)	3075(93)	3280(89)	3690(92)
MOREX	6	-	3800(76)	2500(76)	2900(79)	3070(77)

*Tested as WA8771-78.

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 shorter plant height and/or 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.

Tissue Culture to Induce Somaclonal Variation. A project and lab were set up several years ago to evaluate the potential of somaclonal variation for barley improvement in collaboration with Great Western Malting Co., Vancouver, WA. Immature embryos are cultured to produce callus. Subsequently plants are regenerated with selection in the R_2 and R_3 generation (2nd and 3rd selfed generation after plant regeneration from tissue culture). Considerable genetically stable somaclonal variation has been demonstrated. Some somaclonal variation of agronomic and quality significance was observed in Morex and Klages somaclonal lines such as for plant height (86-103% of parent), heading date (-3 to +2 d vs parent), and malting quality traits, eg. alpha amylase activity (83-116% of parent), diastatic power (92-146% of parent) and protein percentage (94-122% of parent). Several Morex and Klages somaclonal lines appear to have overall agronomic and/or quality improvements compared with the parent cultivars. It appears that there is some potential that somaclonal variation may provide some useful variation for barley improvement.

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, Lind (dryland and irrigated) and Davenport. The Mielke farm near Davenport is our main winter hardiness test site. Extension trial sites are located at Mayview, Dayton, St. John, Farmington, Fairfield, Dusty, Creston, Lamont, Asotin, Bickleton and Moses Lake (irrigated). Spring breeder plot sites include Pullman, Pomeroy, Connell, Lind, Royal Slope (irrigated), Reardan, and Fairfield. Spring extension small plot sites are at Farmington, St. John, Dayton, Dusty, Lamont, Bickleton and Moses Lake (irrigated). The breeder plots are coordinated by Carl Muir and with the spring wheat program (Cal Konzak, Mike Davis and Gary Shelton). Data from the small plot trials are published in various forms including Wheat Life 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 1992 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. Most 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 two years (82 environments) Steptoe had the highest average yield at 3110 lb/a. Camelot and Harrington yielded significantly less than Steptoe, but not compared to each other at 2940 and 2850 lb/a, respectively. Cougbar had the lowest yield, significantly less than the other three cultivars, at 2670 lb/a. In 1991 the yields for Steptoe, Camelot, Crest, Harrington, and Cougbar were 3140a, 3030b, 2985b, 2930b, and 2770c lb/a, respectively. These data will also be 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 Goemmer, WSCIA and Baird Miller and Steve Ullrich, WSU as well coordinators in each of the participating counties.

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 nutritionist, John Froseth. 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 with 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.

Anther Culture to Produce Double Haploid Lines.

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. Liming Hou is heading up the anther cultivar work.

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.

Barley Genome Mapping and QTL Analysis.

The WSU barley improvement team at WSU (Kleinhofs, Nilan, Ullrich, 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 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 also being analyzed. 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.

PROGRESS IN THE DEVELOPMENT OF TECHNIQUES FOR STABLE TRANSFORMATION OF BARLEY

C.M. Stiff, A. Kleinhofs, D. Kudrna, J.F. Poorman, V. McCamant, and L. Hou

Genes that cause insect, viral, and herbicide resistance, or increase overall crop productivity, are being isolated and studied by many researchers worldwide. To utilize these genes in barley improvement programs, a method to introduce foreign DNA into barley needs to be developed. Techniques commonly used to transfer foreign DNA into plant cells, such as tobacco, potato or petunia, have not been widely successful with members of the Gramineae family. A newly developed technique, microprojectile bombardment, provides a potential tool for transformation of the cereals. This technique uses a "biolistic gun" to deliver foreign DNA into intact cells. Tungsten or gold particles coated with DNA are accelerated to high velocities to cause penetration of 1-8 layers of recipient cells or intact tissues. Methods to regenerate barley plants from cell cultures have been developed and thus, it should be possible to achieve stable transformation using the particle gun method.

The goal of this project is stable expression of foreign genes in barley through use of the biolistic particle delivery system. Funding for this project was received from the Washington Technology Center and Great Western Malting Company (Vancouver, WA), and work began in February 1990. Development of a transformation system requires: a plant regeneration system, a efficient DNA delivery system (the biolistic gun), and methods to select cells/calli expressing the foreign genes.

Plant Regeneration System:

Immature embryos, callus (derived from immature embryos), and anther-derived callus of several cultivars of barley, are used in our lab for biolistic gun transformation experiments. Plantlets have been regenerated from these tissues in the past and grown to maturity.

DNA Delivery System (The Biolistic Gun):

The Biolistic Particle Delivery System (leased from the DuPont Company, Wilmington, Delaware) consists of a heavy metal chamber which is placed under vacuum after the DNA and plant tissues are placed inside. High pressure helium, released in a single burst of pressure via a rupture disk, is used to propel DNA-coated particles towards plant tissues.

Expression of the foreign gene in the barley cell can be visualized by various techniques. One of the genes used in our experiments is the GUS gene which codes for the production of β-glucuronidase. In the presence of a synthetic substrate, 5-bromo-4-chloro-3-indolyl glucuronide (X-Gluc), this enzyme produces a blue color (resulting in blue spots), and this is an indication of expression of the DNA introduced into the cells.

Methods to Select Transformants and Detect Foreign Genes:

The other gene used in our experiments is the Basta (*bar*) gene which encodes an enzyme, phosphinothricin acetyltransferase (PAT), that causes inactivation of the herbicides bialaphos and Basta. This gene is being used as a selectable marker to indicate stable transformation. Those cells carrying the Basta gene should be able to survive higher concentrations of herbicide than the non-transformed cells. Cells that survive in the herbicide-containing media are tested for the presence of the PAT enzyme. Presence of this enzyme indicates presence of the foreign *bar* gene. Plants that are regenerated on herbicide-containing media are transferred to soil and later treated with foliar applications of the Basta herbicide to test for functional expression of the new gene.

Southern blot analysis is a molecular biology technique used to locate specific genes or regions from an entire genome. This technique is being used in our project to confirm foreign DNA integration and to estimate the number of copies of the *bar* and *gus* genes in transformed tissues.

Summary of Progress:

Transient GUS expression has been demonstrated in DNA/particle bombarded immature embryos, immature embryo-derived calli, anther-derived calli, and suspension cultures, and conditions are being optimized for maximum gene expression. Basta tolerance levels have been determined for calli, seedlings, and greenhouse plants. Plantlets have regenerated on herbicide selection medium indicating possible activity of the *bar* gene. However, these plantlets, transferred to soil and further grown for 5 weeks in a growth chamber, failed to show functional resistance to the herbicide when treated with foliar applications of 2% Basta. All plants developed necrotic lesions indicating lack of tolerance to the herbicide. Calli tolerant to the Basta herbicide have been developed from DNA/particle bombardments and are currently being studied. Stable GUS activity has been found in 5 herbicide-tolerant callus lines. Efforts are underway to improve the selection process with liquid selection media and to improve tissue culture regeneration systems.

LOCATING AGRONOMIC PERFORMANCE GENES IN THE BARLEY GENOME

A. Kleinhofs, A. Kilian, D. Kudrna, S. E. Ullrich, and R. A. Nilan

Maps are essential tools for everybody entering unknown areas whether you are navigating the stars or just looking for a friend's secret fishing hole. Barley gene mapping has been practiced by barley geneticists and breeders for several decades, but serious exploration of the barley genome has just begun. In order to be able to navigate in the barley genome and rearrange it to our needs and desires, we must have a precise and complete map.

The North American Barley Genome Mapping Project (NABGMP) has set out to accomplish these goals by mapping the barley genome with molecular markers to 10 cMorgan (a measure of genetic distance abbreviated cM) resolution and associating these markers with all of the important agronomic traits such as yield and yield components, malting quality, feed quality, disease resistance, dormancy, winter hardiness, lodging resistance, etc. etc. These traits are typically controlled by numerous genes (except some of the disease resistance loci which may be single genes) and are named quantitative trait loci (QTL). The NABGMP is a cooperative group of scientists from United States and Canada. The WSU group has an active role in all phases of the project including leadership, molecular mapping and QTL analyses.

The molecular mapping of the barley genome was the first requirement and is the most advanced. To date, we have mapped 276 markers covering the 1400 cM barley genome. This represents a marker for every 5 cM, on the average. However, the distribution of the markers along the genome is not uniform and there are some regions left with fairly large gaps. These blank spots on the map will be filled with continued effort.

Three disease resistance loci have been localized on the map. These are, stem rust resistance (Rpg1) found on the short arm of chromosome 1 near the telomere (end of the chromosome) and resistance to powdery mildew, two genes, one located on chromosome 4 (mlo), about 20 cM towards the centromere from Bmy1, the other on chromosome 5 (mla), between the Hor1 and Hor2 loci. Single genes of agronomic interest that have been located include two a-amylase loci, two b-amylase loci, two nitrate reductase loci, one nitrite reductase locus, three b-glucanase loci, one chitinase locus, and others.

We are in the process of analyzing QTL data. Preliminary data are available for daylength sensitivity and seed dormancy. Both traits are inherited in a complex manner. At least seven major genes appear to be involved in controlling the dormancy trait in Steptoe. These are located on chromosomes 1, 2, 3, 6 and 7. The locus on chromosome 7 appears to control approximately 50% of the observed variation.

Maps of the chromosomes will be presented at the Spillman Field Day in Pullman.

DRY PEAS, LENTILS, CHICKPEAS, AND AUSTRIAN WINTER PEAS

F. J. Muehlbauer, 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 on dry peas include improved seed quality, mostly better color, and improved dry seed yields. 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.

Rates of water uptake in germinating seeds may influence emergence rates and susceptibility to root rots. We have devised new ways to measure stresses in seeds. Breeding lines are being tested for differences in water uptake rates and imbibitional stresses to determine whether these traits can be used in pea, lentil and chickpea improvement.

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), early to mature, and has excellent seed quality traits including dark green seed color and resistance to seed bleaching. 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.

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:

'Brewer' consistently has been the highest yielding lentil variety in yield trials. The variety has averaged about 300 pounds per acre more than Chilean 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. Redchief has red cotyledons and is now used to produce decorticated red lentils.

'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.

'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.

'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 intermediate rainfall zones (15-18 inches annually) and therefore could become an alternative crop in rotation with wheat in those areas. Expected yields in those areas would be from 750-1000 pounds per acre. 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. The Palouse environment seems well suited to chickpeas and very favorable yields have been obtained. Varieties and breeding lines, obtained from national and international sources, have been evaluated for yield potential and seed quality. 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.

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. Foundation seed of Sarah should be available for the 1991 cropping season.

The current problem of Ascochyta blight on chickpeas in the Idaho-Washington area has prompted research on identification of resistant lines. Resistance to blight is available; however, the resistance is associated with late maturity and small-medium seed size. We currently have underway a program to incorporate the resistance into more acceptable types. The most advanced breeding material was increased at Yuma, Arizona this past winter. That material is in the F_7 and is expected that several lines in differing genetic backgrounds will be proposed for release at the end of 1992.

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.

'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.

'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.

BREEDING FOR RESISTANCE TO ASCOCHYTA BLIGHT OF CHICKPEA

W.J. Kaiser[1], F.J. Muehlbauer[2], R.W. Short[2], J.L. Coker[1], R.M. Hannan[1], and B.H. Hellier[1]

[1]USDA, ARS, Regional Plant Introduction Station, Washington State University, Pullman, Washington, USA
[2]USDA, ARS, Grain Legume Genetics and Physiology Research Unit, Washington State University, Pullman, Washington, USA

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.

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 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, Renee L. Ader and Douglas Smith. WSU personnel include Garrison E. King, Barbara C. Davis; Drs. Gerald A. Greenblatt, Hanan I. Malkawi and Jeanne Curry; and Victor L. DeMacon and Janet Poorman.

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

A SIMPLE IDEA WITH *IMPACT*

The International Marketing Program for Agricultural Commodities and Trade (IMPACT) Center in the College of Agriculture and Home Economics at Washington State University is based on a simple (but effective) idea. Agriculture in the United States should no longer produce a product first, then try to push that product on a reluctant overseas consumer. Rather, U.S. (and Washington) agriculture should find out what the foreign consumer wants and try to deliver it.

Simple and effective as that idea is, it is still not widely accepted. However, IMPACT studies indicate that the principle applies just as much to bulk items like wheat, barley, peas and lentils as to highly processed items such as wine, candies or gourmet meals.

The IMPACT Center provides scientific support to that concept in many different ways:

1. <u>Studies of the size and future potential of export markets</u>. How populations, incomes, lifestyles and consumption behavior are changing - and they are changing dramatically.

2. <u>What product characteristics do consumers want</u>? For example, in wheat, the desirable characteristics depend on the sort of end products that will be consumed, such as noodles, flat breads, pastas, cakes or cookies. As more and more specialized grain products are being marketed, the extent and quality of starch, gluten, dietary fiber etc. in each wheat variety is of major marketing significance.

3. <u>Adaptation of processing methods</u> to make these new products more effectively from Washington ingredients and to meet new constraints on use of water and energy, new limitations on waste, etc.

4. <u>Improving competitiveness in yield, quality and price</u> at every level of the production and marketing system. This includes everything from increasing the number of tons of barley per acre to improving the efficiency of processing or financing.

5. <u>Maintenance of quality</u>. This includes scientific studies of improved handling, storage, packing, processing, shipping, receiving and delivery.

6. <u>Determining and meeting entry standards in import markets</u>. These may be documentation, customs, phytosanitary, grade, building code or other restrictive standards.

7. <u>Improving marketing efficiency</u>. Analysis to assist marketers in assessing pricing, promotion and other strategies.

8. <u>Distribution research</u>. Examining current, alternative or potential new channels for Washington agricultural exports.

9. <u>New products for market</u> (e.g. azuki beans for Japan), new technologies (e.g. nondestructive testers of quality), new processes (e.g. gluten extraction systems). In many markets, such advances are the key to increased sales.

10. How you can learn more about IMPACT Center activities. Many growers and processors call us about the various activities of the IMPACT Center. We welcome telephone or FAX calls or personal visits to our offices at 123 Hulbert Hall. For specialized needs, we can refer inquiries to many different scientists, both in Pullman and throughout the Washington State University system.

    In addition to our popular IMPACT Information Series, reports on IMPACT Center projects are presented at grower meetings and conferences and in grower magazines such as Wheat Life and the Goodfruit Grower. We also work closely with Cooperative Extension in disseminating results of our projects. Detailed scientific data is also available from project leaders.

VARIATION FOR WATER USE EFFICIENCY IN LENTIL AND ALFALFA

Richard C. Johnson
USDA/ARS Plant Introduction

Water loss from plant surfaces is largely controlled by stomata, the tiny pores concentrated on leaves. For production of carbohydrates during the photosynthetic process, CO_2 uptake occurs through stomata. In this way transpirational water loss to the atmosphere is linked to plant dry matter accumulation.

One definition of water use efficiency (WUE) in crop plants is the ratio of dry matter produced to transpirational water loss. The importance of this to crop production can be illustrated by the following equation:

$$\text{Yield} = \text{WUE} \times \text{Transpiration} \times \text{Harvest Index}$$

For alfalfa and lentil, WUE is in the neighborhood of 0.002 units dry matter per unit transpiration. Stated another way, it takes about 500 units of water to produce one unit of dry matter. In the above equation transpiration integrates many factors related to growth and leaf area development, and can be affected by disease, insects, fertility, and drought. Harvest index is the ratio of grain dry matter to total above ground dry matter produced, so harvest index is a very important factor for grain crops but not a factor in a hay crop such as alfalfa. Based on the above, it takes approximately 120,000 gallons of water to produce one ton of alfalfa hay. With a harvest index value of 0.4, it takes about 300,000 gallons to produce one ton of lentils.

In general most of the gains in yield this century have come with increases in either transpiration and harvest index components of the above equation, but not in WUE. Yet other things being equal, any increase in WUE will also increase yield. It also means that when irrigation water is limited or in drought prone environments, an increase in WUE could result in sustaining higher yield levels.

Much of the variation in WUE results from atmospheric effects associated with changes in evaporative demand, but genetic variation in WUE also exists and its potential application in crop production is being investigated in lentil and alfalfa. We are using a relatively new technique, carbon isotope discrimination, to estimate plant WUE. Work so far has shown that germplasm accessions of alfalfa and lentil do vary in carbon isotope discrimination in different environments, suggesting genetic variation for WUE. In alfalfa, variation in field plots for discrimination has recently been correlated with whole plant WUE in pot studies. Parental lines of lentil have been identified that differ in carbon isotope discrimination. Working with Dr. Fred Muehlbauer and Dr. Chuck Simon, genetic aspects of WUE are being studied. We are examining a segregating population of lentil in an effort to find molecular markers for WUE genes. This work is being completed with a view toward developing germplasm with improved WUE.

ALTERNATIVE CROP ROTATIONS IN THE PALOUSE: ESTIMATED CROP YIELDS, SOIL EROSION, NITROGEN LEACHED, AND ECONOMIC RETURNS

By Kathleen Painter, David Granatstein, and Douglas Young

INTRODUCTION

Crop rotation is a well-established agronomic practice for managing pests, improving nutrient cycling, and reducing economic risk. In the Palouse region of southeastern Washington, dryland farmers rely on winter wheat as the principal cash crop. Winter wheat is well-adapted to the climatic conditions of the region. In addition, government commodity programs have provided generous price supports for wheat during the past 50 years, although these support payments have been declining in recent years. Palouse farmers generally rotate winter wheat with spring barley, peas, or lentils. Other crop options include chickpeas, grass seed, alfalfa, sweetclover, buckwheat, rapeseed, and canola. Farmers have tried these crops over the years, but the lack of established markets, volatile market prices, and restrictive government farm policy has discouraged widespread use of these crops.

This study compares the economic and environmental performance of five alternative systems to that of two common conventional crop rotations. Yields and costs were standardized for conditions in the 18- to 22-inch rainfall annual cropping region of eastern Whitman County, Washington. Eighty-eight percent of the farmland in the region is classified as highly erodible by the Soil Conservation Service. As a result, nearly all farmers in this area are required to have an approved farm plan to control soil erosion in order to participate in the government farm programs. Ninety-seven percent of 92 eastern Palouse farmers surveyed in 1990 participated in government programs.

Both government payments and costs of complying with government commodity program restrictions are incorporated into the net returns in this study. Provisions of the 1990 Farm Bill (Food, Agriculture, Conservation and Trade Act of 1990), which reduce the base acreage eligible for payments by 15%, are reflected in the projected crop returns.

DATA

Information for this report came from several sources. A 1990 random sample survey of farmers in the Palouse, of which 92 were in the eastern Whitman County study region, provided data for the conventional rotations. These include C1, winter wheat/spring pea, and C2, winter wheat/spring barley/spring pea. Additional budget data for these systems are available in Washington State University Cooperative Extension Bulletin EB1437, 1991 Crop Enterprise Budgets, Eastern Whitman County, Washington State. A 1989 survey of 24 farmers using alternative practices in the Palouse provided data for Rotation A1, winter wheat/spring barley/sweet clover green manure, and Rotation A3, a 24-year system including 6 years of bluegrass (Beus et al., 1990). A2, a rotation including rapeseed production, came from Washington State University Cooperative Extension data. The USDA Integrated Crop Management research plots at Washington State University provided the data for A4, no-till winter wheat/min-till winter wheat/min-till spring wheat. Information for A5, winter wheat/spring pea/medic, came from three years of research trials at Washington State University (see Goldstein, 1986).

Any crop or rotation option presents benefits and tradeoffs, both agronomic and economic, that a grower must consider. Researchers have shown yield improvements in moving from continuous wheat to a wheat/barley/pea rotation, due in large part to a reduction in soil-borne diseases. However, lack of an adequate barley base can act as a barrier to the adoption of a three-year rotation. Rapeseed and canola contain bio-active compounds that show promise in controlling diseases, nematodes, and weeds. A limited market has slowed production of this crop. Perennial grass seed production can drastically reduce erosion, but wide price swings in recent years have limited its widespread production. Markets need to be developed for crops such as chickpea and red lentils. Forage legumes such as alfalfa and sweetclover are known for their soil improving qualities and were once widely grown. Low livestock populations and high transportation costs have discouraged forage legume production.

Tables 1, 2, and 3 summarize crop yield, soil loss, nitrate leaching, and economic performance estimates for the two conventional and five alternative rotations. Crop yield estimates are a synthesis of the farm survey and research data sources cited above. They reflect the authors' perception of current "average" yield performance, but, in fact, each grower's absolute and relative yields for these rotations may differ from these estimates.

We present two winter wheat yields for the popular WW/SP rotation, 75 bushels per acre and 85 bushels per acre, due to indeterminate research evidence on this issue. On the one hand, repeated fumigation trials by plant pathologists have shown greater root disease incidence and potential yield suppression in the two-year WW/SP rotation than in three-year rotations which leave a two-year interval between wheat crops (Cook and Veseth, 1991). On the other hand, evidence from other research trials and some growers indicate similar wheat yields from WW/SP and WW/SB/SP rotations (Pannkuk, personal communication; NWAF 1990 Survey).

The yield estimates for alternative rotations are based on a relatively small number of research trials or grower reports. Again, individual growers may obtain yields higher or lower than these and should adjust their profitability expectations accordingly.

Production costs in Table 3 are based on Painter, Granatstein, and Miller. They include the cost of an average projected 7% set-aside rate over 1991-95 for wheat and barley program participation. The crop prices and wheat and barley deficiency payments are also projections of averages over 1991-95 (Painter). If market prices for wheat remain in the $4 range over the next few years, it would further favor the profitability of rotations with higher proportions of wheat in the rotation.

RESULTS: CONVENTIONAL ROTATIONS

C1: Wheat/Pulse

A winter wheat/spring pea or lentil rotation increases to 50% the rotational acreage in the higher value winter wheat crop. Fall and spring field operations are evenly distributed as well. However, high erosion potential exists on winter wheat planted into pulse residue, especially with conventional tillage. As a result, reduced or no-till planting of winter wheat into pulse stubble is becoming a common practice and may be necessary to meet conservation compliance. In a recent survey in the study area, wheat/pea or wheat/lentils was the dominant rotation for 31% of the farmers. Dry peas are more commonly grown than lentils, possibly due to higher price fluctuations for lentils.

Using min-till winter wheat and spring peas, this rotation averages the highest soil loss of 6.53 tons/acre/year. Estimated nitrogen loss through leaching beyond 0.25 meters soil depth was 12.54 pounds/acre/year, which is moderate. Assuming winter wheat yields of 75 and 85 bushels and 19 cwt for peas, this rotation has net returns over total production costs including land, ranging from -$16 to -$2 per acre, depending upon the average wheat yield achieved. <u>If</u> growers can match the wheat yields achieved with the three-year WW/SB/SP rotation, WW/SP is the most profitable conventional rotation examined.

C2: Wheat/Barley/Pulse

A winter wheat/spring barley/pea or lentil rotation is being adopted by more growers for a number of reasons. Thirty-one percent of farmers surveyed in eastern Whitman County used wheat/barley/pulse as their dominant system. Some scientists believe wheat yields increase 10%-15% in moving from a two- to a three-year system, and pulse yields are often improved as well. Weed and disease problems are lessened, translating into lower pesticide costs. Winter annual weeds are discouraged, but spring annuals are favored. Growers have an additional opportunity of planting malting barley that will bring a premium price if the quality is acceptable. This rotation entails more spring field work than a wheat-pulse rotation, and extended wet conditions in the spring can be a problem. High erosion potential following the pulse crop occurs only one year in three. As a result, soil erosion in this rotation is less than in a wheat-pulse rotation with comparable tillage. The erosion potential can be further reduced by no-till seeding of the winter wheat into the pulse residue. Nitrogen leaching is decreased as well, due to a smaller acreage of winter wheat.

Using min-till winter wheat and conventional till spring barley and spring peas, this rotation performs better than the two-year conventional rotation with 75 bu/ac wheat yields in terms of erosion (6.26 tons/acre/year), nitrogen leached (9.75 pounds/acre/year), and net returns (-$13 acre/year). All of the alternative rotations outperform this conventional rotation in terms of economic performance and erosion control. The profitability of these rotations, however, hinges on achieving the yields listed for alternative rotations in Table 1.

RESULTS: ALTERNATIVE ROTATIONS

A1: Wheat/Barley/Sweetclover

Green manure crops, such as sweetclover, winter peas, or alfalfa, were a common part of Palouse cropping rotations prior to the widespread use of nitrogen fertilizer. With adequate forage growth they can supply much of the nitrogen needs of a subsequent winter wheat crop. Several growers in this study hoped to slow soil acidification by using a green manure as a substitute for some nitrogen fertilizer. While this rotation has low variable costs of production and low agrichemical use, a year of crop income is sacrificed. This must be weighed against the direct effect on costs and yields in the following wheat crop and the difficult to measure benefits of long-term soil improvement.

A green manure is typically used once every three to six years in a rotation cycle. Legume green manures require special management, particularly for insects, soil fertility, soil pH, and inoculation. Time of incorporation will affect total nitrogen content, rate of N release, moisture use, and moisture availability for the following crop. Green manures have generally been incorporated with a moldboard plow or disc, but this poses problems in meeting residue requirements on the following wheat crop. Results using chemical kill/no-till management have been inconsistent.

Using min-till winter wheat and conventional till spring barley underseeded with clover, this rotation has just two-thirds the annual erosion of the wheat/pulse rotation. Nitrogen leached is very low, 3.79 pounds/acre/year. However, potential nitrogen leached from the green manure is not included. While winter wheat yields are comparable to those of the wheat/barley/pulse rotation due to the added nitrogen from the green manure, the barley yield is slightly lower due to the low fertilization levels used in this study. (For further information on input levels, see 1991 Alternative Crop Rotation Budgets, Eastern Whitman County, Washington State, forthcoming). Net returns for this rotation, at -$5 per acre, are well above the returns for the conventional rotations except for WW/SP with higher wheat yields.

A2: Rotations With Rapeseed or Canola

Rapeseed and canola differ in their chemical composition and resulting use. Canola has low levels of erucic acid and glucosinolates, making the oil suitable for human consumption and the meal usable as a livestock feed. In contrast, these compounds are present at high levels in rapeseed, making the oil suitable for industrial uses only. Canola and rapeseed belong to the Brassica plant family, which is quite different from cereals and legumes. This allows them to reduce soil-borne diseases and nematodes, but they may face their own disease problems if grown more than once every four or five years in a field. The rotation presented here assumes planting a winter rape or winter canola crop in August on summer fallow ground. With this system, a good stand and considerable plant growth can be achieved by winter, leading to good winter survival and effective weed suppression and erosion control. Large amounts of residue are left after harvest for the next winter wheat crop. Winter rape or canola will produce a deep and strong root system that can penetrate compacted layers and improve soil tilth, which benefit the growth of future crops. Production costs for this crop are similar to those for winter wheat. Winter rape or canola typically require an insecticide treatment for the cabbage seed pod weevil, but herbicides are seldom needed after planting. Several provisions of the 1990 Farm Bill make rapeseed/canola an attractive alternate crop, particularly the income support with a marketing loan. Further market development is needed for rapeseed and canola to become a stable option for dryland grain farmers.

A six-year rotation of winter wheat/summer fallow/rapeseed/winter wheat/spring barley/peas has an erosion rate approximately 10% lower than that of the conventional rotations. Nitrogen leaching is equivalent to the wheat/pulse conventional rotations. Estimated net returns for this rotation are second only to A5 at -$1 per acre.

A3: Rotations With Perennial Grass

Much of the land currently devoted to dryland cereal production in the Palouse was originally covered with perennial grasses. These grasses helped develop the highly productive soils in the Palouse through additions of organic matter and protection from erosion. Conservation minded growers, Cooperative Extension, and researchers have long recognized the value of including a perennial grass in rotation to protect and rebuild the soil resource. By growing a grass with a marketable seed, growers receive an economic return (given favorable prices) for this excellent conservation practice. But grass seed markets are volatile and cannot support a large production acreage. This, as well as past government programs, has minimized the use of perennial grass in the Palouse.

A grass seed stand is typically kept for six or seven years. Annual burning after harvest is necessary to stimulate adequate seed production. Future burning restrictions to protect air quality could pose a problem. With the advent of no-till management, many growers are using chem-kill and no-till to remove the grass crop and plant a spring crop for returning a field to grain production. This eliminates the potential erosion associated with moldboard plowing. The sod breaks down slowly and provides erosion protection for several years after removal.

A 24-year rotation consisting of 6 years of bluegrass, a 3-year no-till sequence of lentils, winter wheat, and lentils, and a 15-year conventional sequence of three cycles of winter wheat/peas/winter wheat/spring barley/peas is used for this study. This rotation is based on an actual farm in the study area. It has an erosion rate 75% of that of the wheat/pea rotation, but the nitrogen leaching rate is higher for this rotation than either of the conventional rotations at nearly 17 pounds/acre/year due to high levels of fall nitrogen applied to bluegrass. This rotation has estimated returns equivalent to those of A1, wheat/barley/clover, at -$5 per acre.

A4: Continuous Wheat Production

Growers and researchers have been experimenting with continuous wheat production, because wheat is the consistently most profitable crop in the region. Approaches include continuous no-till winter wheat (with and without burning), a mix of winter and spring wheat, and various tillage combinations. Disease and weed problems can increase in these systems. Eliminating straw residue, either through burning or moldboard plowing, can also cause management problems. Continuous no-till wheat begins to resemble the perennial grass that was native to the region, and virtually eliminates erosion while increasing soil organic matter.

Farm programs provide a severe barrier to continuous wheat rotations. Use of this rotation on a whole farm basis would require growers to have a 100% wheat base. Eastern Palouse farms surveyed during 1990 averaged 46% of their cropland in wheat base.

Yield and production cost data for this rotation were derived from the USDA Integrated Crop Management research plots near Pullman, Washington, where a winter wheat/winter wheat/spring wheat rotation was used with a combination of no-till and minimum till. This system has the highest variable cost of production and highest agrichemical use of all the rotations. Downy brome and jointed goatgrass can pose serious weed problems. Soil-borne diseases will damage roots in this type of system so that placement of fertilizer near the seed becomes critical. Chisel plowing winter wheat stubble left 30%-35% residue cover, versus 5% when the moldboard plow was used. Soil loss in a continuous winter wheat system using uphill plowing is just 40% of that in the wheat-pea system. Nitrogen leached beyond 0.25 meters was highest for this system, however, at 20.71 pounds/acre/year. Net returns were slightly higher than those for two of the conventional systems at -$11 per acre, but lower than those for the other alternative systems.

A5: Winter Wheat/Spring Pea/Medic

This rotation uses no applied nitrogen or herbicides on the winter wheat crop. Nitrogen is supplied from medic, which is neither harvested nor plowed under. Research has shown that medic can provide the majority of the nitrogen needs for the following wheat crop (Goldstein). This type of system is commonly used in Australia. Currently, a medic and wheat rotation is being successfully used in Montana. The biennial black medic crop is seeded with the spring peas. Medic offers little competition with the peas in its establishment year. The biennial medic is allowed to mature and go to seed. The residue is then incorporated during seedbed preparation for the wheat. Ideally, medic will then revolunteer into the following pea crop and the cycle continues. Research and farmer trials after the initial experiments have met with little success in the Palouse, however, due to consistent problems with medic establishment and weed control.

Using winter wheat, spring peas, and medic as described above, this system has the lowest erosion rate at 2.09 pounds/acre/year, no leaching of applied nitrogen and the highest net returns to management at $2 per acre. The potential economic and environmental benefits of this rotation merit further research to determine whether they can be realized in practice.

CONCLUSIONS

The results in this study show that alternative rotations can compete successfully with the conventional rotations in the study area given the yield and cost assumptions in Tables 1 and 3. Individual yield and cost variations may change these rankings, however. The choice of alternative rotation would depend on individual farmers' goals, their attitudes toward risk, and the attributes of their land.

If erosion control is the highest priority, wheat/pea/medic or continuous wheat perform best. However, these systems are agronomically riskier than some with less erosion control, such as wheat/barley/clover and the bluegrass rotation.

If economic performance were the number one consideration, wheat/pea/medic or the rapeseed rotation would be best among alternative rotations. As market price and deficiency payment levels change, the rankings may change.

Nitrogen leaching may be a concern only on certain portions of the landscape. A rotation with low leaching potential could be used in areas with the potential for water contamination.

Overall, these priorities must be weighted with the agronomic and economic riskiness of each rotation. Farm program considerations may also impact a farmer's ability to use alternative rotations.

Table 1. Expected Yield Per Acre by Rotation, Tillage Method and Crop.

Rotations	Winter Wheat CT	Winter Wheat NT	Spring Wheat CT	Spring Barley	Dry Peas	Lentils	Rapeseed	Bluegrass
	(Bu/Ac)	(Bu/Ac)	(Bu/Ac)	(Tons/Ac)	(Cwt/Ac)	(Cwt/Ac)	(Cwt/Ac)	(Lbs/Ac)
Conventional:								
C1A: WW/SP	75	-	-	-	19	-	-	-
C1B: WW/SP	85	-	-	-	19	-	-	-
C2: WW/SB/SP	85	-	-	1.9	21	-	-	-
Alternative:								
A1: WW/SB/CL	85	-	-	1.7	-	-	-	-
A2: WW/F/WR/ WW/SB/SP	85	-	-	1.9	21	-	20	-
A3: 6xBG + NTSL/NTWW/NTSL + 3x(WW/SP/WW/SB/SP)	80	80	-	-	20	11	-	500
A4: NTWW/WW/SW	59	71	46	-	-	-	-	-
A5: WW/SP/MEDIC	72	-	-	-	18	-	-	-

Legend: WW = Winter Wheat, SW = Spring Wheat, SB = Spring Barley, CL = Sweetclover, F = Summer Fallow, WR = Winter Rapeseed, BG = Bluegrass, NTSL = No-Till Spring Lentils, NTWW = No-Till Winter Wheat, SL = Spring Lentils, CT = Conventional Tillage, NT = No-Till

Note: Clover and medic are green manure crops, so no yield is measured.

Table 2. Predicted Soil Loss and Leaching of Nitrate-Nitrogen by Rotation.

Rotations/Tillage	Soil Loss (t/ac/yr)	Nitrogen Leached (lbs/ac/yr)
Conventional:		
C1: WW/SP	6.53	12.54
C2: WW/SB/SP	6.26	9.75
Alternative:		
A1: WW/SB/CL	4.22	3.79
A2: WW/F/WR/WW/SB/SP	5.74	12.46
A3: 6xBG+ NTSL/NTWW/NTSL + 3X(WW/SP/WW/SB/SP)	4.90	16.92
A4: NTWW/WW/SW	2.61	20.71
A5: WW/SP/MEDIC	2.09	0.00

Legend: WW = Winter Wheat, SW = Spring Wheat, SB = Spring Barley, CL = Sweetclover, F = Summer Fallow, WR = Winter Rapeseed, BG = Bluegrass, NTSL = No-Till Spring Lentils, NTWW = No-Till Winter Wheat, SL = Spring Lentils, CT = Conventional Tillage, NT = No-Till

Note: Nitrogen leaching estimates the amount of nitrate-nitrogen from applied nitrogen fertilizer that moves below 0.25 meters soil depth using an attenuation factor approach. Painter (1992) provides detail on sources and methods for estimates in this table.

Table 3. Production Costs, Expected Revenue (Including Government Program Payments) and Net Profit (Dollars/Rotational Acre/Year) by Rotation.

Rotations	Production Costs	Revenue	Net Profit
Conventional:			
C1A: WW/SP	248	232	-16
C1B: WW/SP	248	246	-2
C2: WW/SB/SP	233	220	-13
Alternative:			
A1: WW/SB/CL	167	162	-5
A2: WW/F/WR/WW/SB/SP	206	207	-1
A3: 6xBG+ NTSL/NTWW/NTSL + 3X(WW/SP/WW/SB/SP)	234	229	-5
A4: NTWW/WW/SW	246	235	-11
A5: WW/SP/MEDIC	152	154	2

Market Price Assumptions: Wheat, $3.37/bu; Barley, $91.17/ton; Peas, $9.16/cwt; Lentils, $18.54/cwt; Bluegrass Seed, $0.56/lb; Rapeseed, $0.10/lb.
Deficiency Payment Assumptions: Wheat, $0.95/bu; Barley, $5.42/ton.
Set Aside Rate Assumptions: Wheat, 7%; Barley, 7.5%.

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BLACKGRASS IDENTIFICATION AND CONTROL

Chris M. Boerboom
Extension Weed Specialist
Washington State University

Most wheat growers may not know what blackgrass is, and many growers may not even know it by its common aliases of pacific meadow foxtail, slender foxtail, or black twitch. However, wheat growers should keep a watchful eye and protect themselves from blackgrass.

Blackgrass is a winter annual grass that is a major grass weed for Europe's wheat farmers. In the Pacific Northwest, it is a potential threat for many growers, but has only been a serious problem for a relatively few. For growers who only have a few plants, it may be "just another grass", but for growers battling blackgrass in the Reardan area, south of Pullman, and in the Willamette Valley of Oregon, blackgrass is real and serious.

Blackgrass gets its name from the black cast it gives to a wheat field when it heads out in June. Mature blackgrass is easy to identify once you have seen it. It has a tapering cylindrical seed head that has a reddish-purple tint. Blackgrass could be mistaken for its relative, meadow foxtail, but meadow foxtail is perennial and is more likely to be growing in a road ditch than in a wheat field and its heads are wider and do not taper as much at the ends. Seedlings of blackgrass are harder to identify, but knowing that blackgrass was in the field in previous years makes identification easier. Blackgrass has small narrow leaves as a seedling. It is not hairy like downy brome, but plants in Washington have reddish purple stems. The underside of the leaf is not shiny like Italian ryegrass. It has a ligule, but it is shorter than the ligule on windgrass.

Blackgrass seems to thrive in wetter flats and draws, so there is a large acreage of wheat land that could infested if given the chance. To help contain blackgrass and stop further spread, it has been classified as a Class B noxious weed in our state, meaning mandatory control except in Lincoln and Spokane counties. Containing blackgrass may protect you and your neighbors from getting this weed and avoiding the added cost for control or the resulting yield loss. I have measured 15 to 22% yield losses in two wheat trials evaluating blackgrass control. Data from England suggests a 12% loss for every 10 plants per square foot.

Controlling blackgrass has been a problem in the past because herbicides such as Treflan, Fargo, or metribuzin only gave suppression. Some Reardan area growers have battled blackgrass and gained control through a combination of growing more spring crops and lengthening the number of years between winter wheat and by using herbicides that give suppression. This has not been as effective around Pullman, probably because of the wetter, more favorable conditions.

Although blackgrass is another winter annual grass that wheat growers should be concerned about, there is good news for growers currently trying to control blackgrass. A newly registered herbicide called Tiller provides excellent postemergence blackgrass control. In extension trials, Tiller has given 95 to 100% blackgrass control. Tiller is a mixture of the ingredients fenoxaprop (the grass herbicide component), 2,4-D, and MCPA. Because Tiller contains some phenoxy herbicide, it should only be applied to tillered wheat. Tiller will also control wild oat and windgrass if they occur in the same field as blackgrass.

Guidelines for Blackgrass Control

Prevention: If blackgrass is not introduced into your fields, you will not have to pay to control it.

1. Plant certified seed. Blackgrass has been introduced by sowing contaminated wheat seed.

2. Rogue isolated plants or prevent small patches from going to seed.

3. Clean equipment, especially combines, so blackgrass seeds are not spread from infested to uninfested fields.

Control

1. Rotate winter wheat with spring crops. Make sure the blackgrass is killed with a herbicide or tillage and not just transplanted before planting the spring crop.

2. Use Tiller to control blackgrass in winter wheat. Infested flats and draws may be spot sprayed to reduce cost.

3. Although Tiller gives excellent blackgrass control, crop and herbicide rotation is still needed to avoid the possible development of Tiller-resistant blackgrass.

Additional information on blackgrass is available in the extension bulletin PNW 377 titled Blackgrass, available through your county extension office.

CONTROL OF ERGOT DISEASE IN KENTUCKY BLUEGRASS SEED FIELDS

W. Johnston, T. Schultz, C. Golob, and J. Maguire
Department of Crop and Soil Sciences
Washington State University
Pullman, WA 99164-6420

INTRODUCTION

Kentucky bluegrass (Poa pratensis L.) seed production is an important component in the agriculture of the northwest. In 1989, there were 42,000 acres of bluegrass grown for seed in Washington state. The yield was 400 lb/A and the total crop value in Washington was $11.5 million. This low price reflects the current decreased demand for bluegrass seed.

The ergot problem in grass seed production is a four-fold one. First, the disease caused by the fungus Claviceps purpurea reduces yield. Losses of 40 to 90% have been reported in grass seed crops. Second, during disease infection a sticky excretion ("honeydew") is formed on seed heads making harvesting extremely difficult. Third, sclerotia (overwintering fruiting bodies which are the ergot of commercial trade) are harvested with the seed. Since many foreign countries set very low import limits on ergot contamination, the sclerotia must be cleaned from the seed. Seven percent ergot was still reported in 1990 in some north Idaho seed lots following cleaning. Fourth, sclerotia which remain in the field serve as source of inoculum for the infection of next year's seed crop.

Presently, there are no fungicides registered to control ergot. The only method of ergot control is open-field burning following harvest. This practice is highly controversial, not always effective, and may be limited or eliminated in the future, thus leaving growers with no means of controlling ergot.

RESULTS AND DISCUSSION

In 1990, the fungicides flusilazole, tebuconazole, propiconazole, and triadimefon (see table for product information) were applied at two rates at pre-and post-anthesis. Treatments were applied at 40 psi using a 28 gpa carrier rate. Prior to harvest, disease severity was rated by observing the amount of sclerotia and panicle exudate ("honeydew") and feeling panicles by hand for stickiness (honeydew). A minimum of 100 panicles were harvested by hand from each plot and the mean weight of clean seed and sclerotia per panicle, 1,000 seed weight, and seed germination were determined. The least amount of disease was observed in plots treated with flusilazole (2.8 and 5.4 lb. a.i./A) at pre-anthesis. Intermediate control was observed with propiconazole (0.5 lb. a.i./A) and tebuconazole (0.5 lb. a.i./A) applied at pre-anthesis. Only flusilazole (5.4 lb a.i./A) showed post-anthesis control. Seed yield per panicle was reduced with pre-anthesis applications. Seed germination was reduced (12 to 14% less than controls) with flusilazole applied pre-anthesis. In general, all late-anthesis applications reduced seed germination.

Product	Manufacture	Composition
Punch 25 EC	Dupont de Nemours	flusilazole (25%)
Folicur 3.6 F	Mobay Chemical	tebuconazole (38%)
Tilt 3.6 E	Ciba Geigy	propiconazole (42%)
Bayleton 50 WP	Mobay Chemical,	tiadimefon (50%)
Penaturf	Chas. H. Lilly Co.	sodium dodecylbenzene sulfonate (20%), nine mole ethoxylated C_{11}-C_{15} alcohol (5%), inert ingredients (75%)

In 1991, tebuconazole and propiconazole were applied at 0.5 and 1.0 lb. a.i./A, and 0.5 and 1.0 lb. a.i./A, respectively. Flusilazole was applied at 1.0, 2.0, and 3.0 lb. a.i./A. In addition, all fungicides were applied at their lowest rate in combination with a wetting agent (Penaturf at 5.3 gal. of product/A). Treatments were applied at pre-anthesis and 30% anthesis. Plots were rated for disease severity before harvest by visually observing the amount of sclerotia and honeydew on the panicles. Twenty panicles were harvested by hand from each plot and the mean weight of clean seed and sclerotia per panicle, 1,000 seed weight, and seed germination were determined.

In 1991, disease was observed in all plots and was severe in untreated plots. All fungicide treatments significantly reduced disease when compared to untreated plots. Disease was reduced to near zero in plots treated with flusilazole at 2.0 or 3.0 lb. a.i./A or treated with a fungicide-wetting agent combination of flusilazole and Penaturf or terbutrazole and Penaturf when applied at pre-anthesis. Fungicides were more effective at controlling disease when applied at pre-anthesis than at mid-anthesis. Disease control was significantly greater when fungicides were used in combination with a wetting agent than when used alone at the same rate. Seed yield per panicle was reduced when using the most efficacious fungicides or fungicide-wetting agent combinations when compared to the untreated control. Date of application was not significant for seed or sclerotia weight per panicle, or 1,000 seed weight. Weight per 1,000 seed was not significantly affected by any of the treatments. In contrast to 1990, pre-anthesis applications did not reduce germination. Mid-anthesis applications reduced seed germination, but not to the extent seen in 1990 with late-anthesis applications.

SUMMARY AND CONCLUSIONS

We have shown that ergot causes loss of yield and reduced seed quality in bluegrass. 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 (data not presented) and wetting agent-fungicide combinations to lower the application rate of fungicides. Implementation of these findings will improve the yield, quality, and export market for Kentucky bluegrass from the northwest.

WHEAT AND BARLEY ROOT DISEASE RESEARCH

R. James Cook, David M. Weller, Linda S. Thomashow
Bonnie H. Ownley, and Loren B. Iten
USDA-ARS Root Disease and Biological Control Research Unit
Washington State University, Pullman, Washington

Take-all caused by *Gaeumannomyces graminis*, var. *tritici*, Pythium root rot caused by several *Pythium* species, and Rhizoctonia root rot caused by *R. solani* AG8 and *R. oryzae* occur in various mixtures in wheat and barley field soils of the Inland Northwest, and collectively cause major damage to these crops. Research over the past 15 years using soil fumigation as a tool gives some idea of the importance of root diseases: The average increase yield of winter wheat in response to soil fumigation in commercial fields has been 70, 22, and 7%, respectively, in fields cropped every year, every other year, and every third year to wheat. Besides showing the importance of root diseases these results also show the value of the 3-year crop rotation, which can be almost as effective as fumigation for root disease control. Soil fumigation is not an option, but neither is the 3-year rotation always acceptable in this area where the climate and soils of the region are so very suitable for wheat and barley at least every other year or two years in three. The poor performance of wheat and barley planted into wheat or barley residue (conservation tillage) is also the result of root diseases, favored by the soil moisture typical of soil covered with straw <u>together with</u> the lack of crop rotation. Water and not root diseases should be the limiting factor to yields of wheat and barley in this region, and because straw mulches make more water available to the crop, yields should increase significantly and not decrease in no-till systems. Root diseases must be controlled to open the way for conservation tillage, increase yields and fertilizer-use efficiency, and permit more frequent cropping to small grains.

An important breakthrough within the past 5 years, in research done cooperatively with Drs. Richard Smiley and Alex Ogg, concerns 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. This growth provides the means for root pathogens to carry over from the decomposing stubble of one crop to the young plants of the next crop. The so-call "combine row" effect commonly observed with spring grains planted directly into winter wheat stubble and where volunteer is sprayed only 1-3 days before planting is almost certainly the result of increased damage from root diseases favored by the concentration of volunteer and weed growth in the combine row. It is best to wait at least 7-10 days and preferably 2-3 weeks rather than only 1-3 days after spraying before planting wheat or barley in these kinds of management systems, to allow time for the soil to "sanitize itself" of the root pathogens hosted by the young roots of these plants. The green bridge effect is less apparent with winter wheat after winter wheat where the stubble, being relatively fresh at the time of the next planting, provides an ample source of pathogen inoculum by itself. An exception may be winter wheat with an intervening chem fallow, where the green bridge and combine-row effect can be important if the volunteer and weeds are not properly managed by a timely application of herbicide.

Another breakthrough during the past 5 years 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, and 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 healthy roots can extend considerable distances to reach a band of fertilizer, but diseased roots need easy access to the band to perform their function. Placing fertilizer 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. There is also evidence that Rhizoctonia root rot is amenable to some control simply by the action of loosening the soil to 2-3 inches below the seed independently of fertilizer placement.

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

1) Use a crop rotation such as spring barley/spring peas or lentils/winter wheat in the high rainfall areas; spring barley/fallow/winter wheat in the intermediate rainfall areas; and winter wheat/fallow/winter wheat or continuous spring grains or spring grain/fallow in the low-rainfall areas;

2) clean up the volunteer at least 7-10 days (or preferably 2-3 weeks before planting or already in the fall) before planting spring barley into winter wheat stubble, and keep fallow clean; and

3) fertilize at the time of planting such as to place the fertilizer band within easy access of the primary root system of young wheat or barley plants. Soil disturbance at the time of planting and within the seed row can also be beneficial in cases of seeding directly into stubble and where Rhizoctonia root rot is important.

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. Most of our research on these beneficial root-associated microorganisms has been aimed at understanding how they control take-all, the root disease that seems to be most amenable to this kind of biological control. 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.

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

We are proposing to use improved strains and strain combinations customized for soils and management systems. In some 10 large-scale field trials carried out since 1982, the average response to seed inoculation in fields of wheat following wheat (no crop rotation), and where take-all was the dominant yield-limiting factor, has been 10.4 % with a mixture of two strains having ability to produce one antibiotic and 15 % with a different single strain that by itself produces three related antibiotics. We have had less success with *Pythium* control, although one strain tested in field plots near Pullman where Pythium root rot was the dominant root disease gave an average yield increase of 25%.

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

CONTROLLING STRAWBREAKER FOOT ROT AND CEPHALOSPORIUM STRIPE

Timothy Murray, Larry Pritchett, Carol Stiles, and Robert de la Peña,
Department of Plant Pathology, W.S.U.

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 important in the high rainfall areas (more than 18" annual precip.), but can also cause significant yield losses in the lower rainfall areas. Both diseases are most common on early-seeded winter wheat, especially when planted following summer fallow. Yield in fields where disease is severe may only be half of that where the disease is controlled.

Since about 1977, strawbreaker foot rot has been controlled largely with one of three fungicides (Benlate, Mertect, or Topsin-M) applied in the spring before jointing. One of the problems with these fungicides is the development of resistance in the fungus causing foot rot. From 1988-1990 we surveyed 225 commercial winter wheat fields and found that about 20% of the fields had fungicide-resistant isolates of the pathogen present. When the fungus becomes resistant to one of these fungicides, it is resistant to all three, a phenomenon known as "cross-resistance." Alternative methods of controlling Strawbreaker foot rot are needed to manage fungicide resistance and limit its spread.

The use of disease resistant varieties, and/or fungicides with different modes of action, that is fungicides having a different effect on the fungus, are two areas we are investigating for control of foot rot. Two foot rot resistant varieties with high levels of resistance (Madsen - common head and Hyak - club head) are already available, however, more are needed. It is important to know that foot rot will still develop on these varieties, but usually will not be severe enough that a fungicide application is needed.

Occasionally, fungicides will be required even with resistant varieties, and for that reason we have been testing experimental materials that act differently on the fungus than the presently registered materials. Results of an experiment where Stephens wheat was treated with several fungicides in a field near Waitsburg, WA are summarized in Table 1.

Disease incidence is the percentage of infected stems at watery-ripe stage, ranging from 0 to 100%, and reflects the degree of disease control. In this experiment, the untreated control had 96% infected stems, whereas the best fungicide treatments had only 10-20% infected stems. A signficant 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, Mertect, and Topsin-M. Yield differences among many of the fungicides were not significant because of the very wet spring, which allowed infected stems to continue growing and producing grain. Under more normal conditions, these infected stems would have died and the yield differences would have been larger. 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; these treatments performed better than the standard foot rot fungicides, but not as good as some of the experimental materials tested. 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 Foliar Fungicide Trial, McCaw Farm, Waitsburg, WA 1990-1991.

Treatment, rate (a.i./acre)	%Infected Stems	Yield, bu/ac	Test Wt. lbs/bu
Punch 25EC, 3.0 oz	10.3	140.2	58.2
Benlate 50DF + Punch, 0.09 lb + 3.0 oz	12.1	145.1	58.4
RPLSR 10064B, 6.4 oz	14.4	148.0	58.4
Benlate 50DF + Punch, 0.06 lb + 2.0 oz	19.4	140.5	57.6
Benlate 50DF + RH7592 + Triton CS7, 0.25 lb+ 4.0 oz + 0.25%	23.5	122.1	57.0
RH7592 + Triton CS7, 4.0 oz + 0.25%	25.7	136.7	58.7
SAN 619F, 1.4 oz	42.5	144.1	57.0
RPLSR 10064B, 3.2 oz	43.1	139.0	57.6
Punch 25EC, 2.0 oz	47.4	131.2	58.4
SAN 619F + Mertect DF, 1.4 oz + 0.334 lb	59.4	151.5	58.8
Benlate 50DF + Tilt 3.6E, 0.25 lb + 1.7 oz	59.4	124.7	56.7
Tilt 3.6E, 1.7 oz	61.7	141.3	57.5
Topsin-M DF + Tilt 3.6E, 4.6 oz + 1.7 oz	68.7	135.2	57.2
Topsin-M DF, 9.2 oz	81.5	98.9	55.3
Benlate 50DF, 0.5 lb	92.2	89.5	55.8
Benlate 50DF, 0.25 lb	92.5	95.5	55.5
Mertect DF, 0.334 lb	95.0	94.9	55.6
Untreated Control	96.0	93.2	56.2
Least Significant Difference* (P=0.05)	3.4	21.3	1.7

*Two numbers in the same column must differ by this amount to be considered statistically different.

Improving methods of screening wheat genotypes for resistance to Strawbreaker foot rot remains a high priority. We have begun working with a commercial diagnostic kit that can specifically determine how much *P. herpotrichoides* is present inside a plant with no symptoms. Robert de la Peña, a graduate student, is using this test to identify disease resistant plants so we can develop molecular markers to identify disease resistance genes. Such markers would allow us to follow and determine which progeny plants have the resistance genes, thus eliminating the need to continually screen for disease resistance in field plots. This approach should greatly accelerate the development of strawbreaker foot rot resistant varieties and with greater accuracy than is now possible in the field. Cooperating on this work is Dr. S. Jones, USDA-ARS wheat geneticist.

Studies on the interaction of seeding date, variety, and rate of lime application were begun. A prilled formulation of lime was applied to soil with an initial pH of 4.8 at the rate of 0, 1.5, or 3.0 tons/acre on 11 June 1991. The varieties Hill 81, Madsen, and Stephens were then seeded on September 10, 20, and 30, 1991. The objectives of this study are to determine whether lime application could be a feasible commercial practice, potential variety x liming interactions exist, and if liming is effective across a range of seeding dates in controlling Cephalosporium stripe. Differences in soil pH were already apparent by 11 October; soil pH for the 0, 1.5, and 3.0 ton/acre treatments was 4.8, 5.2, and 5.5, respectively. Differences in soil population density of the pathogen through the winter did not differ among lime treatments, however.

Another method of controlling Cephalosporium stripe is to grow disease resistant varieties. However, varieties with high levels of resistance to this disease and adapted to the Inland Pacific Northwest are not available. Therefore, one of our primary objectives is to better understand how *C. gramineum* causes disease in order to develop better methods of screening for disease resistance. Carol Stiles, another graduate student, has been studying the infection of field-grown plants and found that infection of plants occurs primarily through stem bases and crown roots. This information allows us to focus our attention on these plant parts for possible differences among resistant and susceptible varieties. We have developed an antibody-based diagnostic test for Cephalosporium stripe similar to the one described above for foot rot. This fall we will begin rating wheat varieties for resistance using this test.

The genetic variation for resistance to Cephalosporium stripe in wheat is low. In order to find better sources of resistance, researchers at Montana State University surveyed over 1,000 common wheat genotypes and several wild relatives of wheat and found that the best source of resistance was *Agropyron elongatum*. All of the accessions of *Agropyron* screened, were resistant, including 70% 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 lines from this survey and have begun screening them for resistance in the growth chamber. Two new graduate students will be arriving this fall to begin working on the problem of identifying Cephalosporium resistant genotypes and the genes responsible for resistance. Again, our goal is to develop molecular markers for these resistance genes in order to accelerate the development of disease resistant varieties.

CONTROL OF *SITONA* PEA LEAF WEEVIL USING MOLECULAR TECHNIQUES

D. F. Bezdicek, L. Forse, and M. Quinn
Department of Crop and Soil Sciences, WSU, Pullman

Introduction:

Like many legumes, species of cool season food legumes enter into beneficial symbioses with *Rhizobium* bacteria which take up residence within root nodules where they fix atmospheric nitrogen into a form which the plant can use. In nitrogen-poor soils, this symbiotic nitrogen fixation can efficiently increase yields of nodulated legume crops. Unfortunately, these legume nodules also are an important food for a number of nodule-feeding insects, particularly the larval stages of *Sitona* spp. The genus *Sitona* (Order: Coleoptera) includes the pea leaf weevil (*S. lineatus*) and clover root curculio (*S. hispidulus*) whose larvae feed on nodules and adults feed on foliage. The life cycle of the pea leaf weevil Its life cycle is shown in Fig. 1. Significant yield losses can occur in peas grown in the Pacific Northwest. A number of other *Sitona* spp. are significant pests of lentils, fababeans, and chickpeas grown in the Middle East. There is no known host plant resistance to *Sitona* herbivory, and the only control measure currently available to control the insect in peas is through the use of insecticides.

In the Palouse, infestation levels vary, requiring treatment of 25 to 75% of all fields. In a three-year study by O'Keefe and Shotzko (unpublished), pea yield decreased from 12 to 26% from larval and adult infestations of *Sitona*. About half of the yield decrease was attributed to larval damage of pea nodules. Therefore, a biological control strategy to control larval feeding (which also would control adult feeding) is justified. The dry pea and lentil industries along with their green pea and seed production counterparts account for $66.7 million in revenue in Washington State alone.

Because the larvae of *Sitona* spp. must feed on legume root nodules in order to complete their life cycle, the *Rhizobium*-legume symbiosis may provide a novel means to develop a biological control strategy in which rhizobia are genetically engineered to produce natural insecticidal toxins within the nodule tissues upon which the *Sitona* larvae feed. *Bacillus thuringiensis* (*B.t.*) produces insecticidal crystals during sporulation. Microbial formulations of *B.t.* toxins have been used for over 25 years to control many of insect pests (primarily lepidopterans) in agriculture and forestry. Different strains of *B.t.* produce crystal proteins (Cry proteins) which are toxic to different insect species (Fig. 2) Whereas most of the described *B.t.* strains produce crystal toxin proteins which are toxic when ingested by lepidopteran (moths) or dipteran (flies and mosquitos) larvae, recently described strains of *B.t.* var. *tenebrionis* and var. *san diego* exhibit activity against the larvae of several coleopteran (beetles) species.

Objectives: The overall objectives of our study were to clone the gene for production of the Bt toxin from *Btt* into rhizobia which could then be inoculated onto pea seeds at planting. We will determine if the Bt toxin is produced in the nodule and if the toxin is effective in controlling feeding by *Sitona*.

Approach: To date, we have made two constructs of the *Btt* gene which utilize different promoters to control expression in *Rhizobium* which produces nodules on legumes. A simplified diagram is shown in Fig. 2. One construct (pBtt-LZ) produces the toxin all the time when the rhizobia are in culture or in the nodule, whereas the other construct (pBtt-nH) produces toxin only when the rhizobia are fixing nitrogen within the root nodule. Our approach has been (1) to inoculate peas and alfalfa seeds with the engineered strains; (2) determine if the toxin is expressed in the nodule; and (3) to determine if nodule feeding by *Sitona* larvae is reduced as compared to inoculation with control rhizobia.

Results:

Production of the toxin in pea nodules: Using Western blots (a method to measure the Bt toxin), the toxin protein has been produced both in cultures of rhizobia and in nodules of pea inoculated with the genetically-engineered rhizobia. These results indicate that the toxin is produced in sufficient quantities to be detected chemically, but other studies were done to determine if these levels are toxic to insects.

Bioassay studies on insects: The recombinant rhizobial cells and nodules were first tested on Colorado potato beetle larvae in assays on potato leaves, which served as a preliminary bioassay to determine success of the preliminary experiments. These studies were conducted on Colorado potato beetle because this bioassay is relatively simple. Results showed that both rhizobial cells and nodules containing the Bt gene were toxic to the insect.

In subsequent experiments on evaluating toxicity to *Sitona*, pea or alfalfa seeds were inoculated with the appropriate wild-type strain of *Rhizobium* or the genetically defined derivatives containing the broad host range vector pRK311 alone, or the vector plus the Bt genes (e.g. pBtt-LZ or pBtt-nifH). Approximately 21 days after sowing in small plastic cone-tainers, and inoculation of the plants with rhizobia, from 10 to 15 pea leaf weevil or clover root curculio eggs were placed at the base of each plant. After 7 additional days of growth, plants and soil were removed and nodule damage and larvae survival were assessed.

For alfalfa, table 1 shows that 45% of the nodules were damaged by inoculation with rhizobia containing the Bt gene (pBtt-LZ) as compared to 71% damage for nodules that were inoculated with the plasmid control.

Table 1. Effect of inoculation of alfalfa rhizobia containing engineered *B.t.* genes on alfalfa nodule damage from feeding by clover root curculio.

	Mean per plant	
Variable	104A14 (pBtt-LZ) rhizobia with *B.t.*	104A14 (pRK311) rhizobia without *B.t.*
Total nodules	13.78	8.80
Nodules damaged-%	44.71	70.75 *

Significantly different at (p=0.05) between inoculated strains. Number of replicates for pBtt-LZ and pRK311 treatments were 9 and 10 plants respectively.

Results of similar studies were conducted for the pea leaf weevil. Nodules containing the recombinant rhizobia were protected from pea-leaf weevil larvae as compared to plants nodulated by rhizobia which carried the plasmid vector alone. In one experiment (Fig. 3), plants nodulated by the engineered rhizobia containing the Bt genes had 31% fewer damaged nodules as compared with plants nodulated by rhizobia which harbored the vector plasmid (no Bt genes) alone. Note that there was no statistical difference in nodule damage from *Sitona* between the two engineered strains of rhizobia.

Conclusions:

Our laboratory studies have shown that Bt genes from *B.thuringiensis* var *tenebrionis* successfully produce toxin in rhizobia and in nodules from inoculation of these strains. Inoculation of alfalfa and pea with these strains reduced nodule feeding by two species of *Sitona*. Studies have also been initiated in the greenhouse at WSU and at ICARDA, Aleppo Syria, on the competitive ability of the engineered rhizobial strains against native strains and their ability to fix nitrogen on peas. Our next step is to clone the gene into the chromosome of rhizobia which would assure better stability of the gene in the event that field studies are warranted. Field trials will be considered in the future to determine how effective the engineered rhizobia control nodule feeding and fix nitrogen.

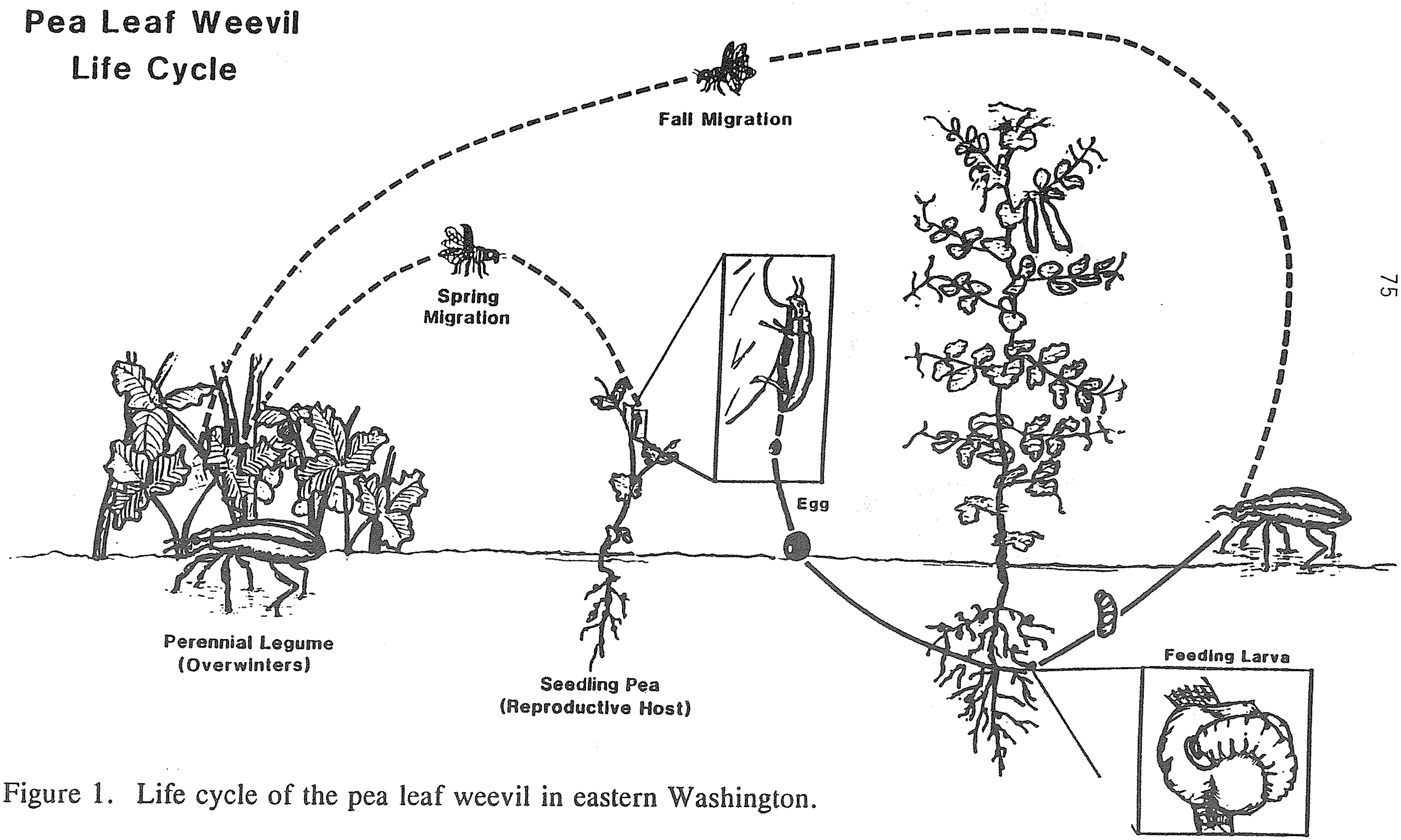

Figure 1. Life cycle of the pea leaf weevil in eastern Washington.

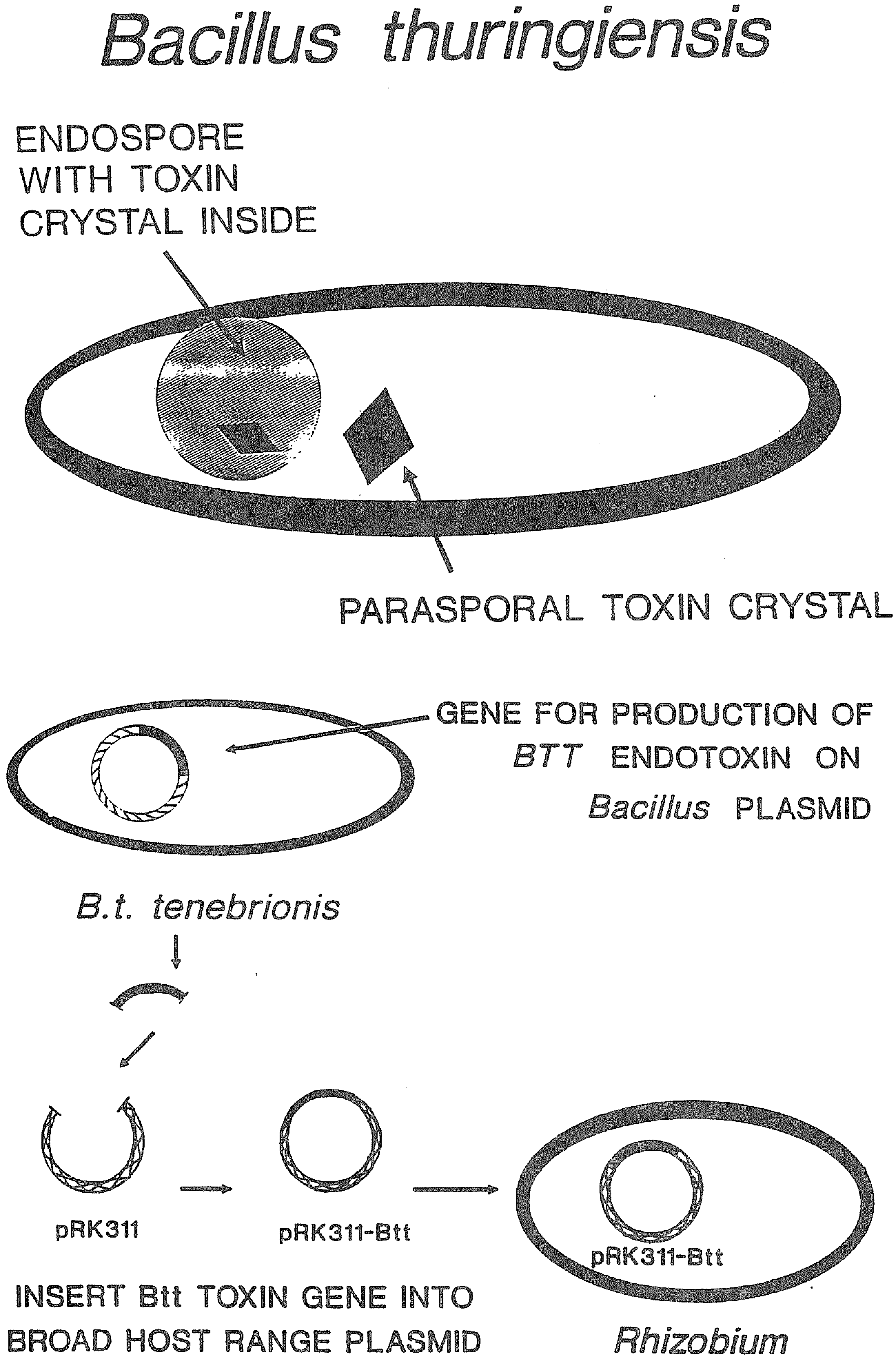

Figure 2. Pictorial description of the Bt endospore crystal within *Bacillus thuringiensis* and a simplified description of the cloning studies.

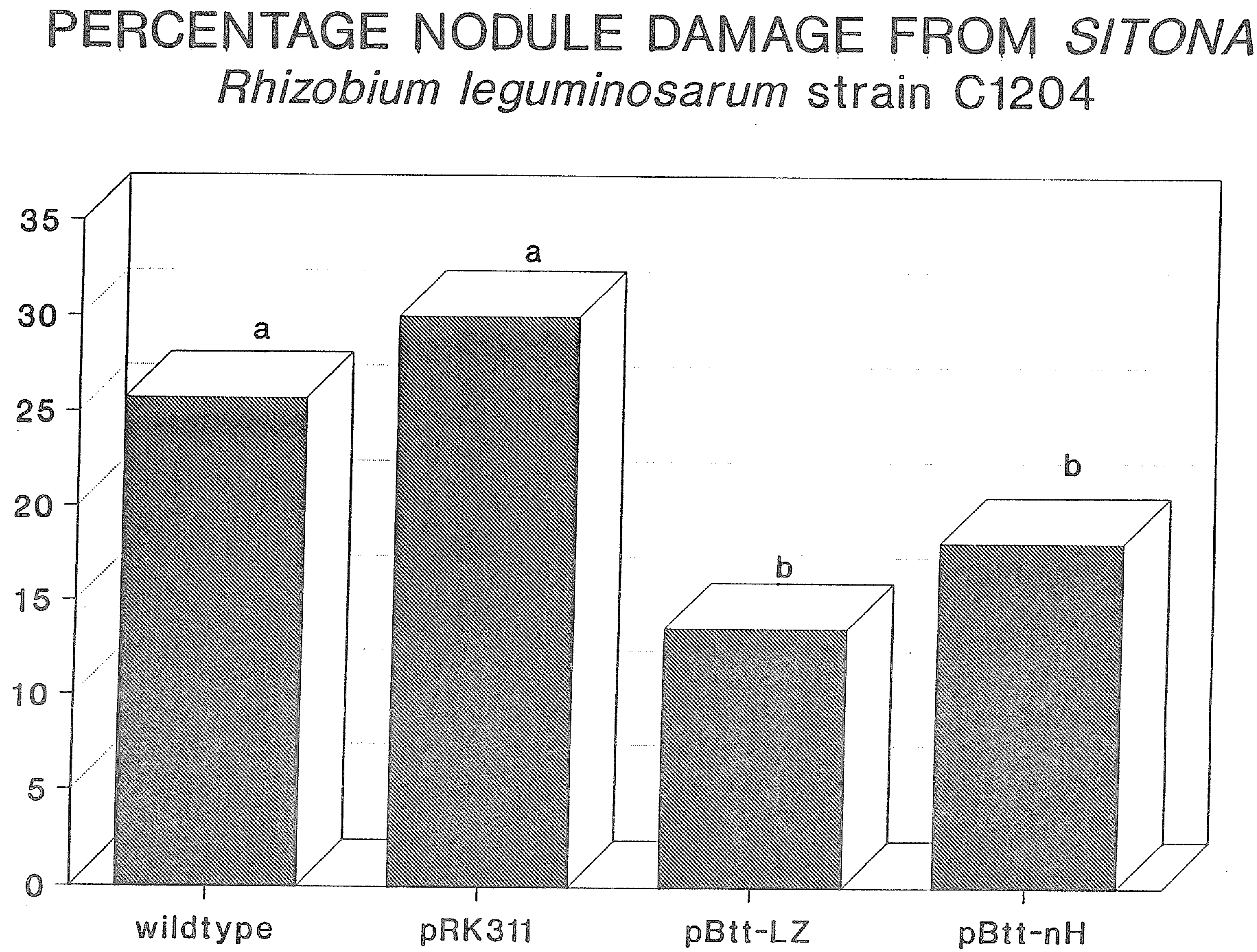

Figure 3. Pea nodule damage from *S. lineatus* when seeds were inoculated with either wild type rhizobia, the plasmid control, or two strains containing the Bt genes.

PRECISION FARM MANAGEMENT OF VARIABLE CROP LAND IN THE PACIFIC NORTHWEST

Baird Miller and Roger Veseth
Department of Crop and Soil Sciences
Washington State University, Pullman

Soil properties and landscapes can be highly variable within fields in the Inland Northwest. As a result of this variability, there are often marked differences in production potential, crop quality, production input requirements and resource protection concerns across fields. Traditional farming systems have often been based on "average" field conditions using uniform production practices across even variable fields. Precision farming of variable cropland strives to meet the specific needs of the crop within management units within fields and offers the potential for increased production efficiency, crop quality and resource protection.

To expand the development and adoption of precision farming strategies in this region, a Northwest conference on "*Precision Farming Variable Cropland for Profit and conservation*" was held February 18, 1992 at Washington State University in Pullman. A detailed Proceedings of conference presentations provides an excellent introductory reference on management considerations and strategies for variable cropland. This Technical Report article briefly highlights a few examples from the Proceedings.

Cropland and Production Variability

The Palouse region is an example of highly variable cropland in the Pacific Northwest. Slopes within fields can range from 0 to over 45 percent. Soil properties, such as topsoil depth, soil organic matter, moisture availability, texture, bulk density, residual fertility and pH can vary tremendously across landscape positions. These changing soil properties result in significant differences in crop growth, grain yield and quality, and resource management approaches. Soft white winter wheat yields varied by more than 50% across four landscape positions in a recent study near Pullman. Reduced yields on ridgetops and north facing backslopes were associated with reduced head density and lighter kernel weights. Test weights ranged from 53.8 to 61.7 lbs/bu and grain protein ranged from 8.6 to 13.1% across landscape positions. Typically, eroded ridgetop positions had much lower test weights and higher grain protein percentages. Other studies found that yields of winter barley yields declined 46% from the toeslope to an eroded ridgetop. Similarly, dry pea yield declined 77% from toeslope and ridgetop positions.

Precision farming of variable cropland starts with the design of unique management units. Factors and technologies to consider when designing management units include: crop growth patterns, yield maps, soil color pattern, soil test results, soil surveys, color or infrared photography of the crop and farmer's knowledge of the field.

Examples of Management Options for Variable Cropland

Fertility Management:

- Identify fertility management units.
- Soil sample each management unit separately.

- Apply N fertilizer based on soil tests and yield potential within each management unit.
- Apply P, K and S fertilizer to management units based on soil test thresholds.

Residue Management:

- Reduce tillage and maintain more surface residue on management units with greater erosion potential, low crop residue production or lower soil organic matter *(i.e. leave stubble stand over winter on upper slopes and ridgetops)*.
- Adjust tillage practices to increase water infiltration where soil moisture limits yields *(i.e. chisel plowing and subsoiling upper slopes and ridgetops)*.
- Reduce surface residue to accelerate soil drying and warming on wet bottomland areas with low erosion potential *(i.e. fall moldboard plowing low lying areas)*.
- Reduce surface residue in management units with high residue production, low erosion potential and a greater incidence of residue-related pest problems *(i.e. fall moldboard plowing low lying areas)*.

Disease Management:

- Use longer crop rotations on management units with high soilborne disease potential *(i.e. in low lying areas use a 3 year Wheat-Barley-Pea rotation)*.
- Adjust tillage and residue management to specific disease potential, erosion and water storage conditions among management units.
- Scout the fields and then only use foliar fungicides on the management units that require treatment.
- Select and plant varieties with disease resistance specific to the needs of the management unit *(i.e. Madsen wheat, resistant to strawbreaker foot rot, in low lying areas)*.

Weed Management:

- Scout management units within a field and use weed control measures only where necessary.
- Intensify weed management on field borders.
- Select the rate of soil active herbicides to match the soil texture and organic matter of the management unit to increase effectiveness and reduce crop injury.
- Adjust herbicide selection and application among management units to minimize the potential for leaching, runoff, and soil carryover.
- Alter crop rotations, seeding dates, tillage and residue management to optimize weed control *(i.e. move from a Wheat-Pea rotation to a Wheat-Barley-Pea)*.

Crop Rotation and Variety Selection:

- Establish cover crops on areas with low yield and high erosion potential *(i.e. perennial grass on eroded ridgetops)*.
- Establish deep tap-rooted crops, such as rapeseed, on units where soil compaction limits productivity and contributes to runoff and erosion.
- Use longer crop rotations in higher moisture areas with greater yield and disease potential *(i.e. use Wheat-Barley-Pea rotation in low lying areas)*.

- Shorten the crop rotation on management units with lower water availability, yield and disease potential *(i.e. continuous cereals on ridgetops)*.
- Seed drought tolerant and winterhardy varieties where needed *(i.e. plant Daws, Eltan or Lewjain on ridgetops and upper slopes)*.
- Plant variety mixtures *(i.e. mix winter hardy Daws with the drought resistant Lewjain)*.
- Plant varieties tolerant to soilborne and foliar diseases, and lodging on management units with higher soil moisture levels *(i.e. Madsen, resistant to strawbreaker foot rot, in low lying areas)*.

Proceedings Available

Copies of the Proceedings from the February 1992 conference on "*Precision Farming Variable Cropland for Profit and Conservation*" are available from: Baird Miller, Department of Crop and Soil Sciences, Washington State University, Pullman WA 99164-6420. Send your request with a $4.00 check payable to the Crop and Soil Sciences Department.

Acknowledgements

The authors wish to acknowledge the numerous individuals involved in the conference who provided input on the design of management units and crop management options, and are continuing with research in the area of variable cropland management. These individuals include: Bill Pan, Tim Fiez, Alan Busacca, Jim Montgomery, Ann Kennedy, Bob Mahler, Keith Saxton, Don McCool, Tim Murray, Jim Cook, Chris Boerboom, Frank Young, Alex Ogg, Stephen Guy, Dennis Roe, Ed Michalson, Bruce Frazier, David Mulla, Charles Peterson, Bin He, John Whitcraft, and Roland Schirman.

DESIGNING SOIL MANAGEMENT UNITS

Bruce E. Frazier, Associate Soil Scientist
Cindy Hill-Wilcox, Graduate Student
Crop and Soil Sciences Department

Much discussion and research effort is being devoted to developing methods to delineate areas of soil that can be managed uniformly. The objective for the grower is to produce profitable crops without causing erosion and without leftover fertilizer, herbicides and pesticides to contaminate the groundwater. This can be accomplished if soils are fertilized to meet their yield potential. The difficulty is that Palouse region soils are heterogeneous with regard to organic matter contents, fertility status, and landscape position and therefore, are difficult to group into units that can be managed uniformly. Those soils that have little yield potential should receive lesser amounts of agricultural chemical inputs. The question is how do we delineate soils on the landscape so that they represent management units. There are numerous approaches to use in answering this question. The one to be addressed here is the use of computer-stored map information known as a geographic information system (GIS).

The project objectives were to: (1) Develop data bases to represent variability found in major portions of the Palouse landscape; (2) Propose data layers that are commonly available and that do not require extensive field sampling; (3) Propose criteria that could serve to measure the appropriateness of data layers used in the design of soil management units; and (4) Evaluate the data layers in light of the proposed criteria.

Selected data layers were encoded into the GIS program (Arc/Info) and made available for analysis. The data layers were rated against the following criteria:

1. Data layers should be chosen from standardized and readily available data, and preferably not involve excessive field or laboratory work.
2. Delineations of the management unit must be easy to visualize and be large enough for average sized equipment to negotiate. A management unit of $5m^2$ is of no use to a grower whose equipment is twice that size.
3. Data layers should be updated often enough to reflect important changes.
4. The ability to georeference the data layer accurately is important.
5. The data layers should accurately reflect field conditions.

The data layers selected for use in the GIS were the United States Department of Agriculture (USDA) soil survey units, topography in the form of digital elevation models (DEM) which could be viewed in 3 dimensions on the computer screen, maps of organic carbon values, and digital line graphs (hydrology, roads, and public land surveys).

The soil map fit the standardized data criterion, and one that easily described visual management units. However, the soil maps were very difficult to overlay accurately on the other data layers and there was considerable question about how well they represented the actual variability.

Topography fit most of the criteria well. The one criterion it did not pass was the accuracy of representing the shape of the actual landscape. In one case drainageways were represented as running over hills, etc. Management units based solely on topography could be poorly designed because of incorrect slopes and slope locations.

Organic carbon maps were the best source of data to design management units. In addition to fitting the criteria better, organic carbon is also an indicator for fertilizer, herbicide and pesticide application rates. Soil management units based in part on organic carbon content are visible and can be defined on the ground, they are mappable from aerial photography or satellite images, and they are an important indicator of what amounts of soil amendments to apply. Organic carbon maps superimposed on 3-d images of the topography were useful to visualize the location of potential management units.

Conventional farming practices rely heavily upon past amendment histories, or utilize few soil tests to determine fertilizer, herbicide and pesticide management schemes. Most fields, although variable in soil characteristics, are managed uniformly for chemical applications. The method explored in this study provides a means to visualize where management units based on organic carbon and topography occur. Technology needed to implement this procedure is currently available and could be provided by consultants or within agricultural support programs of the Soil Conservation Service. The method provides a quick, accurate assessment of the organic carbon distribution in a field, allowing amendment application decisions to be made. Although there are other data layers that could be added to the model (i.e., pH, water holding capacity), these can be time consuming to collect and analyze. The emphasis of this project was to develop simple relationships among readily available data. The final decision on where the management unit boundaries occur will ultimately reside with the grower and will be influenced by size of the equipment (how steep a slope it can turn around on), preferred crop rotation, and requirements of government farm programs.

MANAGEMENT APPROACHES TO FERTILITY AND BIOLOGICAL VARIATION IN THE INLAND PACIFIC NORTHWEST

Pan, William, Baird Miller, *Ann Kennedy, Tim Fiez, Munir Mohammad
Dept. of Crop and Soil Sciences, Washington State Univ., Pullman, WA
*USDA-ARS, Pullman, WA.

Several soil biological and chemical entities and processes vary across the rolling hills of the Palouse region of the Inland Pacific Northwest. To efficiently use agricultural inputs, and to optimize yields while addressing soil, water, and crop quality goals, these factors will need to be better understood before variable landscape management systems can be implemented. Variable yields, often obtained at different landscape positions are an end result of the variation in soil productivity across Palouse landscapes. Variable available water is most often cited as explanation for these variable yields, yet there are many other soil factors that contribute to soil productivity in this region.

Organic matter is an important soil constituent which influences virtually all chemical, biological and physical processes that occur in these soils. The level of organic matter is dependent on temperature, moisture, and degree of erosion. All contribute to variations observed across agroclimatic zones and within fields, ranging from less than 1 % to over 4 %. Improving soil organic matter levels will require effective erosion control, production and recycling of crop residues with proportional N inputs, and an input of organic matter from animal manure, sewage sludge, or green manure. Yields from organic amendments on these soils often exceed those obtained from synthetic fertilizers.

Nitrogen fertility status of these soils also varies across landscapes. N mineralization rates, as estimated from check plots not receiving N fertilizer, vary by position. Low N mineralization was estimated on severely eroded ridgetops with exposed subsoil and low organic matter. Nitrogen losses during a single growing season also vary. High levels of unaccounted N in the crop-soil budget were measured on the north-facing backslope and footslope positions, areas that receive input of water from lateral flow, and are subject to excessive leaching and denitrification. Differences in soil residual N build up over several cropping cycles. High residual N tends to build up in positions of low productivity such as eroded ridgetops, where plant utilization is lower. North-facing backslopes have been found to have lower levels of residual N, likely due to greater N losses . Uptake efficiency varies with slope position and level of N supply, ranging from 70 to 65% at the south facing slope vs. 60 to 35% at the north facing slope. Spring N applications avoid overwinter losses. Recent experiments demonstrated point injected spring N in winter wheat increased N use efficiency over fall applied N.

Phosphorus fertility is closely correlated with organic matter status across these landscapes, and therefore tends to be lower in positions that have sustained topsoil and organic matter losses. Subsoils of eroded soils can be extremely low in available P. In these situations, we can fertilize the surface layer to accommodate early season P uptake, but as that surface layer dries out, the P fertilizer is stranded, and in this example, P uptake during grain-filling was low to negligible in positions lacking adequate subsoil P. We are currently investigating potential benefits from deep P placement with subsoiling equipment. In addition, mycorrhizal inoculation of eroded soils may provide future directions for P management. VAM inoculation elicited substantial increases in growth and nutrient accumulation of growth chamber-grown wheat in soils from eroded ridgetop and backslope, but not in toeslope soil. Soil microorganisms affect nutrient cycling and plant growth. The dehydrogenase assay is a measure of microbial activity. Activity in the ridgetop and north backslope were less than that in the footslope and south backslope. Differences could not be completely explained by the amount of soluble carbon present at each position.

Soil pH also varies across agroclimatic zones, as well as within fields. Zones of above neutral pH's are more commonly found in the lower rainfall zones, where calcareous layers are exposed by erosion. Less in-field variation has been observed in the higher rainfall zones. Some of the problems that could arise as a result of these calcareous outcroppings include decreased micronutrient (Fe, Zn, B, Mn) solubility, lowered P availability, and greater potential for ammonia volatilization. Site specific fertilization practices may need to be established to overcome these problems.

In summary, variable management will need to address all of these factors collectively in defining efficient management schemes across the Palouse landscape. Recent technological advances in remote sensing, yield mapping, global positioning, and variable rate chemical applicators will soon make it possible to variably manage a farm field according to changing soil and microenvironmental changes that occur across the landscape.

TILLAGE AND RESIDUE MANAGEMENT CONSIDERATIONS FOR VARIABLE CROPLAND

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist, Moscow, ID,
Keith Saxton, USDA-ARS Agricultural Engineer, Pullman, WA, and
Don McCool, USDA-ARS Agricultural Engineer, Pullman

Introduction

Landscapes and soil properties can be highly variable within fields in the Northwest cropping region. Production limitations, yield potentials and the need for associated production inputs typically vary with changes in landscapes and soils. In the past, even variable cropland has often been farmed with uniform production practices. In the 1990s, however, increasing environmental concerns and the need for improved production efficiency are demanding more precise farming of variable fields. Making adjustments in tillage, residue management and production inputs for precision farming of variable cropland can offer substantial opportunities to simultaneously improve production efficiency, profitability and resource protection.

Water is one of the most limiting crop production factors in much of the Northwest. Within fields, water is typically most limiting in areas with shallow soil, particularly on ridgetops and upper slopes, where crop residue production is low and soils are usually least conducive to water infiltration and storage. Management practices which improve water storage in these critical areas can significantly improve yield potential and profitability. Fortunately, saving water for crop production and controlling erosion generally go hand in hand. Variable tillage and residue management with a focus on water storage also offer improved protection from soil loss by water and wind erosion, and associated pollution problems.

In contrast to ridgetops and upper slopes, the bottomland and lower slope areas have a lower erosion potential and often water is not the most limiting yield factor. Production problems due to excessive amounts of residue, more intensive weed and disease pressures, and wet soils can often be more yield-limiting than water availability. Intensive residue incorporation with tillage, or partial surface residue removal, might be more appropriate and profitable management practices in these areas.

The need for variable tillage and residue management systems within fields will vary across the region and for each grower and field. The following are four example areas of contrasting production goals to manage for within the same field using variable tillage and residue management practices.

1. Dry areas: Increase water storage with surface residue and other practices in areas where water is most limiting.
2. Highly erodible areas: Control soil erosion with surface residue and other practices in areas which are most vulnerable to erosion, sustain low residue production, and benefit most from organic matter contributions to improve soil quality.
3. Wet areas: Accelerate soil drying and warming in wet areas which have excessive residue production and low erosion potential.
4. Heavy residue areas: Reduce weed and disease problems with more intensive incorporation and/or removal of residue in areas where pest problems are more yield-limiting than water availability.

The greatest need for change in management strategies is to select tillage and residue management methods to increase water storage and erosion protection where needed most within fields. Intensive tillage practices for accelerating soil warming and drying, and reducing weed and disease problems have always been a part of conventional tillage systems.

Achieving Tillage and Residue Objectives

Equipment Considerations

Tillage is the principal manipulator of residue. Almost any field operation, including seeding, will result in some residue incorporation. The primary tillage operation can often result in the most significant reduction in surface residue, and implement selection must be made in light of the final residue level desired after seeding of the next crop. Inversion tillage implements, such as the moldboard plow and heavy disk, are the most severe for residue incorporation. However, with careful adjustment and use, they still can have application to conservation tillage systems, particularly in variable tillage and residue management systems. Plowing uphill is also the only tillage operation which moves soil upslope. Tillage erosion from downhill plowing and other tillage operations over the years has significantly reduced topsoil depth on ridgetops and upper slopes.

Substantial improvements in water conservation and erosion control across variable cropland can be made with equipment that most growers already have. Frequently, minor changes in equipment components, adjustment and operation are all that are needed. Some growers have chosen to make shop modifications of their present equipment. Others have opted for specialized commercial equipment for conservation tillage.

Some relatively new types of equipment, or at least those not considered standard equipment on most farms, may provide some new management options to improve soil water storage potential on Northwest cropland, particularly for ridgetops and upper slope positions. There are an increasing number of types and styles of subsoiling or other deeper tillage implements on the market. Surface pitting implements, some including subsoiling in the operation, are also becoming more common. There is growing interest in these alternative tillage practices for increasing water storage and reducing erosion in a variety of dryland cropping situations in this region, particularly in areas which commonly have runoff on frozen soil or have restricted water infiltration due to soil compaction. Additional research is needed to help identify under what field conditions these different implements might be considered and how they should be used.

Residue Removal

Although tillage is the primary tool for managing residue, other practices might be part of the residue management strategy for variable cropland. Some of the excess residue produced on bottomland areas, where soil erosion potential is low, might occasionally be removed without significant detrimental effects. Where there are available markets, stubble could be clipped and baled. Combine residue spreading attachments could also be disengaged or removed so that the straw and chaff rows are concentrated behind the combine for easier baling.

Burning has been used as a quick residue removal tool. Long-term repeated field burning along with tillage has been shown to be detrimental to soil productivity.

However, burning might be a limited tool to occasionally manage excess residue and associated pest or production problems on wet bottomland areas. Care must be taken to avoid burning upland areas were water is more limiting to production, where erosion potential is higher and organic matter contributions are more critical to sustaining soil productivity. More stringent regulations and increasing public concerns regarding air quality must also be considered.

Approaches of Variable Tillage and Residue Management

Variable tillage and residue management approaches can be and are being utilized within block farming systems on whole fields, as well as within divided slopes and field strips, and field divisions which specifically identify management units. The basic principles can be adapted to much of the Northwest, spanning precipitation zones and topographic regions. However, the degree to which variable tillage and residue management within fields are needed and are possible will depend on each field and farm situation.

In some cases, the use of variable tillage and residue management practices within fields might apply only to the primary tillage operation, with all subsequent field operations the same across the field. In other situations, growers might maintain differences in practices up until seedbed preparation or planting of the following crop across the whole field. Finally, individual "management zones" could be continuously maintained within fields, such as with permanently divided slopes, field strips or other field divisions. The choice is up to the grower, with decisions based on differences in erosion and yield potentials, special production limitations, the particular layout and topography of the field, ease of identifying the management units, travel distance between fields, and many other production concerns.

The final overwinter condition of the field is very important for fall-seeded crops since this water storage period is critical to yield and erosion protection. Tillage and residue management decisions in the fall after harvest are also important for the next spring crop, affecting water storage and erosion potential overwinter and in the spring. Furthermore, they can affect water storage and erosion potential through the subsequent fall and winter when a fall-seeded crop will be planted.

Summary

Differential tillage and residue management practices across field landscapes can optimize residue benefits where they are most needed, while minimizing associated production limitations where excess residue levels can be detrimental. The greatest benefit of surface residue and conservation tillage will be on field areas where water is most limiting to yield, and where soil erosion potential is greatest. Adapting tillage and residue management practices to variable cropland offers the potential for both improved profitability and resource protection.

More information on this topic can be found in "Precision Farming Variable Cropland for Profit and Conservation," the proceedings of 1992 Inland Northwest Conservation Farming Conference at WSU in Pullman. Send a $4.00 check payable to Crop and Soil Sciences Dept. and mail it with the proceedings request to: Baird Miller, Crop and Soil Sciences Dept., WSU, Pullman, 99164-6420.

IMPROVING SOIL QUALITY AND DECREASING SOIL EROSION THROUGH RESERVOIR TILLAGE: SUBSOIL-RIDGE TILL

David Bezdicek and Theresa Beaver

Introduction:

Some Pacific Northwest wheat farmers are experimenting with new tillage practices that show promise in reducing erosion and improving soil quality. We report on the progress of five on-farm trials and one replicated trial initiated last fall. Reservoir tillage is a practice which increases the capacity of soil to capture and hold water. We have used the subsoiler-ridge till implement as a substitute to plowing cereal residue in the fall.

The subsoiler-ridger tool, manufactured by Lenz Manufacturing of Paulina Iowa, has shanks at 36-inch intervals which penetrate to a depth of 18 inches. Sweeps midway between the shanks mix the soil with the wheat residues and form a corrugated soil surface of 6- to 12 -inch deep ridges and valleys over the subsoiled region. This operation was done on the contour in the fall which we hope will eliminate soil erosion during the immediate winter. Sites are either in fallow now or are planted to peas. The effectiveness of the tillage practice on controlling soil erosion will be monitored during the critical winter period following the seeding of winter wheat.

Objectives:

1. Document changes in soil physical, chemical, and microbiological properties and water quality for the subsoil ridge till (SSR) concept as compared to conventional practices;

2. Monitor soil water movement with traditional methods in replicated plots and in on-farm trials by growers using gypsum block methodologies and "farmer self education" programs developed by INFORM;

3. Document changes in crop productivity, soil quality, potential for water quality protection, and economic returns using the SSR concept; and

4. Develop, document, and broadly disseminate field practices which identify more sustainable whole-farm management systems.

Progress:

Five-on farm trials have been established last fall in Walla Walla, Columbia, Latah, and Whitman counties, where the subsoiler was compared to the grower's conventional fall tillage. Two replications were included in the Walla Walla sites. The subsoiler was operated on the contour by growers using their own tractor. Depth varied from 16 to 18 inches. Sites in Walla Walla county are in summer fallow in 1992, whereas all the other sites are cropped either to peas or to pinto beans. All sites are from 3 to 5 acres for each treatment. Tillage operations are compared side-by-side up and down the slope in order to measure and observe erosion for the entire slope. Grower fall tillage operations included combinations of disking, moldboard plowing, and chisel plowing. One grower (Clemm, Troy ID) used the subsoiler immediately after seeding winter wheat as a potential measure for controlling erosion during last winter and this spring.

Slopes varied from a high of 40 to 45% at the Martin (Walla Walla county) and Klingenstein (Columbia county) sites to 10% at the Quist site. Both of the steep slope sites are highly erosive. Lime was included as a variable on the Walla Walla and Latah (Troy) sites. Growers participated in the plot design at some sites. Soils were extensively sampled on all sites for routine analyses and sent to two labs. All sites will be monitored during the next three years and especially during the fall of 1992 and spring of 1993 when the greatest benefits of subsoiling in preventing erosion are expected.

Results:

Data are available on the Quist site for profile soil moisture and wheat residue on the surface after planting of peas. Residue levels were taken on 6 May 1992 by SCS Soil Conservationist David Chain. These results are presented in Table 1.

Table 1. Soil profile moisture and residue cover following the planting of peas in plots where winter wheat residue was tilled in fall of 1991 by either subsoil-ridge till or moldboard plow.

Parameter	Treatment	
	Subsoil	Plowing
Soil Moisture-%		
1ft	23.3	21.8
2ft	23.0	22.2
3ft	22.5	22.1
4ft	20.5	19.2
5ft	16.2	14.2
Average	21.1	19.9
Residue Cover-%	20.0	0.5

Don Quist site, Pullman. Average of 4 replications

Profile soil moisture was higher at all depths following subsoil-ridge till as compared to plowing. Because of the mild slope (15%) and the absence of erosion during the winter, no erosion occurred. Residue cover was appreciably higher following the subsoiling treatment which reflects the maintenance of more residue on the soil surface. The accumulative effect of the additional residue and the effect of deep tillage will be monitored for erosion in the winter of 1992-93 on this site and at the on-farm trials. Physical and biological tests for soil quality and soil moisture using gypsum blocks will be monitored during the next season.

Cooperators: Progressive Farmers Inland Northwest, Walla Walla; Steve Reinertsen, The MacGregor Company, Colfax, WA; Gale Richardson, INFORM, New York, N. Y.; R. I. Papendick, USDA/ARS, Pullman; D. Young, Dept Ag. Econ, WSU; D. Granatstein, Crop and Soil Sciences, WSU.; Dennis Roe, SCS, Whitman Co.; Larry Hooker, SCS, Walla Walla Co.; and R. Schirman, Columbia Ct Coop. Ext. The following growers participated in the study: Bob Klicker, Ed Martin, and Craig Noble of Walla, Walla; Bob Klingenstein, Dayton; Barry Holben, Genesee ID; Cathy and Jerry Clemm, Troy ID; and Don Quist, Pullman.

EROSION CONTROL - RESIDUE VS. ROUGHNESS

D. K. McCool

Meeting compliance requirements of the 1985 Food Security Act is a concern of most crop producers. The process used in developing FSA farm plans considers a number of crop elements including crop canopy, root mass and incorporated residue, surface residue, surface roughness or cloddiness and antecedent moisture. Research data and field experience indicates that, in the annual cropping area of the Palouse, surface residue is the most important factor during the critical winter period. Accordingly, target residue levels are specified in FSA farm plans. Seeding date and surface roughness are generally specified as well.

Surface residue is specified as percent cover and/or pounds per acre. Pounds per acre is determined by clipping or collecting and weighing residue from a number of small areas. The procedure is very labor intensive and unsuitable for compliance checking. Percent cover can be determined by various sampling techniques. The most used is the bead line technique where a line with 100 beads is stretched across the field and one corner of the intersection of each bead with the line is selected as the very small point under which residue must lie to be counted. This technique considers a larger field area. Several samples should be taken to narrow the statistical limits.

Surface roughness is frequently described in terms of predominant clod size, or predominant range of clod sizes. Sometimes a farm plan requires a specified number of hits or counts on a minimum clod size with a bead line. In an attempt to simplify the ranking of surface roughness, a number of areas are photographed and a roughness parameter called random roughness is determined. The photographs, with associated random roughness values, can be compared to the field condition and a random roughness value assigned. This provides a way for both the producer and SCS employees to quickly evaluate the surface roughness of a given field.

Erosion models can be used to determine how much residue requirements might be reduced if surface roughness were increased. Accordingly, FSA farm plans could be written with alternative levels of residue and roughness requirements, allowing the producer more flexibility in meeting compliance requirements.