Washington State University

Department of Crop and Soil Sciences

Technical Report 91-2

Highlights of Research Progress

O.A. Vogel
1907 - 1991

Dryland Research Unit, Lind
June 20, 1991

Spillman Farm, Pullman
July 11, 1991

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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DEDICATION TO DR. ORVILLE A. VOGEL

by R. E. Allan

Dr. Orville A. Vogel died on April 12, 1991 in Lacy, WA. It is indeed fitting that we dedicate the 1991 Field Day Brochure to Orville. Orville Vogel was a world-renowned USDA-ARS wheat breeder. We were fortunate that he spent his entire 42 year career stationed in Pullman. The world knew Orville as the scientist that provided Norman Borlaug with the semidwarf germplasm that was used to bring about the Green Revolution. His variety Gaines attained the world record wheat yield of 209 Bu/Ac and this record still remains unbroken today!

Here in Washington we remember Orville as a "hands-on" wheat breeder and a master at subjecting his breeding materials to critical field situations in order to identify the most superior segregates. His wheats added millions to the income of Pacific Northwest farmers and to quote Clarence Peterson, his varieties literally kept many farmers in business during tough economic times.

Orville used the field as his laboratory and he was a keen observer. He literally lived with each crop as it developed determining which of his selections could best endure what he called the hazards of production. It was in his plots, first at Observatory Hill, then at Spillman Farm as well as in cooperator test plots, where Orville made important selections that included durable stripe rust resistance, tolerance to cephalosporium stripe, multiple gene resistance to common bunt, lodging resistance and superior club wheat milling and baking quality.

Orville realized that an agronomy farm which was readily accessible and with highly productive soils was essential for research progress. He was very instrumental in selecting Spillman Farm as an experimental site and when an adjacent farm was for sale, he worked quickly with a farmer-friend to insure the University would acquire it. This additional land allowed for expansion of field research of both existing and new WSU and ARS programs.

Orville was a skilled mechanic and an ingenious inventor. He designed and built threshers, planters and other experimental machines that are still used in cereal improvement projects worldwide. These machines probably had as great an impact on small grain improvement as his famous semidwarf wheat germplasm. His inventions will be exhibited at the Spillman Farm Field Day.

Orville received many prestigious awards. They included: an Honorary Doctorate of Agriculture, University of Nebraska; Edward M. Browning Award; National Medal of Science; Washington State University Distinguished Alumnus Award; State of Washington Centennial Hall of Fame; State of Washington Medal of Merit; the USDA Agricultural Research Service Hall of Farm; and the John Scott Award. Prestigious as these awards were, Orville treasured most of all his opportunity to work throughout his career with farmers and others of the Pacific Northwest wheat industry, according to Rick Swantz, CAHE Development Director.

After his retirement, Orville and his wife, Bertha, worked tirelessly for the College of Agriculture as fund raisers. They matched contributions on a $1.00 to $20.00 basis and donated $26,000 of their own money. The Vogel Wheat Research Fund now stands at $700,000 and eventually should reach $5 million through deferred gifts.

We will miss Orville but we will never forget him. The legacy he has left behind insures that the Pullman-based WSU-ARS wheat program will be among the very best in the world.

DR. ORVILLE A. VOGEL'S CONTRIBUTION TO THE DEVELOPMENT OF RESEARCH EQUIPMENT

C. J. Peterson

Dr. O.A. Vogel made noteworthy contributions in the development of wheat cultivars and in the development of research equipment. In his 1932 annual report he stated "The necessity for increased efficiency in nursery maintenance has prompted the construction of new equipment such as a special nursery planter for drilling and space planting one and three rows of wheat at a time, a rod row thresher with special cleaning and recleaning devices and other labor saving devices." He spent part of his career (mostly in the evenings, weekends, and holidays) in the development of research equipment.

He designed and built hoes, row markers, recleaners, one, three and eight row planters, spike and bundle threshers of various sizes, combines, a rubber roller thresher, a freezing chamber, seed storage boxes and shelves, a cultivator, modified a small roto-tiller to cultivate rows of wheat, and an eight wheel tractor that would reduce soil compaction. The development and improvement of plot equipment continued throughout his illustrious career.

Commercial construction of the research equipment began at Bills Welding in Pullman in 1946. Other companies soon followed with their versions of Vogel's equipment.

Dr. Vogel designed and built three plot combines one of these after his retirement in 1972. Each one was an improvement over the other one. They were all based on his highly successful nursery thresher. The first one is the combine of choice by the researchers at WSU when they want pure seed.

At the 1954 National Wheat Growers meeting B.B. Bayles stated "that the initial designs of the Vogel Nursery and Head Threshers and recleaners, and the continuous year by year improvements leading to and following commercial production of these machines, has resulted in greater benefits to more different experimental projects on more experiment stations, both foreign and domestic, than the results of any other single project presently carried in the Cereal Crops Division. He also stated that many experiment station workers were finally recognizing that the head threshers and the combination nursery thresher and grain recleaner were valuable not only for greatly increasing the speed and efficiency of threshing small samples but represented the best equipment yet devised for obtaining a direct rating of threshability of many crops other than wheat." Certainly at his time of retirement Dr. Vogel was recognized world wide as having made a tremendous contribution to wheat research through the development of research equipment.

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
F. L. Poston...............................Director of Cooperative Extension
D. G. Miller..............................Chairman of Crop and Soil Sciences

Cereal Breeding, Genetics and Physiology

R.E. Allan, J.A. Pritchett, L.M. Little, USDA..................Wheat Genetics
E. Donaldson, M. Nagamitsu, 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
B.C. Miller, P.E. Reisenauer.........................Cereal Cropping Systems
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,
B.S. Patterson, 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, C.F. Engle, 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 1990-91 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:

Fertilizer, Seed and Amendments

W. Brotherton Seed Co.
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WA Dry Pea & Lentil Comm.
Adams Co. Wheat Growers
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Uniroyal-Gustafson
WA Wheat Commission
American Cyanamid
Great Western Malting Co.
Monsanto Co.
Tri-River Chemical
WA Barley Commission

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

Adams County Wheat Growers
American Malting Barley
Lind Grange
McGregor Co.
Puregro Co. (Ritzville, Harrington & Wilbur)
Wilfac
Whitman County Wheat Growers
Bob Zimmerman Equipment

Farmer Cooperators

Jeff Aune	Lacrosse
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Steve Camp	Lacrosse
Cliff Carsten	Reardan
Cenex-Full Circle/Grant Torrey	Moses Lake
Clark Farms	Pullman
Brian Crow	Oakesdale
Earl Crowe	Farmington
Jesse Davis	Pullman
Don DeArmond	Grangeville
Van Deffenbaugh	Kennewick
Dale Dietrich/Wilke Farm	Davenport
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Dusty Eckhart	Deer Park
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Koller Farms	Mayview
Robert Kramer	Harrington
Quentin Landreth	Espanola
Jerry Linden	Goldendale
Steve Mader	Pullman
Lee Maguire	Thornton

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Reggie Waldher	Pomeroy
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Curt White & Sons	Lamont
Bob Wigen	Lacrosse
Dick/Ron Wilbourn	Pullman
Fred Wilkens	Bickleton
Lyle Wilse	Deer Park
Cliff Wolf	Colton
Steve Wolf	Pomeroy
Gary Wollweber	Edwall
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 semi-arid 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 75th 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 show 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 ^{0}F.		Precipitation		Precipitation
Month	Max.	Min.	1990	1991	70 yrs. Av (in)
January	34	22	1.17	.65	1.01
February	42	24	.32	.53	.86
March	53	32	.30	1.79	.80
April	63	35	1.36	.50	.69
May	72	42	.39		.74
June	83	45	.42		.81
July	90	52	1.00		.26
August	90	50	2.14		.36
September	79	45	.00		.56
October	65	38	2.16		.85
November	47	29	.32		1.22
December	37	26	1.12		1.26
			10.70		9.42

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, 1990-91

Month	Monthly Avg. Temperature(F) Max.	Min.	Precipitation (in) 30-Yr Avg.*	Monthly	Total Accum.	Deviation from Avg. Monthly	Accum.
1990							
January	38.6	29.4	2.89	4.45	4.45	+1.56	+1.56
February	40.4	24.9	2.09	1.46	5.91	- .63	+ .93
March	52.9	31.3	1.96	.90	6.81	-1.06	- .13
April	61.0	37.8	1.58	2.81	9.62	+1.23	+1.10
May	62.7	40.8	1.52	2.55	12.17	+1.03	+2.13
June	71.5	47.1	1.49	1.22	13.39	- .27	+1.86
July	84.7	50.9	.53	.76	14.15	+ .23	+2.09
August	83.5	51.9	.95	.83	14.98	- .12	+1.97
September	84.0	46.4	.99	.03	15.01	- .96	+1.01
October	56.5	35.9	1.61	2.54	17.55	+ .93	+1.94
November	45.8	34.7	2.64	3.66	21.21	+1.02	+2.96
December	29.6	17.1	3.07	1.91	23.12	-1.16	+1.91
TOTAL	59.3	37.4	21.32		23.12		+1.91
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
TOTAL			8.52		6.81		-1.71
1990 CROP YEAR Sept. 1989 thru June 30, 1990			19.84		18.83		-1.01

*Thirty year average for precipitation, 1951-1990.

USDA-ARS WHEAT GENETICS RESEARCH PROGRESS REPORT

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

Rely, A New Club Multiline.

With the occurrence of several stripe rust races that are capable of attacking the Tres type of resistance, vulnerability of club wheat to stripe rust has become a major problem. Rely (WA7527) a multiline club cultivar has been approved for release and is intended to replace Crew multiline. Rely is heterogeneous for resistance to stripe rust, leaf rust and powdery mildew. Among the 10 components of Rely, 7 to 10 have race-specific resistance to the currently predominant biotypes of stripe rust. Seven of the components are uniform or heterogeneous for resistance to stripe rust biotypes that attack the resistance gene of Tres. Rely usually expresses higher field resistance to stripe rust than the multiline Crew. In four 1990 tests, Rely had 8 to 18% less stripe rust on its flag leaves when compared to those of Crew. Rely is susceptible to pathogens causing dwarf bunt, cephalosporium stripe and stem rust; it is moderately susceptible to the strawbreaker fungus. The grain yields of Rely have generally been comparable to other club cultivars. In 32 state of Washington trials Rely, Tres, Crew, and Hyak had mean yields of 81.7, 82.4, 78.3 and 79.3 Bu/Ac, respectively. In 24 regional tests in Oregon, Idaho and Montana, Rely, Tres, Hyak and Moro had mean yields of 88.0 90.0, 87.1, and 72.1 Bu/Ac, respectively. Rely has a mean grain volume weight averaging 0.6 to 1.5 lb/Bu heavier than Hyak and Moro, respectively. Rely is very similar to Tres and Crew for plant height, straw strength, seedling vigor, and coldhardiness. Based on quality evaluations, Rely has milling and baking quality that is comparable to most currently grown club wheat cultivars. It is equal to Tres, Moro, and Hyak for flour yield, milling score, flour ash, sponge cake score, cake volume and noodle score. It is similar to Tres and Hyak for percent flour protein and absorption. Rely is equal to Tres and Moro for cookie diameter.

Stripe Rust Resistance.

We tested 235 advance lines to the stripe rust race that attacks the Tres and Moro genes and found that 42, 30 and 28% of the lines were resistant, segregating and susceptible as seedlings to this race, respectively. Varieties with seedling resistance included Stephens, Hill 81, Dusty, Madsen, Paha, Hyak, Tyee, Faro sib, and OR855. Those susceptible include Tres, Moro, Nugaines, Lewjain, Luke, Faro, and Barbee. Crew, WA7527, WA7526, and Daws are heterogeneous for resistance and susceptibility. Sources of stripe rust resistance that we have yet to exploit in our club wheats include: *T. dicoccoides*, *T. spelta*, and *Agropyron elongatum*. Several lines deriving their resistance from these sources were placed in advanced yield trials.

Enhanced Wheat Adaptation.

Securing and maintaining adequate stands are main strategies for reducing water run-off and soil erosion. The most widely used semidwarf genes of Rht_1 and Rht_2 reduce seedling vigor. We have begun tests with Rht_8 and Rht_9, two semidwarf genes extensively used in eastern Europe and western Asia. Reports indicate that these genes do not adversely affect seedling vigor. Our 1990 results suggest that the agronomic potential may be limited and specific for certain genetic backgrounds. In 1990 the Rht_8 gene enhanced yield in Burt and Brevor genetic backgrounds but reduced yield in Omar and Marfed backgrounds. The cytoplasm of a weedy wheat relative (*Aegilops ovata*) imparts extra coldhardiness to wheat. We are in the process of transferring this cytoplasm into adapted wheat varieties. Our preliminary results indicate that exploiting this unique type of coldhardiness may be difficult. In 1990 early generation lines with this cytoplasm had less than 75% of the yield potential of Daws, Stephens and Lewjain.

Research Assistant Edgar Haro completed his Ph.D. studies involving comparisons among near-isogenic lines (NILS) of Nugaines that represented three distinct heading date phenotypic classes of 148, 152 and 156 d (from 1 Jan). The 156, 152 and 148 d NILS corresponded to heading dates of Nugaines, Early Blackhull derivative and Early Blackhull. Some of the significant findings of this research were: a) very early heading of 148 d was due in part to reduced photoperiod response; b) vernalization requirement was not affected by heading date; c) the 148 and 152 d NILS generally had longer grain fill periods than the 156 d NILS; d) the 148 and 152 d NILS usually had heavier kernel weights and grain volume weights than their 156 d sibs and they tended to have fewer spikes/m^2; e) based on 9 site-year trials, the 152 d NILS had the highest yield potential across all trials while the 148 d lacked yield potential at a cool growing degree day site but had good yield potential at a warm growing degree day site; f) the 148 and 152 d NILS generally had harder kernels and smaller cookie diameters than the 156 d NILS but these relationships appeared to be due to linkage drag rather than pleiotropism. A preliminary study on the genetic control of heading date for several of these NILS indicated that when they were crossed back to Nugaines, their F_2 plant distributions expressed both continuous and discontinuous heading period distributions at 14h photoperiod. Both large and small effect genes for heading period appear to control expression.

Research has demonstrated that vernalization (*Vrn*) and photoperiod (*Ppd*) response genes affect the rate of early spring vegetative growth of wheat. Early spring growth reduces water run-off and soil erosion. We are developing near-isogenic lines (NILS) that differ for several *Ppd* and *Vrn* genes in the varieties of each of the main wheat market classes. Populations of NILS for three *Vrn* genes have reached BC_3 to BC_6 levels. Those for two *Ppd* genes have attained the BC_5 to BC_6 level. Once both series are complete, the lines will be intercrossed to obtain all possible combinations of both sets of genes. The resulting germplasm will have utility for studying interactions with these wheat growth and development genes with various agroecosystems in the Pacific Northwest.

Preharvest sprouting resistance.

Evidence suggests that Brevor, Clark's Cream and Losprout differ in their genetic expression of grain dormancy. A few lines of a Brevor/Clark's Cream cross had germination index (GI) values significantly lower than either parent. Preliminary data on F_4 lines of Losprout/Brevor and Losprout/Clark's Cream also indicated that transgressive segregation occurred for progeny with lower as well as for higher GI values. Lines expressing transgressive segregation for low GI will be intercrossed in an attempt to pyramid their genes for increased grain dormancy in white wheat.

Club Wheat Coldhardiness.

Although no club wheats escaped damage at Spillman Farm, marked differences in survival occurred among club wheat varieties and selections following the 1990-1991 cold weather. The mean survival percentages averaged across replicated early and late sown tests were Hyak 59%, Tyee 58%, Paha 46%, Tres 42%, Crew 41%, Rely 33%, and OR855 9%. Advanced club lines of our ARS genetics program ranged from 10 to 72% survival. A few of our new advanced lines had significantly higher survival percentages than Hyak and Tyee which represent the most coldhardy club wheat varieties currently available. These lines are being used extensively as parents.

HARD RED WINTER WHEAT BREEDING AND TESTING

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

In the hard red winter wheat producing area of eastern Washington, fall (1989) seeding moisture was fair, but deep over most of the area. The Horse Heaven Hills and other areas had inadequate moisture for early seeding. The winter was mild, but dry, followed by a cool spring. Much of the higher rainfall area experienced heavy rains in May, however most of the hard red winter wheat producing area did not receive these rains. Wheat showed moisture stress in early May and without additional moisture, became severely stressed. Considerable acreage of spring wheat and some winter wheat was abandoned. Some fields showed 60 to 70% white heads caused by *Fusarium* foot rot, a stress disease.

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 varieties 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 the western region, including 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. The most emphasis in disease resistance is currently being 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 high flour yield and large loaf volume.

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

Promising selections:

Permission was received to increase breeders seed of WA7679 in 1991/92. WA7679 is a hard white winter wheat with most agronomic and quality characteristics similar to Hatton. WA7679 has fair mature plant type stripe rust resistance.

WA7658, an awnless, mid-tall, hard red winter wheat cultivar, has performed adequately to be considered for release if thrashability is adequate with a rub bar combine cylinder.

Nurseries:

Yields in the nurseries at Lind, Connell and Harrington were about normal; at Waterville the yields were below normal; at Finley (late seeded) the yields were much below normal. The Horse Heaven nursery was abandoned. The near normal yields can be attributed to the cool weather during late May and June during anthesis (flowering) and through much of the grain fill stage. This same cool weather caused extensive stem (culm) elongation where moisture was sufficient.

Table 1. Percent survival of hard red winter wheat cultivars following 1990/91 winter.

Variety	% Survival				
	Lind Dry	Lind Irrigated	Waterville	Harrington	Ave.
WA7658	13.3	55.0	31.7	37.5	34.4
WA7679*	15.0	42.5	30.0	27.5	28.8
Blizzard	15.0	35.0	40.0	25.0	28.8
Hatton	13.3	45.0	33.3	12.5	21.0
Weston	5.0	12.5	18.3	7.5	10.8
Andrews	3.3	12.5	16.6	2.5	8.7
Buchanan	0.0	10.0	10.0	0.0	5.0
Batum	1.7	0.0	5.0	0.0	1.7
Ave.	8.3	21.3	19.4	14.1	

*Hard white winter

Table 2. Percent survival of soft white winter wheat cultivars.

	% Survival			
	Harrington	Lind Irrigated	Lind Dry	Ave.
Eltan	26.7	45.0	20.0	30.6
Daws	15.0	25.0	18.3	19.4
John	11.7	32.5	11.7	18.6
Sprague	3.3	22.5	5.0	10.3
Kmor	8.3	7.5	8.3	8.0
Lewjain	3.3	12.5	6.7	7.5
Hill 81	0.0	10.0	0.0	3.3
Madsen	5.0	5.0	0.0	3.3
Dusty	1.7	5.0	1.7	2.8
Stephens	0.0	0.0	0.0	0.0
Hyak	6.7	17.5	8.3	10.8
Rely	6.7	5.0	3.3	5.0
Moro	3.3	7.5	0.0	3.6
Crew	0.0	5.0	3.3	2.8
Tres	0.0	2.5	0.0	0.8
Ave.	6.1	13.5	5.6	

Table 3. Performance of hard red winter wheat cultivars grown at Harrington

Variety	1990 Plant height in.	1990 Test weight lb/bu	1990 Yield bu/A	1990 % protein	5 yr. Ave. bu/A yield	5 yr. Ave. protein %
Hatton	46	59.1	51.9	9.1	41.0	10.6
Weston	48	59.6	46.4	9.8	37.9	11.3
Batum	38	55.9	56.1	8.7	36.2	10.3
Andrews	37	58.7	57.9	9.9	35.3	11.3
Buchanan	44	56.9	48.4	8.8	40.7	9.2
Blizzard	45	58.2	47.0	9.1		
WA7658	44	59.4	55.4	9.9		
WA7679*	43	57.4	57.4	9.7		

* Hard white winter

Table 4. Performance of hard red winter wheat cultivars grown at Lind (irrigated).

Variety	1990 Plant height in.	1990 Test weight lb/bu	1990 Yield bu/A	1990 % protein	5 yr. Ave.** bu/A yield	5 yr. Ave.** protein %
Hatton	53	58.7	48.2	12.7	70.8	12.7
Weston	52	59.9	63.0	13.7	71.2	13.8
Batum	45	56.9	78.5	13.4	88.5	13.0
Andrews	40	59.1	95.4	13.6	86.9	13.4
Buchanan	52	58.2	74.2	12.8	79.4	12.8
Blizzard	52	59.7	56.1	14.5	75.1	14.3
WA7658	51	59.2	79.8	13.2		
WA7679*	49	59.3	84.3	13.5		

* Hard white winter
** 1985 to 1990, 1989 not harvested.

Table 5. Performance of hard red winter wheat cultivars grown at Lind (dry).

	1990				5 yr. Ave.**	
	Plant height in.	Test weight lb/bu	Yield bu/A	% protein	bu/A yieod	protein %
Hatton	33	63.7	36.4	13.0	29.5	13.5
Weston	33	63.2	36.3	12.7	29.2	13.9
Batum	28	61.1	34.6	11.9	29.2	13.0
Andrews	29	61.2	36.6	13.1	25.4	13.9
Buchanan	32	62.0	30.2	12.7	28.6	13.7
Blizzard	32	62.4	34.4	12.7	28.9	14.4
WA7658	31	62.8	33.5	12.6		
WA7679*	32	62.1	32.6	12.8		

* Hard white winter
** 1985 to 1990, 1989 not harvested.

Table 6. Performance of hard red winter wheat cultivars grown at Finley.

	1990				3 yr. Ave.***	
Variety	Plant height in.	Test weight lb/bu	Yield bu/A	% protein	bu/A yield	protein %
Hatton	22	61.9	13.2	13.7	25.2	12.0
Weston	25	60.4	15.5	14.3	27.5	13.0
Batum	21	58.7	17.7	14.5	27.6	13.4
Andrews	20	59.2	2.9**	14.9	13.9	13.2
Buchanan	20	58.0	13.7	15.2	28.4	13.4
Blizzard	24	60.5	16.0	14.6	25.2	13.8
WA7658	22	58.9	18.5	13.9		
WA7679*	22	58.5	16.5	15.2		

* Hard white winter
** Mouse damage
*** 1986 to 1990, not harvested in 1988 and 1989

Table 7. Performance of hard red winter wheat cultivars grown at Waterville.

Variety	1990 Plant height in.	Test weight lb/bu	Yield bu/A	% protein	5 yr. Ave. bu/A yield	protein %
Hatton	33	63.6	29.7	12.3	30.5	11.8
Weston	35	62.8	24.3	13.3	32.5	12.2
Batum	31	60.3	31.1	12.6	33.4	11.1
Andrews	29	61.2	14.8**	14.3	31.1	12.4
Buchanan	33	61.9	30.8	13.0	34.2	11.1
Blizzard	32	62.1	27.1	12.8	33.8	11.5
WA7658	31	62.3	29.2	13.1		
WA7679*	32	62.0	29.5	13.4		

* Hard white winter
** Mouse damage

Table 8. Performance of hard red winter wheat cultivars grown at Connell.

Variety	1990 Plant height in.	Test weight lb/bu	Yield bu/A	% protein	5 yr. Ave. bu/A yield	protein %
Hatton	32	63.7	34.2	13.6	30.8	13.3
Weston	35	63.5	34.4	12.7	28.2	13.4
Batum	27	61.2	38.9	13.6	26.9	13.5
Andrews	29	61.7	33.8	12.7	21.6	13.3
Buchanan	32	62.2	34.9	13.9	30.0	12.4
Blizzard	32	62.6	34.1	13.9	30.0	13.0
WA7658	31	62.7	37.4	14.5		
WA7679*	34	61.7	34.0	14.2		

* Hard white winter

Table 9. Performance of soft white winter wheats at three locations managed from the Dry Land Research Unit.

Variety	1990 3 location Ave. Plant ht.(in)	1990 3 location Ave. Test wt. (lbs/bu)	Yield bu/A) Harrington 1990	Harrington 4 yr.* Ave.	Lind Dry 1990	Lind Dry 4 yr.** Ave.	Lind Irrigated 1990	Lind Irrigated 5 yr.*** Ave.
Daws	36	58.0	56.2		37.4		75.9	
Lewjain	35	58.8	65.2	48.3	35.5	26.5	62.0	89.0
John	37	59.2	56.2	44.5	36.9	28.7	45.4	77.7
Stephens	36	57.8	65.5	47.4	35.4	23.5	97.4	97.9
Hill 81	40	59.1	64.9	45.0	40.0	27.0	83.7	91.8
Dusty	37	58.6	58.3	47.9	35.9	30.3	54.7	90.4
Madsen	37	58.0	55.4		35.9	23.3	86.2	
Kmor	37	57.5	59.6		34.4		58.3	
Eltan	36	57.9	65.7		37.2		52.1	
Moro	43	57.3	48.4	42.9	34.5	25.9	37.4	67.2
Crew	37	58.0	60.8		36.5	25.7	44.1	77.6
Tres	38	59.1	59.4	42.7	35.2	23.2	62.6	89.2
Hyak	37	57.6	67.0	40.4	33.6	23.7	72.3	85.9
Rely	37	57.6	62.7		33.5		63.2	

* 1985 through 1990, not harvested in 1987 and 1989.
** 1985 through 1990, not harvested in 1988 and 1989.
*** 1985 through 1990, not harvested in 1989.

SPRING WHEAT--1990 RESEARCH RESULTS AND WHAT'S NEW FOR 1991

Cal Konzak, WSU spring wheat breeder

GENERAL SITUATION

The 1990 season was marked by the accelerated development of new production constraints needing attention via breeding. Both major problem areas were predictable --the increase of hessian fly infested acreage and increased grower losses, and the continued presence of the Russian wheat aphid. Damage from the latter was fortunately limited by apparently unfavorable conditions for the insect, but this aphid could yet become a serious pest for wheat unless attention is given to protecting wheat via genetic resistance as a complement to an integrated program involving also the use of natural predators of the insect. Research progress was also affected by the occurrence of above average levels of soil environment variability over the test plot areas. This type of variability has been observed in prior years, but until 1990 we had no tools or personnel to investigate and solve the problems involved. Through Washington Wheat Grower and Washington Wheat Commission support, exceptional new progress has been made in the development of anther culture procedures as a new, efficient, complementary technology for accelerating wheat cultivar development. Some results of the research are described later in this report. The low soil moisture conditions in the fall of 1990 and the severe winter-killing of winter wheats as well as the soil and water erosion that occurred in early 1991 provide a reminder of the need for and security provided growers by modern spring wheats.

Previous cropping history and management of the 1991 spring wheat plots was as listed in Table 1. Results from 1991 and current concerns are headlined below:

THE HESSIAN FLY PROBLEM--The hessian fly continued to cause damage, and apparently spread around and beyond the Tammany area near Lewiston, ID. and into Southeastern WA. The severity of the infestations and yield losses to spring wheats in the area as recorded by Mr Larry Smith, Nez Perce County Extension Agent, was even greater than in 1989. As an example, Centennial yielded only 5% of the resistant cultivar, WPB906R. Wakanz suffered slight damage (3%), while as last year, Wadual showed an intermediate level of injury. It is not clear whether this intermediate reaction represents a level of tolerance or genetic variation for resistance within Wadual. The low level of injury to Wakanz also may be due to genetic variation within the cultivar or variation in the hessian fly population. If the latter, then the H3 gene for resistance in Wakanz will not be effective for long. Another predictable result from Smith's studies was that hessian fly damage reached significant levels for soft white winter wheats, exceeding 30% infested plants for cultivars such as Malcolm.

The adult plant type of stripe rust resistance of Wakanz was inadequate at Pendleton in 1990, where an unexpectedly high plant infection by this disease occurred. The rust did not prove to be a new race, but we have decided to propose for increase and release a sister line of Wakanz, WA7176, which has for several years shown a higher type of resistance to stripe rust. WA7176 has maintained equivalent yields to Wakanz, and otherwise appears to be similar (Table 2).

SOIL SPATIAL VARIABILITY IDENTIFIED BY REMOTE SENSING TECHNOLOGY--Though common for the area, WSU spring wheat research trials were plagued with higher than expected levels of environmental variation. Data from most irrigated trials at the WSU Royal Slope Research Unit were essentially useless and will not be included in most reports because of drought stresses at or after flowering time resulting from the occurrence of water line breaks (over 50). In most cases, the stresses caused yield losses of 30 to 65%, even though grain test weights were unaffected. Effects of soil variability were extreme not only at this irrigated station, but also at Lind, Walla Walla, the Meilke farm near Davenport, and at Mayview. Less variation was encountered in the Pullman area, where spring rainfall levels were higher. Even so, as discussed in last year's Wheat Life report, the soil variability present at all test locations represents a major obstacle to the achievement of definitive results from variety research trials. Fortunately, as many growers who came to Field Days noted, an important step was taken toward the development of practical methods for estimating variety performance differences, and for informed decision-making. One key factor was the application of remote sensing technology to the problem, by use of digitized aerial photography along with computer processing. Although there is yet much to be done as part of the graduate research project of Mr. Shane Ball, it is already evident that by the use of some available computer software, and the development of others, it will be possible to mathematically adjust for the soil variations to obtain better estimates of test variety yield performance. The photographs also can be useful for sitting future trials to permit even better resolution of variety differences.

We also discovered an important secondary benefit of the digitized images. At high magnifications, we could readily identify even individual plants, distinguishing those affected by disease. This suggests that we may be able to select for differences in response to some plant diseases, as Fusarium dry land foot rot, counting via computer the affected plants in each plot. Thus, it appears that remote sensing technology can be exploited effectively as a tool to greatly improve the efficiency, not only of variety testing, but also of selection processes involved in crop breeding.

It is likely also that this tool can be useful for monitoring and evaluating crop and soil responses to tillage and other management treatments. Inspection of some of the digitized images of grower fields suggests that in some cases, limited residue distribution from harvesting operations has a marked influence on the crop variability and average yield. Thus, it may be possible to use the technology to identify and circumscribe problem areas within grower fields that are in need of special attention for correction of localized nutrient imbalances, serious erosion sensitivity or perennial weed infestations. Moreover, preliminary tests indicate that it may be possible to estimate yields based on photographic images taken when the crop is mature, just before harvest. This could be useful in several ways. For on-farm research trial comparisons of varieties, tillage or other treatments, yield analyses could be made on smaller sections of large plots, allowing the calculation of better estimates of crop performance than obtainable from the bulk harvest of the test plots, which in some cases might be unreplicated, long, wide strips as most conveniently accomplished with larger farm scale machinery.

Mr. Shane Ball received his M. S. degree from North Carolina State University. He is a Ph D candidate in Crop and Soil Sciences at WSU. As indicated above, he is developing applications of remote sensing technology (infrared photography) combined with geostatistics methods to assess, quantify and adjust for soil-related variability to improve decision-making from analyses of field trials. Results to date also indicate the technology has potential for estimating the degree of infestation of plots by pathogens or pests, greatly facilitating data collection and analyses for traits that are quantitatively expressed. The possibility that vegetative biomass at near harvest may be closely related to yield is being investigated further to determine if the technology will be useful to assess crop yield variation and its causes on a larger, field scale. He is also conducting simulation experiments to evaluate possible trait modifications to improve the yield potential and yield stability of spring wheat across environments. His knowledge of computers and statistical methodology has been a considerable benefit to all in the program.

NITROGEN USE EFFICIENCY AND GRAIN PROTEIN CONTENT--New results from the more normal trials at Pullman and Lind (Table 3) indicate that there are real genetic differences among spring wheats for the ability to take up, accumulate and convert stored leaf protein N to grain protein. These differences are particularly notable from the performance of Edwall (9.8% protein) vs SD3056 and WPB906R (13.6%, 13.4%) at identical yield levels (Table 4). Even higher protein production capability may be indicated from the 16% grain protein, though slightly lower yield of SD3053 (68bu/A). This trial was conducted via the cooperation of Don Quist, after fall wheat, with 54, 12 and 12 lbs added N, P and S, respectively. Although not as large, similar differences between the hard red and soft white spring wheats are evident also in 1990 data from Pullman's Spillman Farm and the Dry Land Research Unit at Lind. In this instance, WA7176 may outperform both Wakanz and Edwall for yield and reduced grain protein, if the differences are confirmed after removing the effects of soil spatial variation. Butte 86 had a lower than expected grain protein at Pullman, while WA7668 and WA7675, with the highest yields at both locations had above average grain protein (Table 3). In the State HRS trials at Pullman and Connell (Bauermeister farm), Spillman's productivity and grain protein equalled that of WPB906R, though its consistently lower grain test weight was evident. WA7668 and WA7675 appear to be higher yielding at Pullman, but are less adapted to the conditions at Connell than KNC0042, which carries cytoplasm from the goat grass relative, Triticum tauschii (Table 5). The differences in grain protein at comparable yield levels suggests the possibility that those with lower protein grain may retain more of their protein N in their straw. Since this straw N may represent a reservoir of recyclable N, genotype differences in efficiency of soil N uptake and storage may be worthy of further investigation, since the N content would make straw more valuable as a resource to be incorporated for organic matter improvement and a means to reduce the mineral N leachable into ground water.

SOFT WHITE CLUB SPRING WHEAT--If WA soft white wheats are to achieve due recognition for their high processing qualities as developed, it should not be necessary to market mixtures of soft white common and soft white club wheats as the market class, Western White. These wheats have very different protein characteristics and intended end-use properties. Western White Class is defined as having from 10-90% club and 90-10% common soft white wheat. At low protein levels, the impact of the stronger protein common wheats is reduced, accounting for the continued acceptance of Western White by Japanese buyers. However, this may also account for their complaint that WA soft white wheats do not have the desired noodle quality. Because no adapted soft white spring club wheat is available, it is necessary for growers to replant freeze-injured stands of winter wheats with soft white common wheats. Thus, the common spring wheats compound the problem in the resulting "instant" Western White wheat as harvested, because of their usually higher grain protein content. The solution to this problem and a step toward the production and marketing of soft white wheats on the basis of the quality characteristics for which they are bred, is to develop a soft white spring club wheat, which could be used for reseeding. In 1990, we tested a small group of soft whit club spring wheats developed at UC Davis as part of a graduate student study under Dr. C. O. Qualset. Dr. Pam Zwer, OSU-Pendleton coordinated the trial. The lines had been selected earlier as showing promise for their typical soft white club quality properties. Surprisingly, several of the lines not only had resistance to stripe rust, but also had comparable yielding capacity compared with Wakanz and Treasure (Table 5). The grain protein levels were in the same range as the soft white common wheats, as expected. But, not as well publicized is information that the special weak protein characteristics of our typical club wheat change almost insignificantly in strength as flour protein is increased. These properties of the high quality club wheats are well documented in records of the WWQ Laboratory in Pullman. With the aim to offer growers even better adapted soft white club spring wheat in the near future, we will continue evaluating the UC-developed lines, and have begun producing doubled haploid (DH) soft white club spring wheat lines from winter/spring club crosses, using anther culture methods. Plant rows of the DH lines will be field tested and increased in 1991 at Pullman.

RUSSIAN WHEAT APHID RESISTANCE--RWA resistant germ plasm obtained from South Africa in the fall of 1989 was used in crosses with local SWS and HRS lines and DH progenies were screened for RWA tolerance in fall 1990. Resistance to the RWA toxin was separable from aphid resistance or antibiosis, which could readily be overcome by mutations of the RWA. The RWA toxin resistant lines appear to tolerate high levels of aphids, and since the RWA is a poor transmitter of barley yellow dwarf virus (BYDV), and considerable effort is being placed on RWA predator establishment in the area, this route to RWA control seems most promising. Although back-crosses are being made to assure recovery of quality, adaptive traits and other resistances, including hessian fly resistance, seed increases of the RWA resistant lines are under way, hessian fly tests are in progress, and the better lines will be entered in 1991 field trials.

HERBICIDE RESISTANCE STUDIES--Exploratory research on this problem is being conducted in collaboration with Drs. Pat Fuerst and Frank Young in the WSU-USDA Weeds program. M2 populations of mutagenized winter and spring wheats were planted and have been sprayed by Drs. Fuerst and Young with two of the better "grass " herbicides. A few candidate plants with possible resistance have been isolated, but need to be confirmed. The plants have been moved to the Weeds Program greenhouse for further tests and possible increase. A graduate student, Mr. Mohammad Akram, who received his M.S. degree at the University of Agriculture, Faisalabad, Pakistan, and holds a position as Research Scientist in the Virology Section of Agricultural Research Institute, Faisalabad, Pakistan is also working on the herbicide resistance problem in wheat. Akram is a Ph D candidate supported by the USAID Pakistan Program for training scientists in the U. S. . He is working on the induction and selection of genetically-controlled resistance in wheat to "grass" herbicides, such as Poast, Assert, and Fusilade. Using calli developed from anther cultures, he has isolated 7 plants so far which have survived and were growing vigorously on culture medium containing a moderate level of sethoxydim, the active ingredient in Poast. In view of some features of their origin these plants are likely not resistant, but this will need confirmation. He has mutagenized seeds of two spring wheats to obtain more materials for selecting resistant variants. Plants isolated are being grown to maturity, and haploid doubling is also in process to gain experience in the necessary follow-through procedures. Once seeds from the selected plants have been obtained tests will be made to determine if the apparent herbicide tolerance is real or if some other phenomenon is confounding the selection process.

DOUBLED HAPLOID BREEDING TECHNOLOGY--Through WAWG and WAWC support of an outstanding graduate student, Mr. Huaping Zhou and some technical assistance to him, as well as industry contributions to the Calvin F. Konzak Wheat Breeding-Biotechnology Research Fund, important advances have been made at WSU in technology to produce wheat doubled haploids-instantly true-breeding progeny from crosses. These advances include not only the production and selection of the best lines from among over 3000 DH, but also improvements in the culture media used. Particularly significant from the economic standpoint is the substitution of a high molecular weight, carbohydrate in the media by a higher concentration of maltose plus glucose, reducing the cost of a liter of medium from over $150 to about $1. Other improvements suggested from current studies include control of the haploid doubling process and increases in the proportion of green vs albino progeny. Nuclear and cytoplasm genetic differences in culturability are being recombined to develop breeding populations in SWS, HWS, and HRS wheats that are more responsive to culture, while research continues in efforts to reduce the effects of genetic differences by culture medium component changes. Plant hormones appear to be of major importance, and new research indicates that the use of combinations and analogues of active hormones may greatly improve the efficiency of anther culture and contribute to the successful development of methods for culture of isolated microspores of wheat. Efficient culture of wheat microspores will open a host of new opportunities for use of selection methods akin to those employed with bacteria. Success in that effort would shift the impact of the "numbers game" in wheat breeding to the efficiency of field trials, in which soil spatial variability, as discussed above are major factors, for which methods of resolution are being developed. Establishment of a laboratory for wheat anther culture, with a laboratory technician manager is being proposed for 1991, to gain further practical benefits from the graduate student studies (including frequent outside-supported trainees), and to exploit opportunities for guest scientists from other countries to contribute to the research progress. Hungarian scientist and Fulbright Fellow, Dr. Paul Pepo from the University of Debrecen (see description of US-Hungary research project) spent about 4 months at WSU learning anther culture technology. He expects to collaborate in the production of hard red winter wheat DH, and has already contributed valuable new germ plasm to the WSU program of Dr. Edwin Donaldson. As indicated in Dr Pepo's write-up on the proposed cooperation, a more formal International cooperative proposal for breeding of HRW wheats, also involving Dr. Donaldson and several other WSU scientists has been made to the US-Hungary Joint Fund which is a special USDA international program. Preliminary indications are that the project is likely to receive funding in April 1992.

Establishment of the anther culture laboratory, as proposed to The Washington Wheat Commission will assure the continuity of research advances beyond impending retirements of current WSU wheat breeders, and provide opportunities for WA wheat growers to benefit from contributions of future guest scientists and industry and other tax-deductible donations to the above-mentioned WSU Foundation fund.

Two graduate students and Dr. Alan Hodgdon (the proposed anther culture laboratory manager), are now working to produce doubled haploids and further develop the technology. These graduate students include Mr. Huaping Zhou, mentioned earlier, and Mr. YuanMing Zheng, both from the PRC. Mr. Huaping Zhou received his B. S. degree at Jiangsu Agricultural College, Nanjing, Jiangsu, PRC., and his M. S. degree at Washington State University, 1991. Ph D candidate in Crop and Soil Sciences, WSU. Initially supported at WSU by a PRC National Training Fellowship, on which Mr. Zhou adapted, improved and introduced anther culture technology to WSU, providing the basis for the Washington Wheat Commission supported Anther Culture Project in the Department of Crop and Soil Sciences, and for aspects of the Hard White Winter Wheat Project of C. J. Peterson and E. Donaldson, on which he acts as technical advisor. Mr Zhou's research efforts have helped to improve further the anther culture technology, now used by others, he has served as an instructor for International Atomic Energy Agency Training Courses and as a consultant advisor for IAEA projects in South America and North Africa. Practical contributions to the spring wheat project include the production of all of the double haploid lines undergoing field evaluation and increase. These include lines carrying resistance to the RWA and the Hessian fly in both hard red and soft white wheats. Recent developments also include spring club wheat double haploids to which hessian fly resistance and RWA resistance will yet be introduced.

Mr. YuanMing Zheng received his M. S. from Southwest Agricultural University, Chonqing, China. He is on leave from his position as Lecturer, at the Institute of Isotope Application of Southwest Agricultural University, Chonqing, China. Initially supported by an International Atomic Energy Agency Fellowship, he is now supported on local Foundation grant funds. Ming is a Ph. D. candidate in Crop Science studying the influence of plant hormones on the efficiency of anther/microspore culture technology for accelerating the wheat breeding process. An aim of his research is to achieve greater control over the genetic stability of microspore-derived double haploid progeny produced in laboratory cultures. He and Mr. Zhou are producing recombinant progeny more responsive to the culture process, while assisting the spring wheat breeding project to produce HRS lines with high protein, high yield and resistance to diseases and pests-Hessian fly and RWA.

Table 1. Cultural Data for 1990 Spring Wheat Yield Nurseries

Location	Planting Date	Base Fertilizer	Starter Fertilizer	Previous Crop	Moisture Top 3′
Connell	3/02	00#N	6#N,8#P,6#S	Fallow	4.28
Lind Research Station	3/06	00#N	"	Fallow	4.01
Royal Slope Res. Station	3/13	240#N,1#Boron 50#K2O,25#S	"	Fallow	Irrig.
Walla Walla	4/03	100#N	"	Fall Wheat	
Mayview	4/04	100#N,20#S	"	Fall Wheat	2.86
Pullman Spillman Farm	3/27	54#N,12#P,12#S	"	Peas	4.79
Davenport Spillman Farm	4/06	93#N,8#P,20#S	"	Fall Wheat	
Pullman Off-Station	4/05	54#N,12#P,12#S	"	Fall Wheat	5.56

Table 2. Western Regional Nursery Average Yield (BU./AC.)

YEAR	1986	1987	1988	1989	MEAN
# LOCATIONS	15	17	12	14	58
WA007176	73.6	84.3	77.4	77.2	78.1
WAKANZ	71.4	82.6	79.1	77.6	77.7
PENAWAWA	73.6	83.7	75.0	78.9	77.8

Table 3. 1990 Commercial Spring Wheat #46

LOCATION	PULLMAN		LIND	
SOFT WHITE	YIELD(T.WT.)	PRO.	YIELD(T.WT.)	PRO.
FIELDER	73(59.2)	11.3	21(59.7)	14.2
DIRKWIN	87(60.0)	11.8	17(59.7)	14.6
OWENS	74(60.4)	11.6	18(59.8)	14.4
WAVERLY	79(61.1)	12.1	18(59.1)	14.1
FL880022	88(65.1)	12.4	19(59.4)	14.7
CENTENNIAL	87(63.3)	11.6	21(60.3)	13.8
EDWALL	86(60.5)	11.5	22(57.8)	13.3
TREASURE	92(62.3)	11.2	18(60.8)	14.3
PENAWAWA	82(62.2)	11.7	16(57.7)	13.9
WAKANZ	86(63.4)	11.7	16(59.1)	15.1
WA007176	90(62.9)	10.7	21(60.7)	13.9
WADUAL	85(62.7)	12.1	20(58.8)	15.3
WA007496	94(59.6)	11.9	19(57.1)	13.6
WA007497	93(62.5)	11.4	21(59.4)	14.8
WA007677	98(64.4)	10.8	20(60.3)	13.0
SPRITE	98(63.5)	11.5	21(60.3)	14.0
HARD WHITE				
K8705264	99(61.1)	11.5	19(57.6)	15.3
KLASIC	82(65.2)	13.6	16(61.4)	14.9
HARD RED				
YECORA ROJO	72(64.3)	14.4	7(61.0)	15.4
WAMPUM	85(63.1)	13.3	18(59.8)	15.1
MCKAY	85(63.7)	13.2	20(59.6)	15.2
CZAR	82(63.3)	14.0	19(60.5)	15.6
FL880306	81(62.6)	13.7	19(60.0)	15.0
LEN	78(62.0)	12.5	16(60.6)	16.6
STOA	85(62.0)	12.9	16(59.0)	16.5
BUTTE 86	85(61.4)	12.2	20(60.5)	15.8
COPPER	76(63.1)	12.5	17(60.5)	15.7
SPILLMAN	81(62.1)	13.4	16(59.7)	15.7
WA007629	81(62.8)	14.2	20(60.1)	14.7
WA007668	92(63.0)	14.8	21(59.3)	14.9
WA007675	93(63.2)	15.1	20(58.9)	15.4
WA007676	87(63.4)	14.2	20(58.7)	15.1
WPB 906R	85(63.5)	13.7	17(61.2)	16.5

Table 4.

Variety	Yield	Test Weight	Protein	Heading	Plant Height
Marquis	54.9	62.2	15.6	178	44
Chris	49.5	61.2	15.3	176	43
Stoa	63.1	62.9	11.9	174	43
Era	69.8	62.2	11.8	175	28
Butte 86	66.8	61.8	14.2	174	40
SD003014	67.8	62.2	13.0	174	42
SD003036	61.7	62.8	14.3	171	40
SD003052	62.9	62.7	11.8	171	36
SD003053	67.9	63.5	16.0	169	37
SD003055	66.1	63.1	12.7	172	33
SD003056	76.1	61.8	13.6	172	37
MN085324	65.7	62.7	12.6	174	31
MN086383	63.9	64.0	12.5	171	32
MN086165	63.8	63.8	11.7	176	29
MN087106	66.9	63.0	11.3	174	28
MN087150	60.3	63.0	12.1	176	32
ND000655	66.8	63.2	11.7	174	33
ND000656	63.8	62.9	12.2	175	42
ND000657	61.1	63.2	14.0	174	38
ND000659	67.2	61.7	12.5	174	35
ND000660	59.9	62.1	12.3	174	36
XW000371	64.1	61.5	13.0	174	32
MT008402	63.8	63.7	11.6	171	28
MT008651	73.2	63.8	12.6	175	37
N8600370	60.8	62.9	12.4	176	33
N8600903	70.9	64.2	11.7	172	26
N8600542	72.3	62.3	11.7	177	27
N8700002	77.0	62.2	11.9	170	29
DA984034	69.0	63.0	10.9	175	30
PH984045	56.4	58.8	13.7	175	29
BW000114	58.6	62.4	14.4	174	43
BW000120	63.9	62.1	14.0	174	46
Spillman	70.0	61.2	11.5	174	33
WA007668	73.0	59.2	12.1	177	34
WPB 906R	76.1	62.2	13.4	170	32
Edwall	76.6	60.0	9.8	174	33

Table 5. 1990 State Hard Red Spring #47

LOCATION	PULLMAN		CONNELL	
YECORA ROJO	67(64)	15	20(60)	18
WAMPUM	79(63)	14	25(59)	17
MCKAY	82(63)	13	25(60)	17
NORDIC	73(64)	13	22(62)	18
BUTTE 86	77(63)	15	26(60)	18
STOA	79(63)	15	26(60)	18
BUTTE/SD2700	81(62)	14	27(60)	17
SPILLMAN	80(62)	14	25(59)	18
WPB906R	79(63)	14	24(61)	18
WA007629	81(63)	12	26(61)	17
WA007668	93(62)	12	22(60)	17
WA007675	87(63)	13	25(58)	17
WA007676	85(63)	13	25(60)	17
KNC00042	79(63)	13	31(60)	16
KNC00043	76(63)	13	30(61)	16
K8500384	81(64)	13	25(61)	17
K8500405	88(62)	12	23(60)	1

U.S. - HUNGARIAN COLLABORATION ON ADVANCEMENT OF HARD RED WINTER WHEAT & SPRING BARLEY PRODUCTION AND BREEDING

P. Pepo[1] - C.F. Konzak[2] - E. Donaldson[2] - S. Ullrich[2]

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The principal goal of this proposed project is to advance the cereal production and breeding through collaboration in development and exchange of technologies. Exchanges of information and technologies, as well as cooperation and collaboration in the development/advancement of new technologies for wheat and barley production and breeding will assist the Agricultural University, Debrecen to contribute more effectively to Hungarian Agriculture while the shared research and germplasm will likewise benefit wheat and barley producers in the Inland Pacific Northwest.

The collaboration between Washington State University, Pullman began in 1991. One faculty member in Plant Production and Breeding Department from Debrecen is investigating the production and breeding methods used in Washington State, and gaining experience with new technologies being developed to accelerate cultivar development, including anther culture. We exchanged some seed samples of cereal varieties and they are being investigated under specific ecological conditions of each country.

Washington State University and Hungary have similar latitude (47°C) which offer similarly marginal climatic conditions for hard red winter wheat and barley production. Day length is exactly the same. Each area has a winter rainfall environment with similar range of rainfall conditions across small grain growing areas. Because of the similar ecological conditions the problems in the field of production and breeding appear similar in each country requiring similar approaches in the research.

Similarly, the Norin 10 sources of semidwarfing for lodging control in wheats have been unsatisfactory in Hungary and in dryland area of the United States where seedling emergence is extremely important because the Norin 10-derived semidwarfs have a close genetic linkage to short coleoptile. Hungarian breeders have extensively used another source of semidwarfing, but it is not known for certain whether this source (Rht8) provides for longer coleoptile length and thus better seedling emergence potential (this is likely, because all Rht8 wheats are GA_3 responsive).

Among pest and diseases, aphid problems seem universal, as is the barley yellow dwarf virus (BYDV) disease transmitted by aphids. The Russian wheat aphid (RWA) also occurs in Hungary, but has become a more serious pest in the western U.S.A. Some Hungarian hard red winter wheats carry usable resistance to the RWA. Furthermore several recent Hungarian HRW wheats carry good levels of stripe and leaf rust resistance, which made them very attractive as parents for breeding. Some of the U.S. and Hungarian wheats and barleys might also prove useful for direct introduction into production if further evaluations confirm current indications.

The high milling, baking, malting and nutrition quality of Hungarian wheats and barleys has long been of note. It would be therefore of considerable interest to gain greater knowledge of the characteristics and quality of Hungarian cultivars grown in the PNW as evaluated by PNW parameters.

This proposed common project could give new-released wheat and barley varieties, new technological methods which could have benefit for the Pacific Northwest of the U.S.A.

This two-way international cooperation will strengthen the wheat and barley research program at the University of Debrecen, and likewise strengthen important facets of Hungarian and PNW agriculture. This formal project proposed will be funded by U.S. - Hungarian joint fund to a certain extent, but additional funding is needed to improve the efficiency of this project containing practically usable aspects.

BARLEY IMPROVEMENT RESEARCH

S. E. Ullrich, C. E. Muir, J. A. Clancy, J. S. Cochran, D. A. Deerkop, R. A. Nilan, A. Kleinhofs, J. J. Johnson, L. Hou, V. McCamant, J. Davis, B. C. Miller, P. E. Reisenauer, J. A. Froseth and D. C. Honeyfield

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 release is Hundred which is a high yielding semi-dwarf 6-row winter feed barley. Yield performance for Hundred and other winter cultivars can be found in Table 1. The leading spring barley cultivar release candidate is WA8771-78, which is a two-row type with high yield and good feed and malting quality. It's yield performance can be seen in Table 2. along with other spring cultivars. 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 March 1991 Wheat Life issue. Carl Muir, Bud Deerkop, Bob Nilan and Steve Ullrich have been major contributors to the cultivar development aspects of the program.

TABLE 1. WINTER BARLEY YIELD AVERAGES THROUGH 1990, LB/A(% of Boyer)

VARIETY	PULLMAN 8YR	POMEROY 6YR	WALLA[2] 6YR	LIND IRR 4YR	EXTENSION 56LOC-YR
HUNDRED	5620(112)	4730(107)	4530(100)	4580(112)	4560(105)
HESK	5460(109)	4840(109)	4580(101)	4310(105)	4460(103)
BOYER	5010(100)	4430(100)	4520(100)	4090(100)	4330(100)
SHOWIN	4900(98)	4300(97)	4190(93)	4200(103)	4220(97)
KAMIAK	4440(89)	4110(93)	4080(90)	2600(63)	3920(91)

TABLE 2. SPRING BARLEY YIELD AVERAGES THROUGH 1990.

VARIETY	EXTENSION		STATE NURSERIES			
	ROW TYPE	MEAN 47LOC/YR	PULLMAN 10YR	POMEROY 10YR	WALLA[2] 10YR	MEAN 30LOC-YR
			LB/A(%)			
STEPTOE	6	3980(100)	4940(100)	3260(100)	3740(100)	3980(100)
WA8771-78	2	3940(99)	5040(102)	3220(98)	3550(95)	3940(99)
COUGBAR	6	3790(95)	4850(98)	2830(87)	3550(95)	3740(94)
KLAGES	2	-	4660(94)	3070(90)	3360(90)	3650(92)
MOREX	6	-	3740(76)	2500(76)	2830(76)	3020(76)

Germplasm Development

Mutation Breeding. The first induced barley mutant to be released as a new cultivar in the U.S.A. occurred in the WSU Barley Program in 1966. It was the relatively short, lodging resistant Luther induced from the 6-row winter barley Alpine. Other WSU winter barleys to follow that were cross bred from induced semi-dwarf mutants include Boyer, Showin, and Hundred. Semi-dwarfism has been one major trait that has been successfully induced from a variety of mutagens and selected for in both winter and spring types. Approximately 30 semi-dwarf (SD) mutants have been selected in spring type. Several of the better adapted mutants have been used as parents in the breeding program to reduce lodging and have been characterized for N use, agronomic and malting quality traits. Although the raw induced mutants were generally inferior to their standard height isotypes, several mutants have improved traits other than semi-dwarfism useful for crop breeding purposes.

Induced mutagenesis has also been successfully used to select, in spring malting types, for proanthocyanidin-free barley grain, a brewing quality trait. In this project, which began in 1976 in cooperation with the Carlsberg Laboratory in Denmark, 175 mutants have been selected. Mutants at several loci and crossbred progeny have shown good potential in the cultivar development process. Judy Cochran has been the principal person working on this project.

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 with seedling morphological traits including chlorophyll deficient, glossy and lethal phenotypes. 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), 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. At this stage of the evaluations there is some encouragement that somaclonal variation may provide some useful variation for barley improvement. Ginny McCamant is the current principal lab person working on immature embryo tissue culture.

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 and Davenport. The Mielke farm near Davenport is our main winterhardiness test site. Extension trial sites are located in Mayview, Dayton, St. John, Deep Creek, Farrington, Fairfield, Dusty, Lamont, Asotin, Bickleton and Moses Lake (irrigated). Spring breeder plot sites include Pullman, Pomeroy, Walla Walla, Connell, Lind, Royal Slope (irrigated), Davenport, and Fairfield. Spring extension small plot sites are at Farmington, Coulee Hite, St. John, Dayton, Dusty, Lamont, Bickleton and Moses Lake (irrigated). The breeder plots are coordinated by Bud Deerkop (past) and Jim Davis (current) and with the spring wheat program (Cal Konzak, Mike Davis and Gary Shelton). The extension plots are run by Baird Miller and Pat Reisenauer. 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. The counties and number of trials involved were Adams (1), Columbia (1), Franklin (1), Walla Walla (1), Garfield (5), Klichitat (5), Lincoln (8), Spokane (7), Stevens (2), and Whitman (9). 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. Steptoe had the highest average yield at 3071 lb/a and was first in yield at 26 test locations. Camelot and Harrington yielded significantly less than Steptoe but not compared to each other at 2825 and 2764 lb/a, respectively. Cougbar had the lowest average yield (significantly less than the other three cultivars) at 2543 lb/a. These data will also be considered by agroclimatic zone (like environments). Other grain and grain quality data are being analyzed. In 1991 46 locations were planted; Whitman (10), Walla Walla (3), Stevens (2), Spokane (6), Lincoln (8), Klichitat (5), Garfield (5), Franklin (2), Columbia (1), and Adams (4). Five varieties were planted in all locations; Steptoe, Cougbar, Harrington, Camelot and WA8771.78. In addition 12 locations have 1-4 additional varieties including Russell (12), Manly (7), Excel (5) and Crystal (5). Jerry Johnson coordinates the on-farm test project.

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. in Vancouver, WA. As most (70-85%) of Washington barley is used for feed, nutritional quality is also important. The quality characteristics for malting and feed are not mutually exclusive. In general good malting varieties are good feed varieties. Advanced breeding lines are evaluated for nutritional quality through composition analyses (protein, lysine, fiber-soluble, β-glucans and insoluble, ADF, NDF) and feeding trials in cooperation with WSU animal nutritionists, John Froseth and Dale Honeyfield. the new mobile nylon bag technique (for digestible energy) in pigs fitted with intestinal cannulas has been employed for the past two crop years. Large differences in feed quality have been observed with in general spring 2-rows 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 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. Anther culture has been a spin-off of the immature embryo tissue culture work. 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. The goal of the anther culture work is to accelerate the cultivar development and release procedures 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 (in the current narrow sense). 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. Three members of the WSU barley improvement team at WSU (Kleinhofs, Nilan and Ullrich) are 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 phase with trait evaluations in the field and lab commencing this summer. One hundred and fifty double haploid Steptoe/Morex lines are planted at Pullman this year as one of eight locations for this analysis.

THE NORTH AMERICAN BARLEY GENOME MAPPING PROJECT AND ITS IMPACT ON BARLEY IMPROVEMENT

Andy Kleinhofs, Bob Nilan and Steve Ullrich

The North American Barley Genome Mapping Project is a five-year cooperative, multidisciplinary, multi-institutional international endeavor. The objectives of this project are to 1) Construct a detailed, high resolution, and "public" barley genome map using DNA marker fragments called restriction fragment length polymorphisms (RFLP) and doubled haploid populations; 2) Use the map to identify and locate the total array of genes, especially Quantitative Trait Loci (QTL), controlling economically important traits including those for yield, adaptation, pest resistance, and malting and nutritional quality; 3) Provide the basis and framework for efficient selection strategies and barley varietal development by design, and 4) Generate new knowledge about barley genome evolution and structure for genetic engineering of economically important traits.

The barley genome mapping project is unique among all current crop plant mapping projects. It combines basic molecular genetics, innovative data analysis techniques, several plant breeding activities, and a cooperative effort among North American barley breeders and geneticists. The uniqueness of barley and of the organizational elements of the project establishes this endeavor as a <u>model</u> for similar research on other crop plants and organisms in general.

Barley is among the top five plants most amenable for genetic and cytogenetic analyses and is eminently suitable for RFLP mapping. It is a diploid (2n=14), self-fertilizing and an economically important plant with many easily identified traits. It has a small number (n=7) of large chromosomes and a relatively simple genome. Following an appropriate cross, homozygous recombinant lines (doubled haploids) are readily produced.

From the two crosses, Steptoe x Morex (6-row) and Harrington x TR-306 (2-row), doubled haploid lines (DHLs) are produced. The 6-row and 2-row parents were carefully selected for showing considerable genetic diversity, as measured by DNA polymorphisms, and biochemical and morphological markers; important economic trait differences within each cross; and adaptation to the many barley growing regions of North America.

DHLs are used in the mapping by RFLP and classical genetics techniques (Andy Kleinhofs, coordinating). Indeed, these doubled haploid lines (DHLs) provide "immortal" genetic stocks for continued mapping research. What makes this project unique is that the same DHLs are increased and evaluated for agronomic, including pest resistance, and malting and nutritional quality traits (Steve Ullrich, cooperating). Thus, the project will relate to the location of the genes of these traits to the DNA markers. In effect, the DNA markers will permit geneticists and breeders to "see" where a certain gene is located. At present, barley geneticists have identified about 1200 traits, many desirable for barley improvement, but they only know the location of the genes controlling about 120 (10%) of these traits.

This project is pursued through the highly organized and cooperative efforts of 26 scientists in 14 laboratories in the United States and 23 scientists in 12 laboratories in Canada. Each facet of the project involves both Canadian and

United States scientists. The total project is highly organized with an overall coordinator, a five-member steering committee and several subcommittees representing all facets of the project. The coordination of this project is by Bob Nilan of the Crop and Soil Sciences Department of Washington State University.

Special experimental field plot designs, computer based programs and statistical analyses, especially for detecting genes controlling quantitative traits, and for map construction have been devised and utilized. Subcommittees have been assigned and detailed protocols developed for each facet of the project.

Such a cooperative venture brings to bear a wealth of broadly based scientific talent from outstanding laboratories throughout North America. It results in a high degree of efficiency and a project with a minimum of gaps and duplications.

Funding is another unique feature of this project. It is being supported in the United States by grower organizations such as the barley commissions of Washington, Oregon, Idaho, Montana, and North Dakota and related industrial concerns such as the American Malting Barley Association, Anheuser Busch Brewery, Imperial Chemical Industries, Great Western Malting Company and Adolph Coors Brewery. This grower and industrial support has been organized by Dr. Bill Isgrigg of the Washington Barley Commission. It is funded federally through a Special Grant from the USDA Cooperative State Research Service. In Canada it is funded by a four-year federal Strategic Grant from the Natural Sciences and Engineering Research Council of Canada, and by related industrial agencies such as the Brewing and Malting Barley Research Institute and Thompson Seeds and farmer-oriented Alberta and Saskatchewan Wheat Pools. It is hoped that support will soon be forthcoming from Agriculture Canada. Moreover, various aspects of this project are being supported by the International Center for Agricultural Research in the Dry Areas, US Administration for International Development and by the International Fund for Agricultural Research.

The Consortium is developing collaboration with barley genome mapping centers in Denmark, Sweden, Germany, England, the Netherlands and Australia. The aim of this world-wide collaboration is to provide the basis for developing the"complete" and "public" map of barley for basic mapping knowledge and technology and for developing new breeding germplasm and selection strategies for breeders in all barley growing countries around the world.

In terms of progress, DHLs for both crosses have been produced and seed increased. Mapping is proceeding with the 6-row DHLs with the projection of 100 markers mapped by July, 1991. These DHLs will be evaluated for agronomic, including pest resistance, and malting and nutritional quality traits through the summer of 1991. The 2-row cross is about six months behind the 6-row in most phases of the project. Collaborators at Cornell using a cross Proctor x Nudinka have about 130 RFLP markers mapped. In relation to progress in Europe, one center (Risø) in Denmark using Alf x Vogelsanger Gold is mapping about 80 RFLPs. A southern German group (Weihenstephan, Grünbach and Munich) is mapping with offspring of Igri x Franka and the Cambridge Laboratory at Norwich, England is placing a number of RFLP markers on Chromosome 1 with offspring of Steptoe x Winer. Computer programs are being devised to merge all mapping data developed through the different cultivar crosses towards a "complete" very high-density genome map of barley which will provide the basis for new strategies in barley improvement.

SOFT WHITE WINTER WHEAT IMPROVEMENT

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

Washington wheat growers harvested 138.6 million bushels of winter wheat in 1990 for an average yield per acre of 63 bushels. The winter was very mild. The spring was warm and fairly dry. May and June were quite wet and July was very hot. High temperatures during July had an adverse effect on grain production. The diseases that reduced yields in some areas were stripe rust, dryland foot rot, take all, and strawbreaker foot rot.

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.

We were given permission to release WA007662 and foundation seed may be available in the fall of 1992 (depending on it's survival from last winters cold weather).

WA007662 (VH086208, Luke/Daws//Hill81) is a high yielding white chaffed semidwarf soft white winter wheat. It is resistant to the local races of stripe rust, and common bunt and is susceptible to leaf and stem rust. When the grain production was averaged over 26 site/years WA007662 produced 7, 8, and 17 percent more than Kmor, Madsen, and Stephens, respectively. Volume weight of WA007662 is slightly less than that of Madsen and above that of Stephens. WA007662 is approximately 5 cm 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 WA007662 has satisfactory milling and baking quality.

Nurseries.

The WSU soft white winter wheat nurseries were grown at Pullman (early and late), Pomeroy, Walla Walla, Ritzville, Cunningham, and Coulee City, Washington . Kmor (77.35 bu/a) was the best commercial cultivar when the grain yields were averaged across all locations and years (table 1) and Madsen (74.96 bu/a) was second. Hyak (72.34 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. The yield reported in table 2 is an average of both treatments. Grain production was reduced over the years by both strawbreaker foot rot and Cephalosorium stripe. Kmor (80.71) was the highest yielding cultivar and Madsen (80.43 bu/a) was second when the yield were averaged over years. Hyak (73.14 bu/a) was the highest yielding club wheat.

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. Madsen (93.57 bu/a) produced the most grain of the commercial cultivars across treatment and over years and Dusty (93.29) was second. Hyak (88.43 bu/a) was the highest yielding club wheat.

The Pomeroy nursery (table 4) is generally sown the middle of September. When the yields were averaged over years Kmor (68.29 bu/a) was the highest yielding cultivar and Malcolm (64.86 bu/a) was second. Hyak (63.14 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 (92.43 bu/a) was the highest yielding cultivar and Hyak (91.29 bu/a) was the best club wheat.

The Ritzville nursery (table 5) is sown the first week in September. 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 (50.29 bu/a) was the highest yielding commercial wheat and Kmor (48.86 bu/a) was second. The grain production of Sprague averaged 41.29 bu/a. Kmor has very little resistance to snow mold.

Table 1. Average yield data (bu/a) on 13 winter wheat varieties grown for seven years (1984-90) at seven locations in Washington.

	WA6201	WA6202	WA6214	WA6215	WA6217	WA6253	WA6354	AVERAGE
Stephens	62	83	58	87	43	104	41	68.32
DAWS	72	80	61	88	55	109	44	72.73
DUSTY	70	93	61	92	53	103	45	73.96
LEWJAIN	74	87	62	86	58	101	45	73.22
HILL81	73	91	62	88	51	105	40	72.87
MALCOLM	60	89	65	92	48	113	44	73.07
MADSEN	80	94	64	88	55	105	39	74.96
CREW	67	82	63	85	55	96	43	70.11
TRES	66	87	61	89	58	93	44	70.82
HYAK	73	88	63	91	56	95	40	72.34
KMOR	81	93	68	92	60	99	49	77.35
ELTAN	72	91	63	92	56	92	50	73.79

WA6201 = Pullman Early, WA6202 = Pullman Late, WA6214 = Ritzville, WA6215 = Walla Walla, WA6217 = Ritzville, WA6253 = Cunningham, and WA6254 = Coulee City.

Table 2. Yield data (bu/a) on 13 winter wheat varieties grown at Pullman (early), WA.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	Average
STEPHENS	22	51	75	64	55	99	70	62.29
DAWS	52	69	91	43	75	109	62	71.57
DUSTY	50	65	78	50	65	111	69	69.71
LEWJAIN	64	67	84	55	71	107	72	74.29
HILL81	56	67	84	56	75	105	70	73.29
MALCOLM	21	56	75	55	54	89	69	59.86
MADSEN	51	78	83	72	80	102	97	80.43
CREW	52	76	75	38	66	94	71	67.43
TRES	50	71	75	50	58	101	54	65.57
HYAK	50	76	88	70	63	88	77	73.14
KMOR	55	73	105	71	83	108	70	80.71
ELTAN	72	71	82	45	64	107	64	72.14
RELY				47	71		59	
WA007662				65	59	101	48	

Table 3. Yield data (bu/a) on 11 winter wheat varieties grown at Pullman (late), WA.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	Average
STEPHENS	82	49	65	97	71	98	121	83.29
DAWS	83	52	60	100	66	100	101	80.29
DUSTY	93	60	85	103	84	112	116	93.29
LEWJAIN	78	54	88	98	81	108	100	86.71
HILL81	85	56	72	111	78	104	129	90.71
MALCOLM	73	53	74	110	91	114	108	89.00
MADSEN	95	66	85	98	84	109	118	93.57
CREW	89	52	76	86	61	100	112	82.29
TRES	84	59	71	96	81	102	113	86.57
HYAK	100	57	72	93	81	105	111	88.43
KMOR	87	60	94	104	90	112	104	93.00
ELTAN	86	68	79	99	84	119	105	91.43
RELY				96	76		116	
WA007662				115	94	126	119	

Table 4. Yield data (bu/a) on 13 winter wheat varieties grown at Pomeroy, WA.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	Average
STEPHENS	38	36	69	69	52	61	78	57.57
DAWS	67	40	73	61	51	66	69	61.00
DUSTY	65	45	77	63	44	67	69	61.43
LEWJAIN	69	41	72	67	54	64	70	62.43
HILL81	73	38	64	67	49	71	72	62.00
MALCOLM	65	46	65	68	54	66	90	64.86
MADSEN	73	45	70	60	52	63	85	64.00
CREW	73	38	70	67	50	69	71	62.57
TRES	55	42	75	68	47	70	67	60.57
HYAK	76	43	68	63	47	66	79	63.14
KMOR	93	48	75	65	51	74	72	68.29
ELTAN	80	48	61	58	57	68	68	62.86
RELY				67	51		72	
WA007662				68	60	76	75	

Table 5. Yield date (bu/a) on 13 winter wheat varieties grown at Walla Walla, WA.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	Average
STEPHENS	131	58	86	93	62	91	87	86.86
DAWS	120	59	84	87	68	104	92	87.71
DUSTY	137	76	92	89	64	96	89	91.86
LEWJAIN	123	68	85	87	65	86	85	85.57
HILL81	120	66	85	93	67	99	87	88.14
MALCOLM	109	64	96	102	67	114	95	92.43
MADSEN	128	65	90	86	69	100	80	88.29
CREW	113	59	92	89	61	89	91	84.86
TRES	118	64	94	84	63	101	97	88.71
HYAK	140	66	88	89	65	95	96	91.29
KMOR	132	70	88	95	66	98	95	92.00
ELTAN	134	71	81	95	71	109	85	92.29
RELY				89	65		88	
WA007662				100	74	113	89	

Table 6. Yield data (bu/a) on 13 winter wheat varieties grown at Ritzville, WA.

	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	
WA007662				63	54	63	

Table 7. Yield data (bu/a) on 13 winter wheat varieties grown at Cunningham, WA. (Irrigated)

	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	
WA007662				96	105	131	

Table 8. Yield data (bu/a) on 13 winter wheat varieties grown at Coulee City, WA.

	83/84	84/85	85/86	86/87	87/88	88/89	89/90	Average
STEPHENS	47	29	39	29	55	36	52	41.00
DAWS	42	40	46	36	49	45	52	44.29
DUSTY	57	35	39	39	52	38	55	45.00
LEWJAIN	67	31	41	32	48	44	51	44.86
HILL81	50	34	33	33	43	39	51	40.43
MALCOLM	47	27	47	26	53	44	61	43.57
MADSEN		29	37	32	40	45	48	
CREW	64	34	35	32	53	34	47	42.71
TRES	60	40	42	35	45	37	46	43.57
HYAK		30	42	29	51	39	46	
KMOR	59	44	42	39	61	44	53	48.86
ELTAN	60	45	45	31	64	48	59	50.29
JOHN	44	38	37	34	44	35	50	40.29
SPRAGUE	36	38	44	40	50	37	44	41.29
ANDREWS	50	36	34	31	45	36	51	40.43
WESTON	38	36	31	33	46	40	39	37.57
RELY					45		52	
WA007662				44	50	40	56	

TABLE 9. INDEX (1= poor - 10 excellent) AND/OR DISEASE RATINGS FOR 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

PACIFIC NORTHWEST HISTORICAL WHEAT NURSERY

Baird Miller, Clarence Peterson and Ken Kephart

The production of wheat in the Pacific Northwest started when the earliest settlers came to this region in the 1870's. In recognition of those early settlers who brought both their culture and wheat with them, Ken Kephart, former Extension Agronomist at the University of Idaho, identified and collected all the known wheat varieties grown within Washington, Idaho and Oregon over the last 100 years. To date more than 300 wheat varieties have been identified from the historical records as being produced in the Pacific Northwest.

Many varieties were introduced from other countries. A large number of wheat varieties came from Australia around the turn of the century and played an important role in the expanding PNW commercial wheat industry. Other varieties were developed in other states an eventually produced in this region. Many of the better adapted and higher yielding varieties resulted from the tremendous public investments made in the wheat breeding programs at the three land-grant institutions: Washington State University, University of Idaho and Oregon State University.

Seed form most of the post-World War II varieties was obtained from the regional wheat breeding programs in Pullman, WA; Moscow and Aberdeen, ID; Corvallis and Pendleton, OR; and Logan, UT. Most of the very old varieties were obtained from the USDA Repository in Beltsville, MD, which is currently located in Aberdeen, ID. The national repositories of Australia and Canada were also sources of seed of the early varieties which originated from these countries.

The variety breeding and production management research programs at Washington State Unvieristy and the other land-grant institutions in the PNW over the last 100 years have contributed tremendously to increase in Washington wheat yields (Figure 1). From 1900 through the 1930's, the

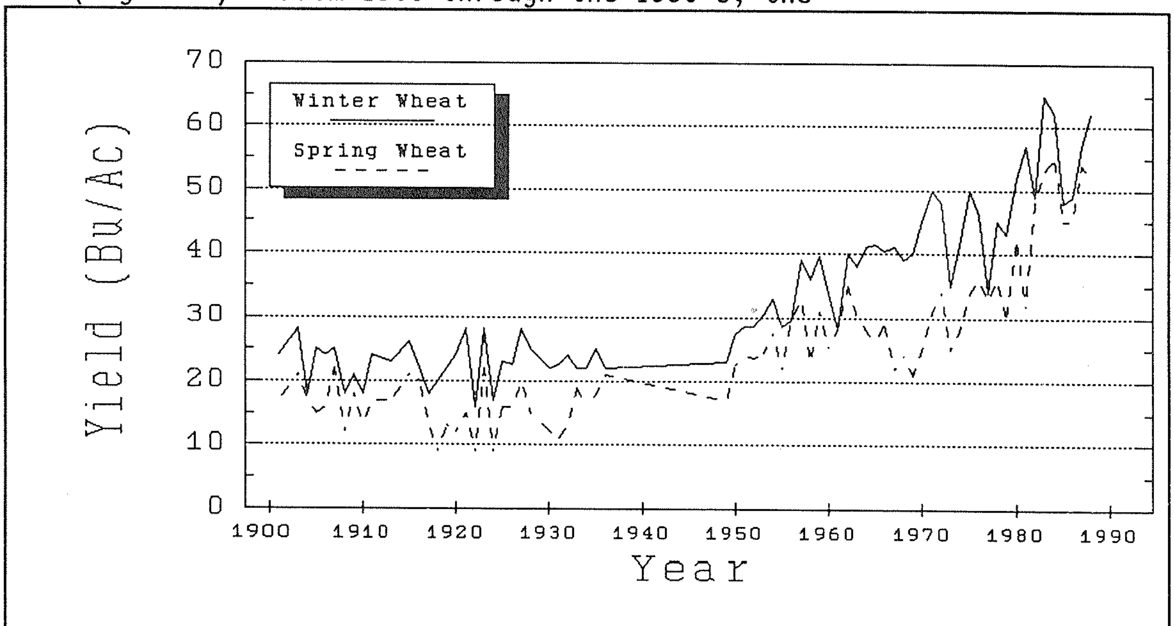
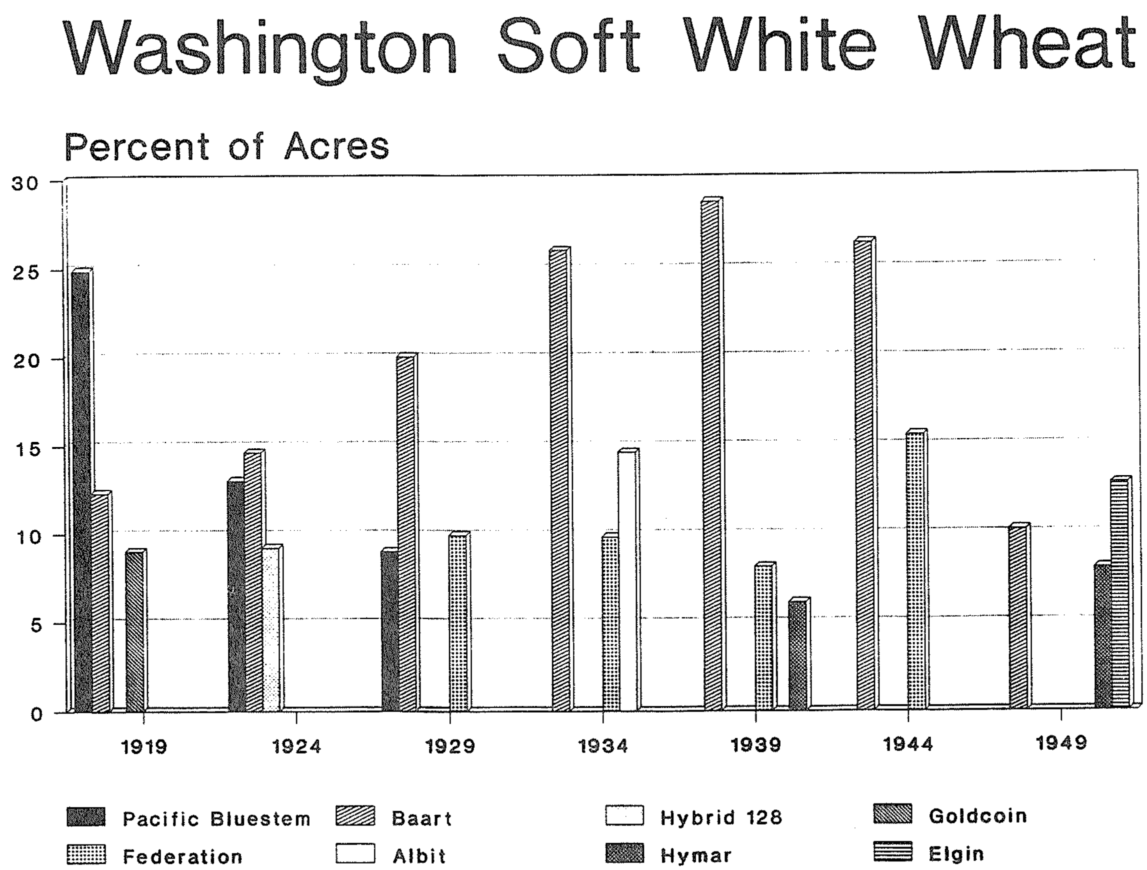


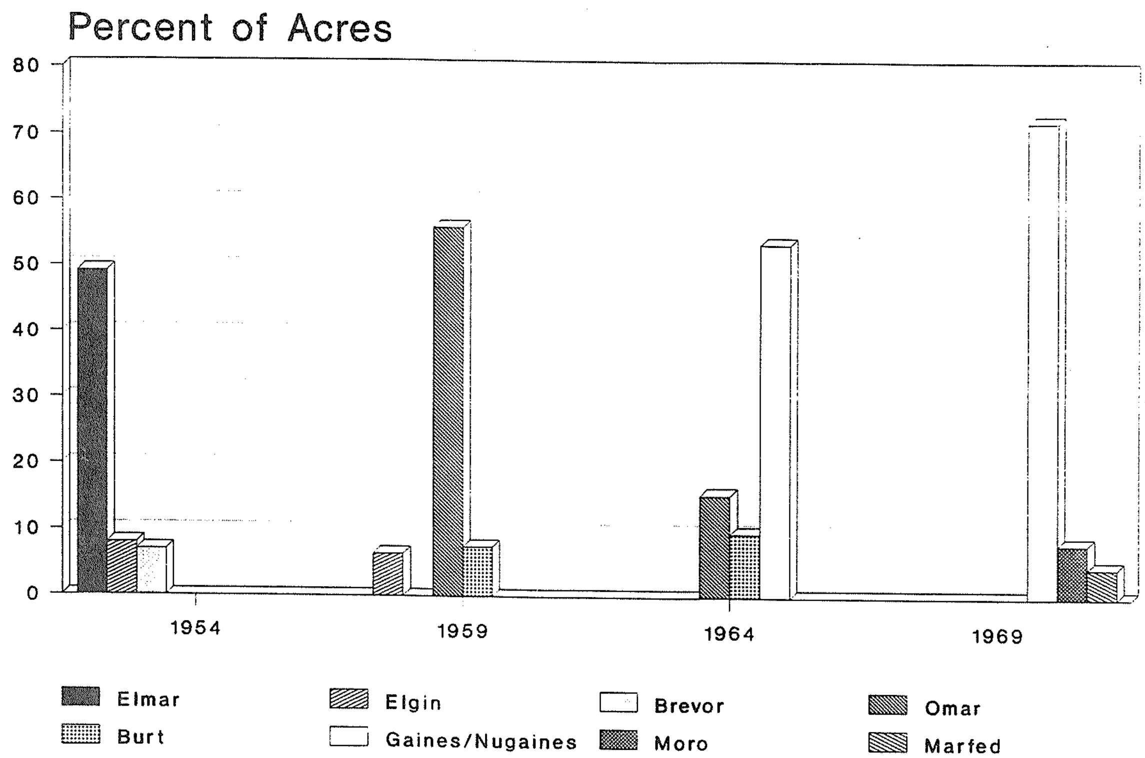
Figure 1. Progress in Washington wheat yields, 1900 - 1988.

Washington wheat yields remained relatively unchanged, with winter wheat averaging 22.8 Bu/Ac and spring wheat averaging 15.9 Bu/Ac statewide. These spring wheat yields were 30% less than the winter wheat yields during this time. From the 1940's to the late 1980's the average Washington winter wheat yields have increased to over 60 Bu/Ac and the average spring wheat yields have increase to over 50 Bu/Ac. Average winter wheat yields statewide now are only 23% higher than the average spring wheat yields. This improvement in wheat yields can be attributed to significantly improved production practices and varieties which are better adapted to Washington, more disease resistant, shorter and more lodging resistant.

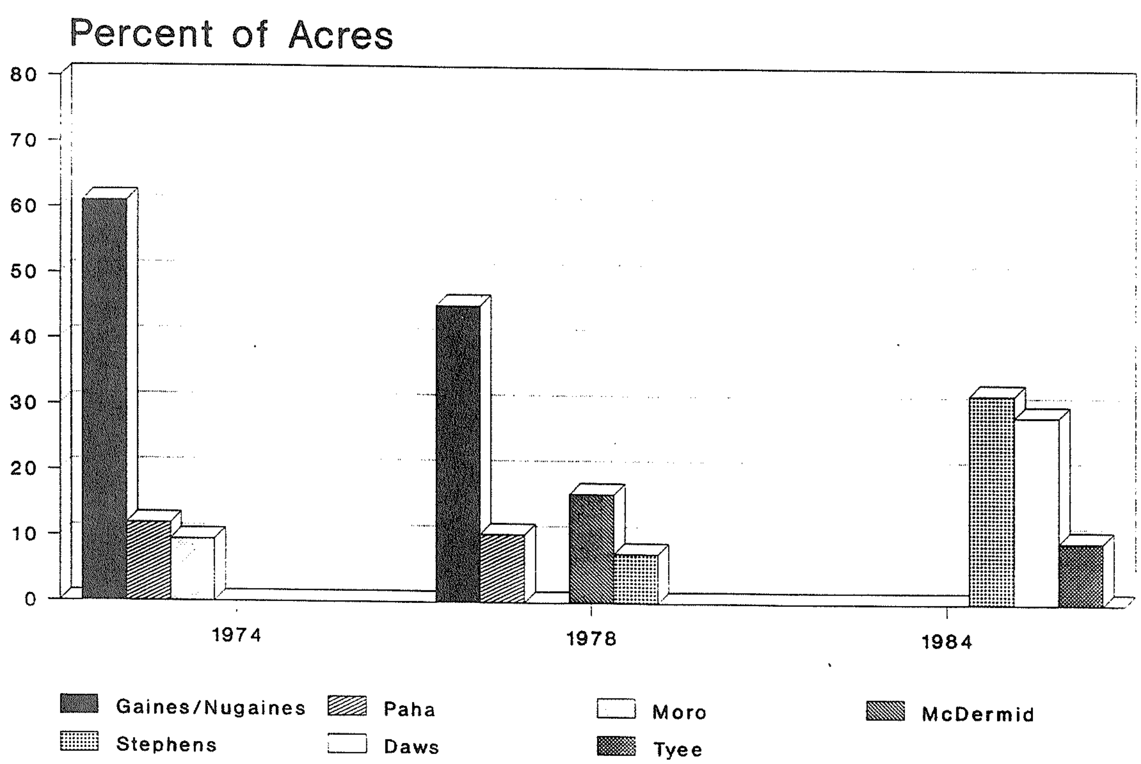
The PNW Historical Wheat Nursery on display at Spillman Farm this year contains almost 300 wheat varieties which have been grown in this area over the last 100 years. Single rows of each variety of winter and spring varieties were planted. Take the opportunity to step back into the past and reminisce. Recall varieties such as Pacific Bluestem, Baart, Hydrid 128, Goldcoin, Federation, Elgin, Elmar, Brevor, Omar, Burt, Moro, Marfed, Gaines and Nugaines. Figure 2 shows the three most popular soft white wheats grown in Washington dating back to 1919. In addition, table 1 lists the varieties planted in the PNW Historical Wheat Nursery, their class, origin and date of release.

Figure 2. Three most popular soft white wheat varieties grown in Washington from 1919 to 1984.





Percent of Acres
80
70
60
50
40
30
20
10
0
1954
1959
1964
1969
Elmar
Burt
Elgin
Gaines/Nugaines
Brevor
Moro
Omar
Marfed



Percent of Acres
80
70
60
50
40
30
20
10
0
1974
1978
1984
Gaines/Nugaines
Stephens
Paha
Daws
Moro
Tyee
McDermid

Table 1. Varieties planted in the 1990 PNW Historical Wheat Nursery at Spillman Farm, Pullman, WA.

WINTER WHEAT

SOFT WHITE

CULTIVAR	SPIKE	ORIGIN	YEAR
WHITE WINTER	COMMON	ENGLAND	1855
DAWSON	COMMON	ONTARIO	1881
GOLDCOIN	COMMON	NEW YORK	1890
GENESEE GIANT	COMMON	NEW YORK	1893
EATON	COMMON	ENGLAND	1894
SATISFACTION	COMMON	NEW YORK	1895
HYBRID 128	CLUB	WASHINGTON	1907
FLORENCE	COMMON	AUSTRALIA	1914
WILHEMINIA (HOLLAND)	COMMON	NETHERLAND	1914
ALBIT	CLUB	WASHINGTON	1926
POWERCLUB	CLUB	IDAHO	1926
ARCO	COMMON	OREGON	1928
GENRO	CLUB	WASHINGTON	1928
WHITE ODESSA	COMMON	IDAHO	1928
HOOD	CLUB	OREGON	1929
GOLDEN	COMMON	OREGON	1930
ATHENA	COMMON	OREGON	1931
ALICEL	CLUB	OREGON	1932
REX	COMMON	OREGON	1933
HYMAR	CLUB	OREGON	1935
REQUA	COMMON	WASHINGTON	1935
REX M2	COMMON	WASHINGTON	1938
ELGIN	CLUB	OREGON	1943
ALBA	COMMON	BELGIUM	1948
BREVOR	COMMON	WASHINGTON	1949
DRUCHAMP	COMMON	FRANCE	1949
ELMAR	CLUB	WASHINGTON	1949
OMAR	CLUB	WASHINGTON	1955
GAINES	COMMON	WASHINGTON	1961
LUFT	COMMON	IDAHO	1963
MORO	CLUB	OREGON	1965
NUGAINES	COMMON	WASHINGTON	1965
YAMHILL	COMMON	OREGON	1969
HYSLOP	COMMON	OREGON	1970
LUKE	COMMON	WASHINGTON	1970
PAHA	CLUB	WASHINGTON	1970
SPRAGUE	COMMON	WASHINGTON	1972
McDERMID	COMMON	OREGON	1974
PECK	COMMON	IDAHO	1974
REW	COMMON	OREGON	1974
BARBEE	CLUB	WASHINGTON	1976
DAWS	COMMON	WASHINGTON	1976
FARO	CLUB	OREGON	1976
RAEDER	COMMON	WASHINGTON	1976
STEPHENS	COMMON	OREGON	1977
GREER	COMMON	IDAHO	1978
JACMAR	CLUB	WASHINGTON	1978
LENORE	COMMON	IDAHO	1978
TYEE	CLUB	WASHINGTON	1979
CREW	CLUB	WASHINGTON	1982
HILL81	COMMON	OREGON	1982
LEWJAIN	COMMON	WASHINGTON	1982
DUSTY	COMMON	WASHINGTON	1984
TRES	CLUB	WASHINGTON	1984
BASIN	COMMON	WASHINGTON	1985
CASHUP	COMMON	WASHINGTON	1985
JOHN	COMMON	WASHINGTON	1985
OVESON	COMMON	OREGON	1986
HYAK	CLUB	WASHINGTON	1987
MADSEN	COMMON	WASHINGTON	1987
MALCOLM	COMMON	OREGON	1987
SYRINGA	COMMON	IDAHO	1989

SOFT RED WINTER

CULTIVAR	SPIKE	ORIGIN	YEAR
MEDITERRANEAN	COMMON	S. EUROPE	1842
ODESSA	COMMON	RUSSIA	1865
FULTZ	COMMON	PENNYSLVANI	1871
GOLDEN CROSS	COMMON	NEW YORK	1888
JONES FIFE	COMMON	NEW YORK	1889
LOFTHOUSE	COMMON	UTAH	1890
RED RUSSIAN (1)	COMMON	ENGLAND	1890
PRIDE OF GENESEE	COMMON	NEW YORK	1893
HARVEST QUEEN	COMMON	KANSAS	1897
COPPEI	CLUB	WASHINGTON	1911
SUN (SOL)	COMMON	SWEDEN	1911
TRIPLET	COMMON	WASHINGTON	1918
RUDDY	COMMON	WASHINGTON	1919
THORNE	COMMON	OHIO	1937
NORIN 10/BREVOR 14	COMMON	WASHINGTON	1953
SPOKANE CHIEF	CLUB	WASHINGTON	1953
DUAL	COMMON	INDIANA	1955

HARD WHITE WINTER

CULTIVAR	SPIKE	ORIGIN	YEAR
BURT	COMMON	WASHINGTON	1956
COULEE	COMMON	WASHINGTON	1972

HARD RED WINTER

CULTIVAR	SPIKE	ORIGIN	YEAR
GOLD DROP	COMMON	NEW YORK	1843
TURKEY RED (KHARKOF)	COMMON	RUSSIA	1873
KHARKOF.	COMMON	RUSSIA	1900
MONTANA 36	COMMON	MONTANA	1915
BLACKHULL	COMMON	KANSAS	1917
KANRED	COMMON	KANSAS	1917
RIDIT	COMMON	WASHINGTON	1923
MOSIDA	COMMON	IDAHO	1924
ORO	COMMON	OREGON	1927
EARLY BLACKHULL	COMMON	KANSAS	1928
SHERMAN	COMMON	OREGON	1928
RIO	COMMON	OREGON	1931
TENMARQ	COMMON	KANSAS	1932
YOGO	COMMON	MONTANA	1932
CHEYENNE	COMMON	NEBRASKA	1933
RELIEF	COMMON	UTAH	1934
CHIEFKAN	COMMON	KANSAS	1935
CACHE	COMMON	UTAH	1937
TRIUMPH	COMMON	OKLAHOMA	1940
PAWNEE	COMMON	NEBRASKA	1942
WASATCH	COMMON	UTAH	1944
BLUE JACKET	COMMON	KANSAS	1946
PI178383	COMMON	RUSSIA	1948
KIOWA	COMMON	KANSAS	1950
COLUMBIA	COMMON	OREGON	1955
BISON	COMMON	KANSAS	1956
ITANA	COMMON	OREGON	1956
WESTMONT	COMMON	MONTANA	1956
TENDOY	COMMON	IDAHO	1960
DELMAR	COMMON	UTAH	1961
ITANA 65	COMMON	IDAHO	1965
McCALL	COMMON	OREGON	1965
WANSER	COMMON	WASHINGTON	1965
CREST	COMMON	MONTANA	1967
ARK	COMMON	IDAHO	1972
FRANKLIN	COMMON	IDAHO	1972
RANGER	COMMON	IDAHO	1972
HANSEL	COMMON	UTAH	1974
HEGLAR	COMMON	IDAHO	1974
JEFF	COMMON	IDAHO	1974
ARBON	COMMON	IDAHO	1978
WESTON	COMMON	IDAHO	1978
HATTON	COMMON	WASHINGTON	1979
MANNING	COMMON	UTAH	1979
NEELEY	COMMON	IDAHO	1980
WINRIDGE	COMMON	MONTANA	1981
UTE	COMMON	UTAH	1983
NORWIN	COMMON	MONTANA	1984
BATUM	COMMON	WASHINGTON	1985
ANDREWS	COMMON	WASHINGTON	1987
BLIZZARD (ID0297)	COMMON	IDAHO	1988
SURVIVOR	COMMON	IDAHO	1988
BUCHANAN	COMMON	WASHINGTON	1989

SPRING WHEAT

SOFT WHITE SPRING

CULTIVAR	SPIKE	ORIGIN	YEAR
LITTLE CLUB	CLUB	CHILE	1700
SONORA	COMMON	MEXICO	1770
FOISY	COMMON	OREGON	1865
BIG CLUB	CLUB	CHILE	1870
TOUSE	COMMON	FRANCE	1870
DEFIANCE	COMMON	VERMONT	1878
SURPRISE	COMMON	VERMONT	187?
PACIFIC BLUESTEM	COMMON	AUSTRALIA	1882
WHITE FIFE	COMMON	CANADA	1888
WHITE MARQUIS	COMMON	MINNESOTA	1890
NEW ZEALAND	COMMON	FRANCE	1890
BLUECHAFF CLUB	CLUB	OREGON	1894
JENKIN CLUB	CLUB	WASHINGTON	1895
WILBUR	CLUB	WASHINGTON	1897
ALLEN	CLUB	WASHINGTON	1900
EARLY BAART	COMMON	AUSTRALIA	1900
GALGALOS	COMMON	RUSSIA	1903
MACKEY	COMMON	IDAHO	1906
HYBRID 63	CLUB	WASHINGTON	1907
HYBRID 143	CLUB	WASHINGTON	1907
RINK	COMMON	OREGON	1909
DICKLOW	COMMON	IDAHO	1912
GYPSUM	COMMON	COLORADO	1912
BUNYIP	COMMON	AUSTRALIA	1914
FEDERATION	COMMON	AUSTRALIA	1914
HARD FEDERATION	COMMON	AUSTRALIA	1915
CURRAWA	COMMON	AUSTRALIA	1916
MAJOR	COMMON	AUSTRALIA	1916
WHITE FEDERATION	COMMON	AUSTRALIA	1916
INDIAN	COMMON	UTAH	1917
PILCRAW	COMMON	CALIFORNIA	1917
ONAS	COMMON	AUSTRALIA	1918
OREGON ZIMMERMAN	COMMON	OREGON	1921
UNION	CLUB	OREGON	1923
HARD FEDERATION 31	COMMON	OREGON	1928
HYPER	COMMON	WASHINGTON	1929
RAMONA	COMMON	CALIFORNIA	1935
PACIFIC BLUESTEM 37	COMMON	CALIFORNIA	1937
IDAED	COMMON	CALIFORNIA/IDAHO	1938
ORFED	COMMON	WASHINGTON	1943
BIG CLUB 43	CLUB	CALIFORNIA	1944
MARFED	COMMON	WASHINGTON	1947
BAART 46	COMMON	CALIFORNIA	1948
AWNED ONAS	COMMON	CALIFORNIA	1950
LEMHI	COMMON	IDAHO	1953
LEMHI 53	COMMON	IDAHO	1953
ONAS 53	COMMON	CALIFORNIA	1953
KENHI	COMMON	ALBERTA	1958
IDAED 59	COMMON	IDAHO	1962
BEAVER	COMMON	OREGON	1965
FEDERATION 67	COMMON	IDAHO	1966
LEMHI 66	COMMON	IDAHO	1966
SPRINGFIELD	COMMON	IDAHO	1970
TWIN	COMMON	IDAHO	1971
FIELDER	COMMON	IDAHO	1974
URQUIE	COMMON	WASHINGTON	1975
FIELDWIN	COMMON	IDAHO	1976
DIRKWIN	COMMON	IDAHO	1978

SOFT WHITE SPRING CONTINUED

CULTIVAR	SPIKE	ORIGIN	YEAR
STERLING	COMMON	IDAHO	1980
OWENS	COMMON	IDAHO	1981
BLISS	COMMON	IDAHO	1982
WAVERLY	COMMON	WASHINGTON	1982
EDWALL	COMMON	WASHINGTON	1984
PENEWAWA	COMMON	WASHINGTON	1985
TREASURE	COMMON	IDAHO	1986
WADUAL	COMMON	WASHINGTON	1987
WAKANZ	COMMON	WASHINGTON	1987

SOFT RED SPRING

CULTIVAR	SPIKE	ORIGIN	YEAR
PURPLESTRAW	COMMON	AUSTRALIA	1820
RED FIFE	COMMON	GALICIA	1842
KINNEY	COMMON	FRANCE	1870
HUSTON	COMMON	BULGARIA	1876
DALE	COMMON	OREGON	1901
HYBRID 123	CLUB	WASHINGTON	1907
SCHLANSTEDT	COMMON	GERMANY	1909

HARD WHITE SPRING

CULTIVAR	SPIKE	ORIGIN	YEAR
CANADIAN RED	COMMON	CALIFORNIA	1919
UTAC	CLUB	UTAH	1928
FLOMAR	COMMON	WASHINGTON	1933
RAMONA 50	COMMON	CALIFORNIA	1951
ADAMS	COMMON	OREGON	1972
WORLD SEEDS 1	COMMON	CALIFORNIA	1974

HARD RED SPRING

CULTIVAR	SPIKE	ORIGIN	YEAR
LADOGA	COMMON	RUSSIA	1888
SEA ISLAND	COMMON	UNKNOWN	1890
PRESTON	COMMON	CANADA	1893
MARQUIS	COMMON	CANADA	1911
RUBY	COMMON	CANADA	1917
RED BOBS	COMMON	SASKATCHEWAN	1918
SUPREME	COMMON	CANADA	1922
CERES	COMMON	NORTH DAKOTA	1926
RELIANCE	COMMON	MONTANA/N. DAKOTA	1926
HOPE	COMMON	SOUTH DAKOTA	1927
REWARD	COMMON	CANADA	1928
KOMAR	COMMON	NORTH DAKOTA	1930
CANUS	COMMON	CANADA	1934
THATCHER	COMMON	MINNESOTA	1934
PREMIER	COMMON	NORTH DAKOTA	1938
PILOT	COMMON	NORTH DAKOTA	1939
REGENT	COMMON	MANITOBA	1939
RIVAL	COMMON	NORTH DAKOTA	1939
COMET	COMMON	MONTANA	1940
HENRY	COMMON	WISCONSIN	1944
MIDA	COMMON	NORTH DAKOTA	1944
SPINKOTA	COMMON	SOUTH DAKOTA	1944
CADET	COMMON	NORTH DAKOTA	1946
RESCUE	COMMON	CANADA	1946
REDMAN	COMMON	MANITOBA	1947
SAUNDERS	COMMON	ONTARIO	1948
RUSHMORE	COMMON	SOUTH DAKOTA	1949
LEE	COMMON	MINNESOTA	1951
CHINOOK	COMMON	CANADA	1952
SELKIRK	COMMON	MANITOBA	1953
CONLEY	COMMON	NORTH DAKOTA	1955
CENTANA	COMMON	MONTANA	1958
CANTHATCH	COMMON	MANITOBA	1959
JUSTIN	COMMON	NORTH DAKOTA	1962
PITIC 62	COMMON	CIMMYT	1962
MANITOU	COMMON	MANITOBA	1965
CHRIS	COMMON	MINNESOTA	1967
FORTUNA	COMMON	NORTH DAKOTA	1967
RED RIVER 68	COMMON	MEXICO (CIMMYT)	1968
NEEPAWA	COMMON	MANITOBA	1969
ERA	COMMON	MINNESOTA	1970
FREMONT	COMMON	UTAH	1970
ANZA	COMMON	CALIFORNIA	1971
BOUNTY 208	COMMON	MEXICO (CIMMYT)	1971
PEAK	COMMON	IDAHO	1971
BANNOCK	COMMON	IDAHO	1972
MORAN	COMMON	IDAHO	1972
PEAK 72	COMMON	IDAHO	1972
PRODAX	COMMON	CIMMYT	1972
WARED	COMMON	WASHINGTON	1972
NORANA	COMMON	MONTANA	1973
OLAF	COMMON	NORTH DAKOTA	1973
BORAH	COMMON	IDAHO	1974
BOUNTY 309	COMMON	MEXICO (CIMMYT)	1974
KITT	COMMON	MINNESOTA	1975
PROSPUR	COMMON	MINNESOTA	1975
PROTOR	COMMON	MINNESOTA	1975
YECORA ROJO	COMMON	CALIFORNIA	1975
NEWANA	COMMON	MONTANA	1976
SAWTELL	COMMON	IDAHO	1978
WAMPUM	COMMON	WASHINGTON	1978
PROBRAND 751	COMMON	CIMMYT	1979
AIM	COMMON	MONTANA	1979
PONDERA	COMMON	MONTANA	1980
MCKAY	COMMON	IDAHO	1981
WESTBRED 911	COMMON	MONTANA	1982
WESTBRED 906R	COMMON	MONTANA	1984

HARD RED SPRING CONTINUED

CULTIVAR	SPIKE	ORIGIN	YEAR
BRONZE CHEIF	COMMON	MONTANA	1985
KODIAK DWARF	COMMON	MONTANA	1985
COPPER	COMMON	IDAHO	1987
SPILLMAN	COMMON	WASHINGTON	1987

DURUM SPRING

CULTIVAR	SPIKE	ORIGIN	YEAR
KUBANKA	COMMON	RUSSIA	1900
KAHLA	COMMON	ALGERIA	1901
SENTRY	COMMON	NORTH DAKOTA	1954
LANGDON	COMMON	NORTH DAKOTA	1956
WELLS	COMMON	NORTH DAKOTA	1960
LEEDS	COMMON	NORTH DAKOTA	1967
WANDELL	COMMON	WASHINGTON	1972
WARD	COMMON	WASHINGTON	1973
PRODURA	COMMON	CIMMYT	1975
WAID	COMMON	WASHINGTON	1979
IRRIDUR	COMMON	IDAHO	1980
WHITE POLISH	COMMON	ENGLAND	1845

1990 SPRING CANOLA VARIETY EVALUATION TRIALS

B.C. Miller, P.E. Reisenauer and V. DeMacon

In the spring of 1990, three spring canola variety evaluation trials were established at Dayton, Pullman and Farmington. Three seed companies participated in the testing program, DNA Plant Technologies, SeedTec and Spectrum Crop Development. Variety entries included both numbered and commercially available varieties of spring canola. Both Brassica campestris and Brassica napus species were included in the trials, with varieties Tobin and Westar representing the respective check varieties.

Cropping History and Results

Previous crop was winter wheat at each location. The land preparation included standard cultivation followed by a cross harrow. The soil test results are for the upper 4 feet of soil. Soil tests were taken just prior to or after N and S fertilization, so the total N available is not accurate.

Plots were seeded in 6" row spacings. Excellent planting conditions at each location allowed us to plant at a depth of 1" into good soil moisture. The DNAP varieties were seeded at 6 lbs/acre and the Spectrum and SeedTec varieties were seeded at 8 lbs/acre. At each location, and to a greater extent at Pullman, the stand established was not uniform. The stands were heavier at each end of the plots. However, by midseason this lack of uniformity had been compensated for by the variable growth of plants within the plots. The 8 lb/acre seeding rate appeared to be to high, resulting in intraspecific plant competition, and will be cut back in the future.

At Pullman the plots were sprayed with Sevin to control the flea beetle. The flea beetle damage was significant on the young leaves, and appeared to be more of a problem in the B. campestris varieties. It's not clear whether the damage was significant to reduce yields. Mustar was used as an experimental broadleaf weed control (registered in Canada) at Dayton and Farmington. Weed populations were not significant, although wild mustard was present to a limited extent at Dayton and Farmington.

The yields at the Dayton location were significantly reduced as a result of heat stress during the flowering period. Plots were direct combined with Hege 140, using screens setup for canola. Oil analysis was conducted by Dick Auld at the University of Idaho. The DNAP varieties were analyzed for oil content by DNAP.

The following tables included information on the cropping history, plot management, data summaries and raw data listings for each location.

Table 1. Cropping history summary.

	Dayton	Farmington	Pullman
N appl. (lbs/Ac)	90	100	100
S appl. (lbs/Ac)	20	25	25
Planting Date (Julian)	4/5/90 (75)	4/4/90 (94)	4/6/90 (96)
Harvest Date (Julian)	8/9/90 (221)	8/24/90 (236)	8/23/90 (235)
Soil Test Results			
pH	5.90	5.90	6.10
O.M.(%)	2.73	4.2	2.67
Avail. water (inches)	4.95	7.85	7.19
Rainfall: Apr-Aug (inches)	5.32	7.05	6.31
P (ppm)	7.2	6.2	6.7
K (ppm)	240	334	24
NO_3 (lbs/Ac)	170.3	80.8	95.2
NH_4 (lbs/Ac)	24.7	12.9	20.5
Total N (lbs/Ac)	195	93.7	115.7
SO_4 (ppm)	5	3	4
Experimental Methods:			
Replications	4	4	4
Area Planted (ft^2)	80	80	80
Area Harvested (ft^2)	68	80	80

Table 2. Summary of spring canola trials at Pullman, planted on April 6, 1990 (JD 96).

Variety	Emergence (Julian Date)	Flower Initiation (Julian Date)	Flower Completion (Julian Date)	Plant Height (in)	Yield (lbs/Ac)	Oil (%)
DNAP						
DNAP1	122	164	173	57	1965	42.1
2	118	171	181	61	2256	43.0
3	123	169	179	60	2010	43.0
4	121	167	176	58	2005	41.9
5	122	167	177	58	2176	41.9
6	121	169	178	59	1889	43.0
7	121	169	180	61	1537	42.5
8	118	164	173	54	2004	44.6
SEEDTEC						
Candida	--	--	--	--	--	--
Moneta	116	169	181	--	1790	42.9
SPECTRUM						
Eclipse	122	159	166	--	1896	41.3
Excaliber	123	159	166	--	1883	41.2
SDC8903	122	159	166	--	2265	39.9
CHECKS						
Tobin	123	159	166	--	1837	39.8
Westar	123	169	181	--	1935	40.8

Table 3. Summary of spring canola trials at Farmington, planted on April 4, 1990 (JD 94).

Variety	Emergence (Julian Date)	Flower Initiation (Julian Date)	Flower Completion (Julian Date)	Plant Height (in)	Yield (lbs/Ac)	Oil (%)
DNAP						
DNAP1	123	168	178	60	1962	42.3
2	123	172	183	60	1991	40.2
3	122	170	181	62	2066	40.2
4	123	167	178	61	2191	42.4
5	123	168	178	60	1938	44.2
6	123	170	180	58	2082	42.1
7	123	170	182	60	2192	41.3
8	123	166	176	60	2334	38.3
SEEDTEC						
Candida	--	--	--	--	--	--
Moneta	122	171	178	--	2259	39.9
CHECKS						
Tobin	122	170	177	--	2321	38.8
Westar	123	164	173	--	2329	40.0

Table 4. Summary of spring canola trials at Dayton, planted on April 5, 1990 (JD 95).

Variety	Emergence (Julian Date)	Flower Initiation (Julian Date)	Flower Completion (Julian Date)	Plant Height (in)	Yield (lbs/Ac)	Oil (%)
DNAP						
DNAP1	104	163	181	49	568	31.3
2	108	168	188	49	536	27.2
3	105	167	185	51	558	29.7
4	106	166	185	49	628	33.3
5	106	167	182	49	533	31.3
6	106	166	185	46	490	29.6
7	105	169	184	51	557	30.1
8	107	164	181	46	656	28.5
SEEDTEC						
Candida	104	168	184	52	555	28.8
Moneta	104	169	187	53	583	28.4
SPECTRUM						
Eclipse	102	156	178	46	587	31.4
Excaliber	101	156	178	45	484	30.4
SDC8903	103	153	178	45	548	32.3
CHECKS						
Tobin	104	153	178	45	566	31.6
Westar	104	167	183	48	579	30.0

EXPRESSION OF ABA-RESPONSIVE GENES IN ENVIRONMENTALLY-STRESSED WHEAT SEEDLINGS

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Environmental stresses including drought and freezing stress all cause dehydration of plant tissue. When plant tissue is dehydrated, levels of the plant hormone, abscisic acid (ABA) increase. Evidence from ABA-deficient plant mutants and prehardening experiments indicate that ABA-regulated processes are critically required for plant acclimation and survival of tissue dehydration.

Our research program is directed at identifying ABA-responsive genes associated with tolerance of environmental stress in wheat seedlings. We have characterized ABA-responsive genes that are preferentially expressed in dormant or growth-arrested wheat embryos. We have obtained 16 molecular markers or cDNA clones from five different wheat gene families for ABA-responsive genes (Plant Physiology 95: 814-821, 1991). Our DNA sequence analyses of these genes indicate that many encode proteins with a high affinity for water (Plant Molecular Biology 1991, in press). Such "water-grabbing" proteins may have a role in protecting cellular structures during plant tissue dehydration caused by freezing or drought stress.

When wheat seedling tissue is dehydrated, large increases in ABA occur. This is accompanied by increases in ABA-responsive gene transcripts and proteins. We now have preliminary evidence that correlates the accumulation of these ABA-responsive proteins with capability of plant tissue to tolerate dehydration and resume growth upon rehydration. Work is in progress to evaluate the potential of these ABA-responsive genes as molecular markers for improving dehydration and freezing stress tolerance in wheat.

ENHANCEMENT OF SEED PERFORMANCE BY MATRI-CONDITIONING

Dr. James D. Maguire

The field performance of crop seeds can be enhanced by matri-conditioning them in solid matrix carriers such as Micro-Cel E or Vermiculite and water in suitable ratios to maintain high negative water potential. Such partial hydration of seed (matri-conditioning) initiates germination processes without radicle protrusion. Upon seeding, rapid and uniform emergence is achieved - an interplay of seed's physiological state with the dynamics of the soil environment. Matri-conditioning with solid matrix carriers offers some advantages over osmotic carriers such as PEG and can be used for early planting of crops under stress conditions. Thermo dormancy can be overcome by matri-conditioning. Growth regulators, bioactive chemicals, and beneficial organisms can also be incorporated to improve seed performance.

Improvement in Emergence By manipulating the ratio of seed to carrier to water-maintaining a highly negative water potential it was possible to improve emergence of seeds at suboptimal temperatures. Compared to PEG osmo-conditioning the matri-conditioning with Micro Cel E reduced the time for 50% emergence (T50) and improved shoot weight for onion, beet, tomato, pepper, carrot, and celery seed. Addition of gibberellin to beans with matri-conditioning further improved their performance. Other growth compounds-ethylene, kinetin were also effective on vegetable seeds. Matri-conditioning overcame thermo dormancy in lettuce and celery planted at high temperatures.

Integration of biological control agents At favorable pH levels (pH 4.1) Agro-lite improved the performance of cucumber and tomato seed. Treatment with *Trichoderma* strains and matri-conditioning gave 80-96% initial seedling emergence and post emergence damping-off was less than when unconditioned seeds were treated with thiram. Matri-conditioning alone provided more rapid emergence than untreated seeds.

Improved performance in cold wet soils Matri-conditioning improved emergence and stand establishment of carrot, pepper, tomato, and beans in the field. With fungicides and matri-conditioning the stand establishment and yield of table beets was improved in early plantings. With wheat and barley improved emergence in cold, dry soils was obtained by matri-conditioning. Field emergence studies are being conducted in the Skagit Valley, Palouse and Columbia Basin in 1991.

STRAWBREAKER FOOT ROT AND CEPHALOSPORIUM STRIPE RESEARCH PROGRESS

Timothy Murray, Cheryl Walter, Larry Pritchett, and Carol Stiles

Strawbreaker foot rot and Cephalosporium stripe are two of the most important diseases of winter wheat in eastern Washington and northern Idaho. Both diseases are most important in the higher rainfall areas of the region, but can also occur and cause significant losses in yield in the lower rainfall areas. These diseases are prevalent on early-seeded winter wheat, but for different reasons. Older plants are more susceptible to *Pseudocercosporella herpotrichoides*, the fungus that causes foot rot, and are larger targets for spores of the fungus that are splashed around and start the infection. For Cephalosporium stripe, older plants have larger root systems that are more prone to winter injury. Winter root injury allows *Cephalosporium gramineum*, the fungus that causes Cephalosporium stripe, to penetrate and establish itself in the roots.

Strawbreaker foot rot has been controlled largely with fungicides since about 1977, when Benlate was first registered. Since then Mertect and Topsin-M have been registered and used widely. One of the problems with all of these fungicides is the potential for development of resistance in the fungus causing foot rot. Over the past two years, we surveyed 225 commercial winter wheat fields and tested for fungicide resistance in *P. herpotrichoides*. A total of 26 fields with resistant fungus isolates were found, which represents about 12% of the fields tested. Fields with resistant fungus isolates were found in Washington (15 fields), Oregon (10 fields), and Idaho (1 field), and in all types of management systems ranging from annually-cropped, irrigated wheat, to 2-3 year rotations of dryland wheat. In general, fields with fungicide-resistant fungus isolates had received five or more applications of a foot rot fungicide since 1977. In some of the fields where resistance was discovered, the proportion of resistant isolates was so high that Strawbreaker foot rot was not controlled by fungicide application; this is called practical resistance.

The implications of this discovery are significant. When resistance develops, the fungus becomes resistant to all three of these fungicides. Therefore, switching from Benlate to Mertect, for example, will not solve the problem. In most of the fields surveyed, practical resistance was not apparent. However, with continued use of the standard foot rot fungicides, practical resistance will develop. Alternative methods of controlling Strawbreaker foot rot are needed to manage fungicide resistance.

Growing disease resistant varieties, and/or using fungicides with different modes of action, that is fungicides having a different effect on the fungus, are two areas we are investigating. The varieties Madsen (common head) and Hyak (club head) have high levels of resistance to Strawbreaker foot rot and are effective in controlling disease.

Results of an experiment where Madsen and Stephens were treated with several fungicides in a field near Pendleton, OR that has practical resistance are summarized in Table 1. Disease index is on a scale of 0-100, where 0 is a healthy stem, and 100 is a severely-diseased stem. In the untreated control, Stephens had a very high disease score (77) compared with Madsen (30). None of the fungicide treatments improved the yield of Madsen; this is the benefit of growing a foot rot resistant variety. For Stephens, the standard foot rot fungicides did not improve yield; this is an example of what happens with practical resistance. Currently, Tilt is the only fungicide registered for foot rot control having a different mode of action. 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 (Punch and SAN619F).

Some of the experimental fungicide treatments look very promising, however, growing a resistant variety such as Madsen will reduce the need for fungicide application. We are testing these varieties again this year in the same field with these and other fungicide treatments.

Table 1. Control of Strawbreaker foot rot with foliar fungicides in a field with Practical Resistance, Simpson Farm, Pendleton, OR, 1989-1990.

	Stephens		Madsen	
Treatment, rate a.i.[a]	Disease Index	Yield, bu/ac	Disease Index	Yield, bu/ac
Untreated Control	77	62	30	105
Punch, 3 oz.	36	110	17	103
Punch + Benlate	37	110	17	103
SAN619F 1.4 oz.	34	100	30	100
SAN619F + Mertect	57	108	18	108
Tilt 1.7 oz.	52	99	15	102
Tilt + Benlate	51	93	17	98
Tilt + Topsin-M	52	95	23	106
Tilt + Mertect	56	90	18	104
Benlate DF 0.5 lb.	54	67	38	101
Mertect DF 11 oz.	56	64	28	101
Topsin-M 4.5F 9.2 oz.	65	64	26	96
LSD[b]	15	12	12	9

Developing ways of screening for resistance to Strawbreaker foot rot remains a high priority. This year we have begun working with a commercial diagnostic kit that can specifically detect and determine how much *P. herpotrichoides* is present inside a plant with no symptoms. Plants are inoculated with the foot rot fungus in growth chambers, incubated to

[a]-In combination treatments, Punch, Tilt, and SAN619F were applied at the full-rate, i.e. 3, 1.7, and 1.4 oz., respectively, whereas Benlate, Mertect, and Topsin-M were applied at one-half the full-rate.

[b]-Least significant difference. Two figures in a column must differ by this amount to be considered statistically different.

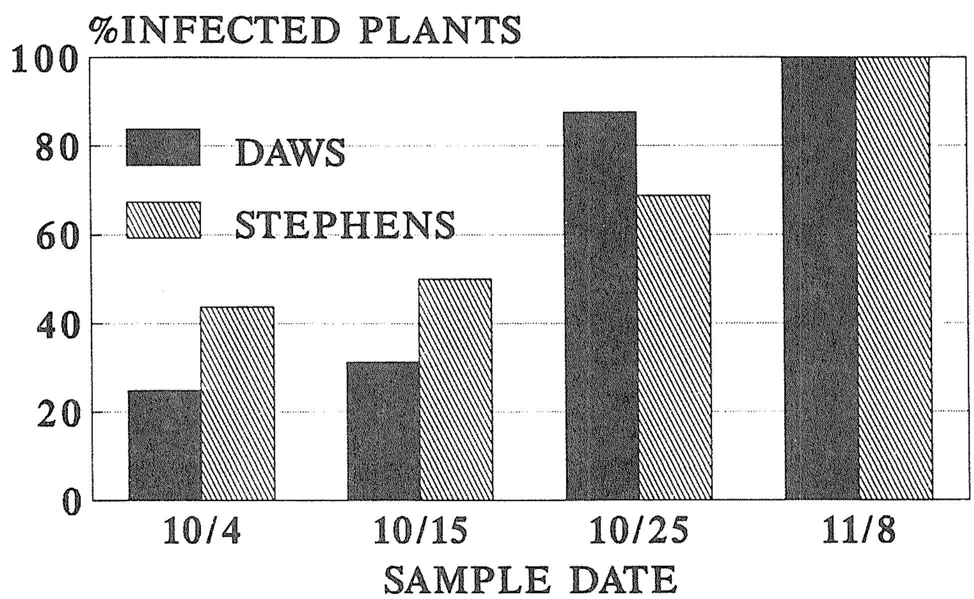
allow disease development, then tested for fungal colonization. By testing varieties of known reaction, we will determine the best time to screen for resistance, before testing germplasm of unknown reaction. This method of screening would allow testing to occur all year, and more material could be tested with greater accuracy than is now possible in the field.

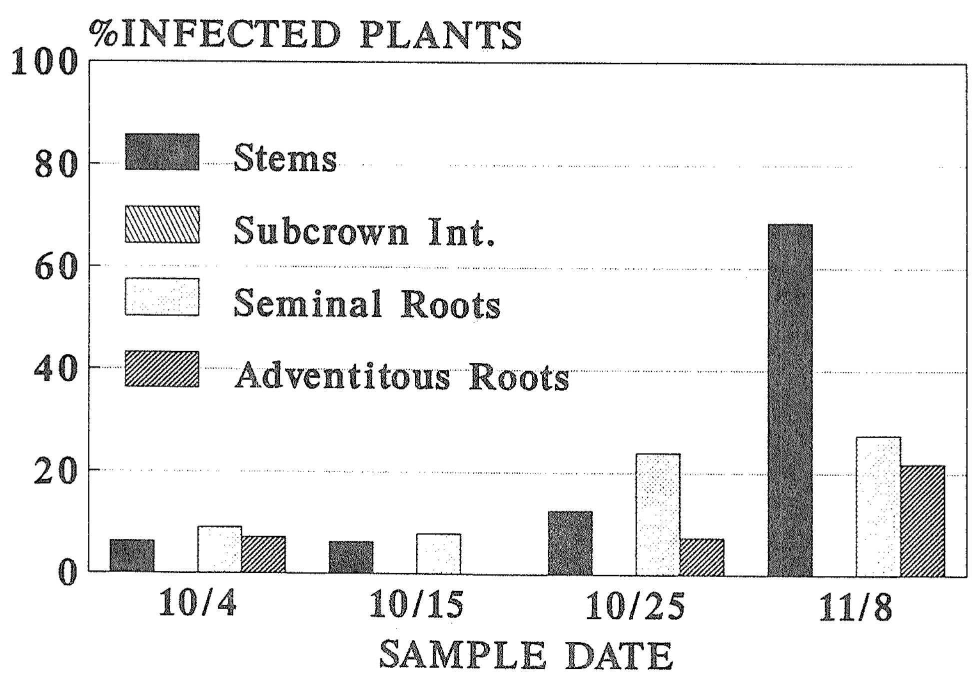
Small plot studies on the interaction of soil pH and Cephalosporium stripe have been concluded. In two out of four years of field testing, liming soil to raise pH from 5.1-5.3 to greater than 6.0 resulted in significant control of Cephalosporium stripe. In three out of four years there were significant increases in yield and test weight with liming. In a third year when frost heaving was prevalent, incidence of Cephalosporium stripe was moderately-high (30-45% infected stems) and soil pH had no effect. We now believe that liming will have the greatest benefit in years when root wounding due to heaving is not great. This can have a cumulative effect, however, because reducing disease in those years when environmental conditions are as not favorable for Cephalosporium stripe reduces the amount of pathogen-colonized straw, which will result in less disease in years when environmental conditions are favorable.

Cephalosporium stripe can also be controlled by growing disease resistant varieties. However, there are no varieties with high levels of resistance to this disease that are adapted to the Inland Pacific Northwest. A primary objective of our research on Cephalosporium stripe is to better understand how *C. gramineum* causes disease in order to develop better methods of screening for disease resistance. Carol Stiles, a graduate student, has been studying field-grown plants and found infection of stem bases and crown roots occurs in the fall before soil freezing (Figure 1). This is significant because it indicates that infection is occurring much sooner than previously believed. This work is now being done in growth chambers under controlled environmental conditions to determine whether the timing and location of infection can be exploited in screening for disease resistance.

We are developing a diagnostic test for Cephalosporium stripe similar to the one described above for foot rot, that will be used to screen for disease resistance. After determining the timing and location of infection varieties of known resistance reaction will be inoculated in the growth chamber and tested for the amount of fungal colonization.

Figure 1. Isolation of *Cephalosporium gramineum* from different varieties and parts of winter wheat plants grown at the W.S.U. Plant Pathology farm, 1990.





Wheat and Barley Root Disease Research

R. James Cook, David M. Weller, and Linda S. Thomashow
USDA-ARS Root Disease and Biological Control Research Unit

This research program on control of the root diseases of wheat and barley in the Pacific Northwest has three objectives:

1) To improve our understanding of the causes and conditions favorable to wheat and barley root diseases;

2) to improve our understanding of natural biological control in the rhizosphere of wheat and barley, including the ecology and molecular biology of root-associated microorganisms with potential to protect against the diseases; and

3) to develop practical biological controls of wheat and barley root diseases effective in modern farming systems.

Under **Objective 1**, we have identified 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* as present in various mixtures in wheat and barley field soils of the Inland Northwest, and collectively to 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 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.

We have also shown that the disappointingly poor performance of wheat and barley planted into wheat or barley residue (conservation tillage) and long attributed to suspected phytotoxins from rotting straw is, in fact, 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. Root diseases must be controlled to increase fertilizer-use efficiency, open the way for conservation tillage, and permit more frequent cropping to small grains.

Under **Objective 2** 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 "resistance" to take-all in strains of bacteria. These bacteria become naturally associated with root of wheat after several successive outbreaks of the disease, so now we must find ways to derive disease-control benefits from them but without waiting through several years of destructive disease for the cycle 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 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.

Objective 3 is aimed at practical application of root-associated microorganisms in combination with improved cultural practices for root disease control in fields managed with conservation tillage. 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%.

A major 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 at the time of planting, <u>and</u> place fertilizer directly below the seed, all in a one-pass operation. Results to date show that the soil disturbance and fertilizer placement are not as critical (the shanks for fertilizer placement and loosening the soil can be up to 6 inches to one side of the seed row, with no reduction in yield) if the soil is fumigated to remove root disease as a factor. However, where root diseases are potentially severe (wheat after wheat or barley and no preplant tillage), it is critical to loosen the soil within the seed row and place the fertilizer 2-3 inches directly beneath the seed. 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 independently of fertilizer placement.

Another important finding within the past 5 years, in research done cooperatively with Dr. 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 the growth of volunteer wheat or barley together with 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" 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 rather than only 1-3 days after spraying before planting 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 disease pressure by itself. But 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.

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 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.

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 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.

NEW WHEAT HEALTH MANAGEMENT BOOK

R. James Cook, USDA-ARS and Roger Veseth, WSU/UI Cooperative Extension

Wheat Health Management, printed January 1991, is the first book in a new "Plant Health Management Series" by the American Phytopathological Society Press. We wrote this book to help guide wheat health managers -- farmers, fieldmen, farm advisors, Extension and other agricultural service and support personnel -- to an understanding of the basic concepts and approaches to wheat health management. It integrates all important facets of wheat health management into a decision framework to help growers develop more efficient, environmentally-sound production systems which optimize yields within the constraints of the environment. The "holistic" approach of this book focuses on the whole cropping system -- not just on the wheat plant or on individual management choices apart from interactions within the overall system.

The opening chapter of ***Wheat Health Management*** describes wheat in the wild to make key points on how wheat manages its own health, including its own innate ability to avoid, resist or tolerate diseases, insect pests, drought, temperature extremes and other hazards, and how these traits have been lost or enhanced through domestication and breeding. Chapter 2 describes how healthy wheat plants grow. The limiting effects of climate, weather, and soils on wheat development and production potential are covered in chapter 3. It introduces the concept that the crop should be managed for realistic yield goals. To manage current varieties for higher yields than attainable within the limits of growing degree-days, available water, or other constraints of the environment not only can be inefficient and wasteful of resources, but can lead to crop stress and greater susceptibility to some diseases.

The fourth chapter describes the real world of pests and diseases, and their effects on the wheat crop from seedlings in the field to grain in the bin. Both short-term and long-term economic implications of wheat health management are considered in Chapter 5, including discussions of maximum economic yield and alternative agriculture. Chapter 6 presents principles and concepts of disease and pest management in a simplified format of physical, chemical, and biological methods. This chapter is intended to help the reader develop strategies for wheat health management within the limits of their natural and economic resources.

The most innovative feature of this book is the format developed in Chapters 7-9 to integrate the technical information on management of diseases, weeds, insect pests, parasitic nematodes and abiotic environmental constraints to wheat health. Chapter 7 deals with practices applied before planting. These include crop rotations, tillage, residue management, soil testing and fertilizer application, and preplant herbicide treatments. Chapter 8 covers practices carried out at planting -- the choice of variety, seed quality, planting date, rate and depth, and at-planting applications of fertilizer and pesticides. Chapter 9 covers practices carried out in the growing crop after planting, including at harvest and after harvest when the grain is in the bin. The final chapter introduces eight scientifically-based principles of holistic health for wheat, giving attention to the whole cropping systems, as well as the wheat crop.

There is a growing awareness worldwide that agriculture must become more productive and efficient yet also be sustainable and ecologically sound in the long-term. To accomplish these sometimes seemingly contradictory goals, agriculture must become increasingly more sophisticated and technical. ***Wheat Health Management*** is intended to help growers develop management strategies which focus on both profitability and environmental protection.

From a Northwest perspective on sustainability, ***Wheat Health Management*** incorporates much of the new STEEP technology for improving wheat health and production potential under conservation farming systems. Since 1975, the tristate STEEP (Solutions To Environmental and Economic Problems) program has involved more than 80 Pacific Northwest USDA-ARS and university scientists in multidisciplinary research efforts each year.

The soft cover, 152-page book contains 94 color and 83 black and white photos and 70 graphics. To order a copy or request more ordering information, call APS Press toll-free at 1-800-328-7560 between 8 a.m. and 4 p.m. CST. The price is $28. We receive no royalties on book sales, just the satisfaction of contributing to the health of the wheat industry.

CONTROL OF STRIPE RUST, LEAF RUST AND STEM RUST

Roland F. Line
USDA/ARS, Pullman, WA

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

Historical Importance. In the late 1950's and early 1960's stripe rust caused losses in excess of 50 percent. Since then, destructive epidemics of stripe rust have occurred in fields of susceptible varieties in three out of four years. Stripe rust reduced yields in the Pacific Northwest by more than 20 percent in 1981 and more than 15 percent in 1983 and 1984. Without development of resistant varieties and emergency registration of a fungicide (Bayleton) for rust control, losses caused by stripe rust in Washington would have exceeded 50 percent in 1981 and 30 percent in 1983 and 1984.

As we develop varieties with better stripe rust resistance, leaf rust becomes more important because tissue not damaged by stripe rust is damaged by the later developing leaf rust. Consequently, leaf rust has become increasingly more important since 1962. Losses caused by leaf rust in susceptible varieties have exceeded 50 percent in some years. When not controlled, leaf rust has reduced yields by more than 15% in one out of two years since 1974. In irrigated fields, leaf rust can cause losses almost every year. Those losses have sometimes exceeded 60 percent in some fields.

Stem rust is less frequently severe, but when present, it can cause major damage in specific areas. In 1980 to 1984, stem rust significantly damaged both wheat and barley in eastern Washington and Oregon and northern Idaho, especially in late maturing fields.

Monitoring Rust. Races of <u>Puccinia striiformis</u>, the pathogen that causes stripe rust, are identified by the varieties that they attack, and new races of the pathogen frequently evolve to attack varieties that were previously resistant. Table 1 lists the races of <u>Puccinia striiformis</u> that have been detected in North America and their virulence on differential varieties. Forty-five stripe rust races have been identified of which 37 have been detected in eastern Washington. In 1990, the most prevalent races in the Pacific Northwest were those virulent on Hatton, Tres, Tyee, Moro, Jacmar, Weston, Paha, Yamhill, Fielder, Owens, and seedlings of Stephens and Daws (Races CDL-5, CDL-20, CDL-22, CDL-25, CDL-26, CDL-27, CDL-29, CDL-33, CDL-38, CDL-41, CDL-42, and CDL-43). A

Table 1. Virulence (V) and avirulence (A) of North American races of <u>Puccinia</u> <u>striiformis</u> the cause of stripe rust of wheat on differential varieties 1) Lemhi, 2) Chinese 166, 3) Heines VII, 4) Moro, 5) Paha, 6) Druchamp, 7) Riebesel 47-51, 8) Produra, 9) Yamhill, 10) Stephens, 11) Lee, 12) Fielder, 13) Tyee, 14) Tres and 15) Hyak.

Virulence Component of North American race description	CDL[a] race	Differential cultivar														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1,2	1	V	V	A	A	A	A	A	A	A	A	A	A	A	A	A
1,2,5	2	V	V	A	A	V	A	A	A	A	A	A	A	A	A	A
1,3	3	V	A	V	A	A	A	A	A	A	A	A	A	A	A	A
1,3	4	V	A	V	A	A	A	A				A	A			A
1,3,4	5	V	A	V	V	A	A	A	A	A	A	A	A	A	A	A
1,6,8,12	6	V	A	A	A	A	V	A	V	A	A	A	V	A	A	A
1,3,5	7	V	A	V	A	V	A	A	A	A	A	A	A	A	A	A
1,3,9	8	V	A	V	A	A	A	A	A	V	A	A	A	A	A	A
1,3,6,8,12	9	V	A	V	A	A	V	A	V	A	A	A	V	A	A	A
1,2,3,9	10	V	V	V	A	A	A	A	A	V	A	A	A	A	A	A
1	11	V	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1,5,6,12	12	V	A	A	A	V	V	A	A	A	A	A	V	A	A	A
1,5,6,8,12	13	V	A	A	A	V	V	A	V	A	A	A	V	A	A	A
1,8,12	14	V	A	A	A	A	A	A	V	A	A	A	V	A	A	A
1,3,6,10	15	V	A	V	A	A	V	A	A	A	V	A	A	A	A	A
1,3,9,11	16	V	A	V	A	A	A	A	A	V	A	V	A	A	A	A
1,2,3,9,11	17	V	V	V	A	A	A	A	A	V	A	V	A	A	A	A
1,3,4,9	18	V	A	V	V	A	A	A	A	V	A	A	A	A	A	A
1,3,6,8,10,12	19	V	A	V	A	A	V	A	V	A	V	A	V	A	A	A
1,6,8,10,12	20	V	A	A	A	A	V	A	V	A	V	A	V	A	A	A
2	21	A	V	A	A	A	A	A	A	A	A	A	A	A	A	A
1,3,12	22	V	A	V	A	A	A	A	A	A	A	A	V	A	A	A
1,3,6,9,10	23	V	A	V	A	A	V	A	A	V	V	A	A	A	A	A
1,3,5,12	24	V	A	V	A	V	A	A	A	A	A	A	V	A	A	A
1,3,6,8,9,10,12	25	V	A	V	A	A	V	A	V	V	V	A	V	A	A	A
1,3,9,12	26	V	A	V	A	A	A	A	A	V	A	A	V	A	A	A
1,3,12,13	27	V	A	V	A	A	A	A	A	A	A	A	V	V	A	A
1,3,4,12	28	V	A	V	V	A	A	A	A	A	A	A	V	A	A	A
1,3,4,5	29	V	A	V	V	V	A	A	A	A	A	A	A	A	A	A
1,4,6,8,12	30	V	A	A	V	A	V	A	V	A	A	A	V	A	A	A
1,3,5,11	31	V	A	V	A	V	A	A	A	A	A	V	A	A	A	A
1,4	32	V	A	A	V	A	A	A	A	A	A	A	A	A	A	A
1,3,9,12,13	33	V	A	V	A	A	A	A	A	V	A	A	V	V	A	A
1,3,4,5,12	34	V	A	V	V	V	A	A	A	A	A	A	V	A	A	A
1,10	35	V	A	A	A	A	A	A	A	A	V	A	A	A	A	A
1,3,4,9,12	36	V	A	V	V	A	A	A	A	V	A	A	V	A	A	A
1,3,6,8,9,10,11,12	37	V	A	V	A	A	V	A	V	V	V	V	V	A	A	A
1,3,11	38	V	A	V	A	A	A	A	A	A	A	V	A	A	A	A
1,2,4	39	V	V	A	V	A	A	A	A	A	A	A	A	A	A	A
1,4,14	40	V	A	A	V	A	A	A	A	A	A	A	A	A	V	A

1,4,14	40	V	A	A	V	A	A	A	A	A	A	A	A	A	A	V
A1,3,4,14	41	V	A	V	V	A	A	A	A	A	A	A	A	A	V	A
1,3,11,12	42	V	A	V	A	A	A	A	A	A	A	V	V	A	A	A
1,3,4,5,12,14	43	V	A	V	V	V	A	A	A	A	A	A	V	A	V	A
1,4,5	44	V	A	A	V	V	A	A	A	A	A	A	A	A	A	A
1,3,12,13,15	45	V	A	V	A	A	A	A	A	A	A	A	V	V	A	V

[a] Cereal Disease Laboratory type race

A new race (CDL-45) that is virulent on seedlings of Hyak was identified for the first time in 1990.

Most winter wheat varieties currently grown in the region are very susceptible to leaf rust. Since the current races can attack most varieties, there is no major selective pressure for new races of leaf rust. Consequently, no significant new races of <u>Puccinia recondita</u>, the pathogen causing leaf rust, were detected in 1990.

We have more races of stem rust in the Pacific Northwest than in all of the other regions of the United States, and races of <u>Puccinia graminis</u>, the pathogen causing stem rust, are uniquely different from races in the other regions. This is because new races more easily arise from the stage of rust that occurs on the barberry.

Effect of Weather. The rusts are obligate parasites and must have a living host to grow on. The continual presence of living wheat plants throughout the year provides hosts for the rusts and adequate inoculum for initiation of new stripe rust and leaf rust epidemics. Also, many current varieties are susceptible to races of rust that occur in the region. Therefore, the factor that is most limiting for rust development is often the weather. When used in combination with monitoring data, a model for predicting stripe rust, based on winter and spring temperatures has proved to be reliable since 1979. When that information is used with precipitation data, it has also enabled prediction of leaf rust and stem rust. The following factors were important in the 1990 season. Rain in late August 1989 provided moisture for early emergence of wheat and a host for early rust establishment. January and February temperatures were favorable for rust survival. Consequently severe stripe rust epidemics developed in unsprayed fields of susceptible varieties. Cool spring temperatures delayed leaf rust development. Thus, leaf rust was highly severe only in late maturing irrigated fields. Stripe rust reduced yields in western Washington by more than 20%, and in eastern Washington and Oregon and northern Idaho by 0% to 20% depending on variety and location. When not controlled in the irrigated fields, leaf rust caused losses of 20% or more, but in nonirrigated fields it only caused minor losses. Losses caused by stem rust were minor.

Resistance. High-temperature, adult-plant resistance to stripe rust, which has now been incorporated into all major soft white winter wheats and most spring wheats (see Table 2), has continued to be durable against all races in the Pacific Northwest. In contrast, the high resistance expressed in both seedling and adult plant stages at all temperatures has been effective for three years or less. Information on the characteristics and inheritance of high-temperature, adult-plant resistance has been obtained, and that resistance has been or is being used in development of new resistant varieties. New information on the inheritance of race-specific resistance has been obtained, and that information and material should be useful in developing new disease control programs, identifying races, and understanding how resistance works.

We are currently evaluating the national germplasm collection for resistance to stripe rust in the field at Mt. Vernon and Pullman, WA and for specific resistance to the five most virulent stripe rust races in the greenhouse. The five races include all of the identified virulences in North America. As of this data, more than 30,000 germplasm entries have been evaluated in the field and half of those have been evaluated for resistance to the stripe rust races.

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

We annually evaluate commercial varieties, advanced breeding lines from breeders in the Pacific Northwest, and differential varieties for resistance to

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

Variety	Stripe Rust		Variety	Stripe Rust	
	Seedling	Adult		Seedling	Adult
Soft White Winter Wheat			Hard Red Winter Wheat		
Madsen	S	R			
Stephens	S	R	Batum	S	R
Luke	S	R	Wanser	S	MR-MS
Lewjain	S	R	McCall	S	MS
Dusty	S	R	Century	S	MS-S
Daws	S	R-MR	Hatton	S	MS-S
Hill 81	S	R-MR	Weston	S	S
Malcolm	S	R-MR			
Hyslop	S	R-MR			
McDermid	S	MR-MS			
Nugaines	S	MR-MS	Soft White Spring Wheat		
Gaines	S	MR-MS			
Walladay	S	MS-S	Penewawa	S	R-MR
Yamhill	S	S	Edwall	S	R-MR
			Waverly	S	R-MR
Club Wheat			World Seeds 1	S	R-MR
Hyak	S	S	Wadual	S	R-MR
Crew	R+S	R+S	Wakanz	S	MR-MS
Tres	S	MS-S	Urquie	S	MR-MS
Moro	S	S	Walladay	S	S

Club Wheat			Soft White Spring Wheat		
Jacmar	S	S	Fielder	S	S
Barbee	S	S	Fieldwin	S	S
Paha	S	S	Twin	S	S
Tyee	S	S	Dirkwin	S	S
			Owens	S	S

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

stripe rust and leaf rust. The information on resistance of germplasm and advanced lines has made possible the development and release of rust resistant varieties and should provide breeders with new sources of resistance, lead to a better understanding of how to use rust resistance, and improve the resistance of wheat varieties in the future.

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

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.

<u>Lentils</u>: 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:

'<u>Brewer</u>' 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.

'<u>Redchief</u>', 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.

'<u>Chilean 78</u>' 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 Chilean78 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.

'<u>Palouse</u>'. 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 orginated 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 being tested this year is in the F7 and it is expected that several lines in differing genetic backgrounds will be proposed for increase to the breeder seed class by the end of 1991.

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.

WEED MANAGEMENT RESEARCH IN DRY PEAS AND LENTILS

Chris Boerboom
Extension Weed Specialist

Effective and consistent weed control in pea and lentil production has been a major concern of Washington's growers. The problem exists because of two major reasons. First, peas and lentils are minor crops according to agrichemical industry and as such they can't afford to develop new herbicides specifically for peas and lentils. The herbicides that are used are usually herbicides "borrowed" from the lucrative soybean market. Unfortunately, lentils and sometimes peas are not tolerant to all of the soybean herbicides and many of them are expensive.. The second problem growers face is the broad spectrum of broadleaf weeds that must be controlled. Although some of the herbicides provide good or excellent control of some weeds, a single herbicide cannot completely control all broadleaf weeds. As a result, tank mixes might be desirable, but the cost drastically increases. To address this weed management problem, I have started several projects to search for possible solutions which I would like to describe.

One set of studies that are in their second year is evaluating the effect of increased planting rates and post-plant tillage by rotary hoeing or harrowing to aid chemical weed control in peas and lentils. From the preliminary results, any benefits provided by these techniques do not appear to be cost effective compared to herbicides. However, these studies may be very valuable in the future in supporting the continued use of herbicides in peas and lentils because nonchemical alternatives have been evaluated and documented.

More traditional solutions to improve weed control may be found by either identifying new herbicides that do not injure the crops or by finding the most effective application method. Several unregistered herbicides are being evaluated for possible use in peas and lentils this year. They include pendamethalin, lactofen, cyanazine, and C-4243. Different rates and application methods are being tested and compared with standard treatments such as Lexone/Sencor, Pursuit, and Sonalan. Maintaining crop safety often becomes a problem on the Palouse hills, so all of these trials are being conducted on two sites in each field, one on low ground with good organic matter and the second on a hill top with low organic matter. Weed control, crop injury, and crop yields will be recorded.

Red lentils are also being encouraged as a possible alternate crop in the intermediate rainfall areas and weed control will also be a challenge there. Different rates and application methods of Lexone/Sencor and Pursuit (the only labeled broadleaf herbicides on lentils) are being tested at Davenport. In the intermediate rainfall areas, the frequency and amount of spring rains are less predictable and with pre-emergence applications of these herbicides, rainfall or light incorporation are required for activation. However, too much rain may cause injury from Lexone or Sencor. These facts may cause problems in two ways. First, if the herbicides are applied pre-emergence without incorporation and without rain, poor weed control will result. On the other hand, if the herbicides are incorporated and followed by a significant rain, the lentils may be injured.

A possible solution to the problems of lentil injury and inconsistent weed control from Lexone or Sencor (metribuzin is the common name) may be to identify lentils that are more tolerant to metribuzin. With improved tolerance, higher labeled metribuzin rates could be used to provide more consistent control with less potential for lentil injury. The possibility exists that lentils may vary in metribuzin tolerance similar to other crops. Wheat, soybean, barley, potato, tomato and sweet potato all differ in tolerance to metribuzin. To explore the possibility of identifying lentil lines with improved metribuzin tolerance, 300 lentil lines from the world core collection are being tested at Spillman Farm with the aid of Dr. Fred Muehlbauer. These lines will be compared to Brewer lentils for tolerance to twice the labeled rate of metribuzin. If a lines with greater tolerance can be found, the trait could be moved into commercial cultivars.

Other research efforts to improve weed management in peas and lentils are also under way at Washington State University along with studies on fertility, and a study addressing drift injury to peas and lentils. The goal of all of these studies is to improve production of peas and lentils. .

CONTROL OF DOWNY BROME AND JOINTED GOATGRASS USING SOIL BACTERIA

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H. D. Skipper, T. L. Stubbs, and F. L. Young
USDA- ARS, Pullman, WA

INTRODUCTION

Downy brome and jointed goatgrass are problem weeds, infesting over 14 million acres of small grain lands in western United States. Each of these weed species reduces wheat yields 10 to 15%. This lost yield costs farmers approximately $300 million annually. Herbicide programs have been developed for the control of some major winter annual grass weeds, yet selective chemical control for downy brome and jointed goatgrass is not available or costs are prohibitive. The search for alternate means of weed control is therefore warranted. Plant-suppressive rhizobacteria exert a subtle effect on plants but may greatly impact plant growth and development. They have the potential to be used in the biological control of weeds. We have isolated bacteria that specifically inhibit the grass weeds downy brome or jointed goatgrass, but do not affect the crop. These bacteria, as biological control agents, colonize the root and deliver plant-suppressive compounds during a critical point in the growth of the weed, which allows the crop to be more competitive. The goal of this research is to develop the practice of using rhizobacteria to suppress grass weeds in conjunction with herbicides and cultural practices for an effective, economical, and environmentally safe weed management program in winter wheat.

ECOLOGY

In a survey of 3500 naturally-occurring soil bacteria, half were inhibitory to downy brome seedling growth in an agar plate bioassay. Only 6% inhibited downy brome and not winter wheat. Winter wheat was less susceptible than the weed to plant-suppressive bacteria. Conventional and minimum tillage systems maintained the highest populations of inhibitory bacteria. Those isolates noninhibitory to winter wheat and inhibitory to the weeds were further tested in the greenhouse. Ten of the isolates tested inhibited weed growth in greenhouse studies. While the prescreening of the bacteria for production of plant-suppressive compounds is necessary, the survival and competitive ability of these bacteria in soil systems is critical to the development of these bacteria as biological control agents.

Bacterial survival is critical to the success of this biological control but the influence of the environment on bacterial survival is not fully understood. Early seed colonization by the bacterium is thought to be critical to subsequent root colonization and growth inhibition. Wheat seeds supported greater numbers of bacteria compared to downy brome seeds on a per seed basis. Downy brome, however, supported greater numbers of plant-suppressive bacteria per surface area at all soil moisture contents. Thus, downy brome seed germination inhibition by these organisms could be a result of these higher numbers. It is possible that downy brome seed imbibes water at lower soil moisture contents, thus providing readily available nutrients for the bacteria to utilize. This would account for the higher population levels on downy brome seed at low soil moisture contents. Seed colonization in dry soil could be critical since these organisms are often fall-applied when soil is dry.

Fluctuating soil temperatures and water contents during periods of early downy brome growth also may affect the suppression of weeds by the bacterium. We determined influences of temperature and soil water content on these factors in growth chambers. The bacteria reduced root growth in wet and dry soil, although bacterial populations on root apices in dry soil were low. Growth temperature also influenced weed suppression. Root inhibition by the bacterium was greatest at 18°C, while root colonization was greatest at 10°C.

APPLICATION TECHNOLOGY

To be effective in weed management, the bacteria must survive in the soil long enough to colonize roots. An alternate approach would be to apply the rhizobacteria to the wheat/crop seeds at planting. With subsequent root colonization, the wheat roots could serve as a live carrier to transfer the biocontrol agent to weed roots upon contact or close association. Application of the bacteria to winter wheat seed furrows may enhance survival be protecting the bacterium from desiccation and possibly sunlight. We conducted a series of studies in the greenhouse to determine if subsurface placement would increase inoculum survival and downy brome root colonization. Populations surface-applied to a Ritzville soil declined by 8 log units to near-background levels over a 14 day period. With placement in a 2" furrow, the decline was only 1.5 log units; subsurface placement was an efficient means of maintaining inoculum levels, and thus may enhance biocontrol expression.

In the fall of 1988, 1989, and 1990, we established a series of field experiments at Lind, LaCrosse, Ralston, and Pullman, WA to determine the effectiveness of rhizobacteria for suppressing downy brome under field conditions. When the bacterium survived, downy brome populations were reduced by 34%. The bacteria were applied when the soil was moist and the downy brome had just began to emerge. The bacteria also survived when applied to cold, wet soil under cloudy conditions. The bacteria never survived when applied to dry, warm soils.

When bacteria were sprayed on emerged wheat and downy brome growing under cool, moist conditions and when rain followed soon after, the bacteria were recovered from root systems of wheat and downy brome. The organisms had moved from the plant foliage or soil surface into the rhizosphere.

SUMMARY

Thus far, field and laboratory studies have indicated that inhibitory bacteria can suppress the growth of weeds, resulting in increased winter wheat yields. More information is needed on the effect of environmental conditions on the survival and growth of the bacteria and on the optimum timing and application of these bacteria for successful control of grass weeds.

HERBICIDE TOLERANT CROPS

E. Patrick Fuerst

Introduction:

Weed management remains a major production problem in our crops, despite major cultural and chemical inputs. Unfortunately, there are relatively few new options on the horizon for improved weed control. However, one possibility is to develop crops with tolerance to herbicides. The herbicide chosen should be one that will control a broad spectrum of weeds while presenting very low levels of risk to the environment and our food supply. The herbicides we are proposing to work with have safe environmental and toxicological properties.

One goal is to develop pea and lentil cultivars with tolerance to Roundup. Roundup would control virtually all weed problems, it has very low toxicity and very low risk of contaminating groundwater. Another goal is to develop wheat and barley cultivars with tolerance to Select or Fusilade. These herbicides would control all grasses, including wild oats, downy brome (cheat grass), and jointed goatgrass; these herbicides have very safe properties, similar to Roundup.

The goal of developing a herbicide tolerant crop cultivar cannot be accomplished by a single individual; experts in weed science, biotechnology, and plant breeding must work together to achieve success. We have assembled cooperators with the necessary expertise to achieve this goal, and research has been initiated with financial support from our commissions and other sources.

Pea and Lentil Project:
Collaborators: Z. Cai, C. Stiff, P. Lurquin, C. Boerboom, A. Kleinhofs, F. Muehlbauer

We are attempting to genetically engineer peas and lentils. Before we can genetically engineer herbicide tolerance, we must optimize two procedures: 1) transformation: the ability to introduce a new trait, carried by a gene, into cells of the crop plant, and 2) regeneration: the ability to obtain a plant from the cells that contain the new genes. In our case, we ultimately hope to insert a gene that contains the Roundup tolerance trait.

So far, we have been able to obtain a few transformed cells of peas and lentils but still have considerable work to do before this technique is optimized. Several different techniques are being evaluated. We have made progress with regeneration techniques with peas and lentils, but regeneration remains a significant challenge. One hopeful spinoff of this research is the engineering of disease resistance as well. Plant Pathologists, Steve Wyatt and Phil Berger have indicated their interest in conducting cooperative research in this area.

Wheat and Barley Project:
Collaborators: F. Young, C. Konzak, S. Ullrich, R. Allan

We cannot engineer herbicide tolerance in wheat and barley because procedures to genetically engineer these crops are not available, and because genes are not available for tolerance to the herbicides we are interested in. Instead, we are using chemical mutagenesis, a process that causes random changes in genes, and then screening the mutants for tolerance to Fusilade and Select, and looking for survivors. The process is more lengthy than it first appears, because only second generation plants are screened for resistance. We screened a mutant barley population last year, had several survivors, but none of the progeny of these plants was resistant. This year we are screening barley, winter wheat, and spring wheat populations.

CROP DAMAGE BY THE RUSSIAN WHEAT APHID

F.K. van Evert, B.G. McConkey, A.E. Grable,
J.R. Farmer, G.S. Campbell

The Russian wheat aphid is a new threat to American wheat. It was first spotted in the U.S. in 1986. The first Russian wheat aphid (RWA) in Washington was found in 1988. Although the presence of this aphid has so far not led to serious losses in the U.S., it is well known from experiences in other countries that it can devastate a crop. This is mainly so because the RWA, when sucking sap from a plant, at the same time injects a toxin powerful enough to kill the whole tiller. It seems that at most only a few aphids are needed to accomplish this.

To help determine a management strategy for control of the RWA in a situation where there is no practical experience with such control, we have constructed a computer simulation model. This model has components for (1) crop growth and the effect of aphids on the crop, (2) aphid population growth, and (3) the effect of using a pesticide on the aphid population and thus on the crop. In addition, the model is capable of tracing the pesticide residues in the crop and in the soil.

The crop growth component is a simple formulation of a crop growth model that we had available and have had extensive experience with. For our present objective, we added to the crop model procedures describing the deposition of pesticide on the canopy, washing of the pesticides off the leaves in case of rain, uptake of pesticide into the plant, and degradation of pesticide with time. Pesticides that wash off the canopy onto the ground, or are deposited directly onto the ground, are moved into the soil with precipitation. Once in the soil, they may be taken up by the plant, or simply degrade into non-toxic products.

We used the structure of a model that was developed for the English grain aphid to simulate growth and development of our RWA. We were able to extract from the recent scientific literature, numbers that describe the RWA more accurately than the numbers used in the original model. The most striking difference between the two aphid species is that adult RWAs live much longer than adult English grain aphids. Thus, the RWA produced many more offspring during its lifetime. When we ran our model with data for the Palouse, it turned out that these long-lived adults are in large measure responsible for the explosive growth of the RWA population.

We searched the literature to determine the plant sap consumption of the RWA. It turned out that even at very high infestation levels, the amount of plant sap sucked by the aphids is too small to reduce crop yield. In contrast with this, the number of tillers killed by aphid toxins, and thus the reduction of crop yield, is considerable even at very low infestation levels. Our present efforts are directed at a better prediction of the percentage of tillers killed.

Disyston, the pesticide that in most cases would be used to control the Russian wheat aphid, degrades rather quickly. Our model indicates a necessity for a new application after about three weeks. The rapid degradation of disyston also means that the danger of groundwater contamination is relatively small. In spite of this, however, at least some pesticide is often being taken up by the plant via the root system several weeks after the initial application. At that point in time, the pesticide concentration in the crop increases and may for a certain period of time be higher than one would have expected. If the grain is to be consumed shortly after harvest, this may a concern.

ECONOMICS OF WEED CONTROL, TILLAGE, AND CROP ROTATIONS: RESULTS OF FIVE YEARS INTEGRATED CROPPING SYSTEMS RESEARCH

Douglas L. Young and Frank L. Young

Introduction

Five years of crop yields have been collected through 1990 on the "IPM trials" located northwest of Pullman, Washington. Spring rainfall and crop yields were exceptionally high during 1990. During April through June 1990, Pullman received 6.6 inches of precipitation, 40 percent more than the long-term average for these months. The wet spring was a welcome occurrence because it permitted testing the robustness of the treatments under conditions favoring vigorous growth of crops and weeds. Crop yields reached record levels for the experiment in 1990 for all crops except peas which suffered from diseases.

This report emphasizes preliminary results on average profitability and profit risk for the 12 cropping systems tested over the past five years. These systems represent combinations of two rotations (winter wheat-winter wheat-spring wheat or WW-WW-SW and winter wheat-spring barley-spring pea or WW-SB-SP), two tillages (conservation and conventional), and three weed management levels (MAX, MOD, and MIN). Each crop in each rotation is grown every year. There are four replications of each treatment. This design produces a total of 144 plots each year. Each plot is 40 feet wide by 150 feet long (except the fourth replication). The large plot size permits use of standard farm machinery and better approximates typical farming conditions. Pests other than weeds are managed uniformly across all treatments in accordance with recommendations by entomologists and plant pathologists. Fertility treatments are also uniform within crops.

Five-Year Average Profitability Analysis

In comparing cropping system profitability, the actual crop yields recorded over the five years were used. The same crop prices were used for each year in order to abstract from the confounding effects of annual price variations. Prices for the program crops of wheat and barley are computed as the "effective price" received by growers participating in the 1991 wheat and barley programs, not on market price alone. The recent five-year average market price was used for peas, a non-program crop. Actual herbicide costs and typical application costs were used for each weed management level. Over the past five years, application and herbicide costs for the MIN level has averaged 59 percent of the MAX level and MOD has averaged 77 percent of MAX. Machinery operation costs accounted for differences in tillage intensity over treatments.

The profitability analysis in this report is based on returns over total costs. Total costs include land and other fixed costs as well as variable costs like fertilizer, machine operations, and seed. Land costs are based on the typical share rents paid in the Palouse. Typically, landlords receive one-third of the wheat crop, one-third of the barley crop, and one-fourth of the pea crop net of some sharing of expenses. Fixed costs are a relatively greater share of total costs for wheat than for barley and peas; therefore, the choice of returns over total costs rather than returns over variable costs as a profitability measure will diminish the relative profitability of wheat- intensive rotations. The reported profitability levels defined as returns over total costs are appropriate for a renter who has to pay the full share rent on utilized land. Owner-operators for whom land use represents an opportunity cost may wish to employ a different profitability measure.

Table 1 reports indices of average net returns over total costs and profit risk measured by standard deviation of net returns for the 12 examined systems over the 1986-90 period. These results are preliminary and subject to change as final data are made available on such factors as harvest costs over treatments and all costs are updated to 1991-92 lands. The final economic evaluation will also make use of the full six years agronomic data. Winter wheat-spring barley-spring pea rotations under MAX or MOD herbicide levels emerge as clearly superior systems economically. These systems have an average profitability advantage of 35-40 percentage points over the other ten systems. Of equal importance to many growers, these systems are the least risky among those examined. The top ranked wheat-barley-pea, conservation tillage, MAX weed management system dominates all others in terms of high profitability and minimum risk. The large reduction in average profit from the second to the third ranked system shows that higher levels of weed control are required to maintain profitability with conservation tillage wheat-barley-pea system. Five of the top six systems in terms of average profitability utilized the wheat-barley-pea rotation. Four of the top six systems employ conservation tillage. Continuous wheat and conventional tillage systems are frequently represented among the least profitable and most risky based on these 1986-90 results.

Table 2 reports the most profitable weed management levels for winter wheat and spring crops based on the past five years results. These results display a remarkably consistent pattern of higher economically optimal herbicide rates under conservation tillage. For example, profitable chemical weed control increased two levels from MIN to MAX for winter wheat after winter wheat when conservation tillage was employed instead of conventional tillage. Profit maximizing weed management increased by one level for winter wheat after either spring wheat or peas, and for all spring crops. These five-year results document a clear tradeoff between tillage and herbicides for these eastern Palouse dryland crops. The results also indicate a modest increase under conventional tillage in weed control requirements for winter wheat after peas compared to winter wheat after other crops. Spring barley justified higher levels of herbicide use than did other spring crops.

Comparison of Profitability Over the Past Five Years

Weather, pest incidence, and other natural conditions have varied over the five years of the IPM experiments. Table 3 reports crop year and spring rainfall for the past five years and also for the 30-year average. Average crop year rainfall over 1986-90 has been about 10% less than the long-term average. Spring rainfall, however, has been nearly identical to the long-term average. Crop yields in the area tend to be more closely correlated to spring rainfall than to total annual rainfall. The fairly wide range in spring rainfall from a low of 2.9 inches in 1986 to a high of 6.6 inches in 1990 provides a scientifically welcome dispersion of weather patterns against which to test the robustness of the treatment effects. Of course, many other uncontrolled natural factors influence annual crop yields in addition to spring rainfall.

Over all rotations and weed management levels, conservation tillage maintained a profitability lead over conventional for all years except 1990 which was characterized by a wet spring. The moisture conservation benefits of conservation tillage were probably less needed during 1990 and crop diseases normally associated with higher residue levels possibly were exacerbated by the wet conditions. When the comparison is restricted to conservation tillage versus conventional tillage within the economically preferred wheat-barley-pea rotation, with each system at its profit-maximizing weed management level, conservation tillage maintained its profitability advantage all five years. However, this advantage was reduced to its narrowest level during 1990.

Results over the past five years help explain the risk-reducing contribution of conservation tillage. Yields were reduced less during drier years such as 1985-86 (2.9 inches spring rainfall) or 1987-88 (16 inches annual rainfall) under conservation tillage than with conventional tillage. The moisture-conserving benefits of conservation tillage seemed to pay off in these low-yielding years. In high-yielding years like 1989-90, there was relatively little difference between the two tillage systems. These patterns add up to lower yield variability over time with conservation tillage, which translates into less income risk to the grower. Field evaluations in the spring of 1991 have shown higher stand survival in conservation tillage than in conventional tillage winter wheat. This suggests increased resistance to adverse winter weather might also contribute to the risk reducing potential of winter wheat grown with higher levels of surface residue and soil cloddiness.

Over all tillages and weed management levels, the diversified three-crop rotation maintained a profitability advantage over the monoculture wheat rotation for all years except for the high spring rainfall year of 1990. Also, as expected for a diversified rotation compared to a monoculture, the wheat-barley-pea rotation showed less economic variability than the wheat rotation. When the two rotations are compared under the economically preferred conservation tillage and at optimal weed management levels, wheat-barley-peas maintained a profitability advantage over continuous wheat in all five years. The profitability edge of wheat-barley-peas shrunk to its narrowest level in 1990. Clearly, the high spring and early summer rainfall in 1990 contributed to good growing conditions for spring and winter wheat. The heavy disease incidence in spring peas during 1990 also handicapped the diversified rotation.

Conclusions

Based on five years of experimental results from the IPM field trials in Pullman, Washington, some consistent patterns of economic response have emerged. The most important preliminary conclusions include:

1. Higher levels of chemical weed management are economically justified under conservation tillage than under conventional tillage.

2. Higher levels of chemical weed management are economically justified in a winter wheat-spring barley-spring pea rotation than in a winter wheat-winter wheat-spring wheat rotation.

3. Higher levels of chemical weed management are economically justified in winter wheat after peas than in winter wheat after spring wheat.

4. Higher levels of chemical weed control are economically justified in spring barley than in spring wheat or spring peas.

5. Conservation tillage winter wheat-spring barley-spring peas at MAX and MOD weed management levels dominate all other systems in high profitability and low economic risk.

6. Conservation tillage is more profitable and less risky than conventional tillage, but wet springs favor conventional tillage.

7. Winter wheat-spring barley-spring peas earned more and was less risky than winter wheat-winter wheat-spring wheat.

8. Not only was the conservation tillage, MAX/MOD weed management, winter wheat-spring barley-spring pea system economically superior, it satisfied soil conservation compliance, reduced nitrogen use, and seemed to sustain biological life in the soil.

Final confirmation of these conclusions must await receipt of the sixth year of experimental results, statistical analysis of the economic comparisons, and final refinement and updating of the economic analysis. It is believed, however, that most of the patterns demonstrated to date will be confirmed by the final study.

Table 1. Indices of the Average and Standard Deviation of Net Returns Over Total Costs by Cropping System, 1986-90

Profit Rank	Rotation/ Tillage/WML[a]	Index[b] Av. Profit	S.D.
1	WBP/CS/MAX	100	44
2	WBP/CS/MOD	95	56
3	WBP/CS/MIN	60	53
4	WBP/CV/MOD	56	69
5	WWW/CS/MOD	53	54
6	WBP/CV/MAX	51	65
7	WWW/CV/MIN	51	93
8	WWW/CS/MAX	48	69
9	WBP/CV/MIN	43	64
10	WWW/CS/MIN	40	54
11	WWW/CV/MOD	38	91
12	WWW/CV/MAX	32	100

[a]WBP = Winter Wheat-Spring Barley-Spring Pea
WWW = Winter Wheat-Winter Wheat-Spring Wheat
CS = Conservation-Tillage
CV = Conventional-Tillage
MIN, MOD, MAX = Minimum, Moderate, and Maximum chemical weed management levels

[b]The highest average profit and S.D. were assigned indices of 100. The indices of lower ranking profits and S.D.'s are expressed as a percent of the highest value.

Table 2. Most Profitable Weed Management Levels by Crop and Tillage, 1986-90 Average

Crop	Conservation Tillage	Conventional Tillage
W. Wheat after W. Wheat	MAX	MIN
W. Wheat after S. Wheat	MOD	MIN
W. Wheat after S. Peas	MAX	MOD
S. Wheat	MOD	MIN
S. Barley	MAX	MOD
S. Peas	MOD	MIN

Table 3. Pullman, Washington Precipitation (Inches)

Year	Crop Year	April-June
1985-86	19.5	2.9
1986-87	18.8	4.8
1987-88	16.0	5.2
1988-89	21.4	3.6
1989-90	20.4	6.6
IPM Av.	19.2	4.6
30-Yr.Av.	21.1	4.7

EVALUATING GERMPLASM FOR WATER USE EFFICIENCY

Richard C. Johnson
USDA/ARS Plant Introduction

Improving the dry matter to water use ratio in plants, water use efficiency (WUE), has been of long-standing interest in crop science. Direct measurements of long-term or seasonal WUE requires careful accounting of the amount of water used by plants. These methods are extremely laborious and not realistically applicable to screening germplasm or to genetic studies associated with cultivar improvement.

New techniques involving naturally occurring stable carbon isotopes may provide an efficient method for estimating WUE in many crop species. Most of the CO_2 in the atmosphere is carbon 12, but about 1% is carbon 13. During photosynthetic CO_2 assimilation, plants discriminate against carbon 13, and the ratio of carbon 13 to carbon 12 is reduced compared to the carbon 13 to carbon 12 ratio in the atmosphere. In studies with individual plants growing in pots it has been shown that discrimination is correlated with the dry matter to transpiration ratio, or WUE.

Cooperative with Washington State University, the Agricultural Research Service maintains germplasm collections at Pullman that are a rich source of genetic diversity for crop improvement. Included are collections of numerous forage grasses, forage legumes, and food legumes important to the State and region. The utility of these collections in breeding programs has been hampered by the lack of evaluations for traits important for crop adaptation to environmental factors such as WUE. Work is underway in Tall Fescue, Alfalfa, and Lentils to determine if discrimination can be used to evaluate and enhance germplasm for WUE.

In a field study with four forage grasses including Tall Fescue, differences in discrimination among accessions within species were found, and these differences were consistent in both irrigated and drought-stress environments. Measurements of WUE in pots were also made under greenhouse conditions and it was found that WUE of plants in pots was related to discrimination in a way consistent with theoretical expectations. Further work showed that differences in discrimination between Tall Fescue accessions was consistent over years, and that variation for discrimination among plants within accessions was substantial. This suggests that use of discrimination to select for WUE within populations of Tall Fescue is feasible. A germplasm enhancement program to develop high and low WUE populations of Tall Fescue is underway. In related work, variation in discrimination has been found among alfalfa and lentil accessions. Experiments to relate discrimination to WUE in these species is underway with a view toward germplasm enhancement programs.

Using discrimination to improve WUE appears promising, but it is not known if WUE of isolated individual plants will always correlate with WUE in dense crop stands. Our goal is to develop genetic material with high and low WUE based on discrimination measurements, and to test for crop WUE and overall performance under different environmental conditions.

1990 PALOUSE FARM SURVEY--FERTILITY MANAGEMENT RESULTS

D. Granatstein, R. Halverson, and D. Young[1]

During the winter of 1989-90, a random sample of 239 farmers were interviewed in Whitman County, Washington and Latah County, Idaho in a WSU/UI survey, entitled "Palouse Agriculture: A Study on Production Practices, Policies, and Problems." These personal interviews represented a response rate of 75% of the farmers initially contacted. Some of the questions were identical to those in past surveys, designed to measure change over time, while others were tied to current issues such as government farm policy options. One section gathered detailed information on fertilizer and pesticide use by farmers.

The results from the fertility management questions are summarized below. Hopefully these results will be useful to growers who wish to compare their fertility management to average practices in their subregion. Researchers, extension personnel, industry representatives, and others working with growers in the Washington-Idaho Palouse should also find these random sample estimates of growers' reported management practices a useful source of benchmark data.

Although "the Palouse" is frequently referred to as a large relatively homogeneous prairie that has been converted to wheatland, it includes a wide range of climatic and topographic conditions. Annual average precipitation ranges from 11 inches in the extreme west of the Palouse Basin cropland to 26 inches at the eastern boundary. This climatic diversity leads to corresponding variations in crop yields, rotations, and cultural practices. Consequently, reports of growers' management practices should be separated into agro-climatic subregions. Accordingly, farms were classified into the following mean annual precipitation zones for the analysis of fertility management practices:

1. Western Whitman Co. subregion - 11 to 15 inches (47 farms)
2. Central Whitman Co. subregion - >15 to 18 inches (68 farms)
3. Eastern Whitman Co. subregion - >18 to 22 inches (68 farms)
4. West Latah Co. subregion - >18 to 26 inches (56 farms)

The survey solicited information on fertilization practices for winter wheat after various rotation crops, including fallow, peas or lentils, barley, wheat, and green manure.

Nitrogen

Nitrogen is the most widely and heavily used fertilizer in dryland cereal production. Anhydrous ammonia and aqua were the primary N sources for farmers in the survey, accounting for 92% of the N fertilizer applied. Nitrogen rates reported by farmers increased with higher rainfall, due to greater yield potential (Table 1). In contrast, nitrogen rates within a subregion were quite similar regardless of the previous crop. Only one grower in the survey, who farmed in the W. Latah subregion, reported using green manure. This grower

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[1]Joint contribution from the Dept. of Crop and Soil Sciences and Dept. of Agricultural Economics, Washington State University. Funding for the survey was provided by the Northwest Area Foundation, WA Ecology, and STEEP. The authors wish to acknowledge the major contributions and leadership of Curt Beus, Don Dillman, and John Carlson for the survey effort.

applied 84 lb N/ac to the following wheat crop, which is high because the proper N credits for a green manure crop are not factored in.

Table 1. Average nitrogen fertilizer rates on dryland winter wheat by preceding crop, 1989.

Previous Crop	Precipitation Subregion			
	Western	Central	Eastern	W. Latah
	lb N/ac			
Peas, lentils	---	87 (36)*	99 (57)	102 (44)
Barley	---	---	107 (5)	97 (8)
Fallow	75 (44)	83 (58)	94 (46)	104 (28)
Wheat	77 (6)	89 (7)	110 (6)	113 (7)

* ( ) represents number of farms in sample.

Other Nutrients

Throughout the Palouse, two other fertilizer nutrients, phosphorus (P) and sulfur (S), were commonly used on winter wheat. Phosphorus applications generally increased with increasing precipitation, while sulfur rates were quite uniform across climatic zones (Table 2). There was no strong evidence of varying P or S rates according to the preceding crop.

The percent of farms using P and S fertilizers was lowest in the Western subregion, while a majority of farms used them in the other regions (Table 3). A small number of farms in the Eastern and W. Latah subregions were also applying potassium or calcium fertilizers, generally at low rates.

Table 2. Average rates of P and S fertilizers on dryland winter wheat by preceding crop, 1989.

Previous Crop	Precipitation Subregion			
	Western	Central	Eastern	W. Latah
	lb/ac			
Phosphorus (P_2O_5)				
Peas, lentils	--	15	19	25
Barley	--	--	17	17
Fallow	4	12	16	20
Wheat	6	17	14	23
Sulfur (S)				
Peas, lentils	--	15	16	16
Barley	--	--	11	17
Fallow	7	12	16	16
Wheat	9	17	15	14

Table 3. Percent of farms using P and S fertilizers on winter wheat by preceding crop, 1989.

Previous Crop	Precipitation Subregion Western	Central	Eastern	W. Latah
	- - - - - - - % using P or S - - - - - - -			
Phosphorus				
Peas, lentils	--	72	79	82
Fallow	23	47	74	61
Sulfur				
Peas, lentils	--	92	90	91
Fallow	57	60	87	78

Fertilizer Use Trends

When asked about fertilizer use trends on winter wheat over the past five years, about 60% of the respondents indicated no change, while about 20% each indicated some decrease or some increase. These percentages were similar across subregions. Only two respondents out of 231 said they had made a significant decrease in fertilizer use. Another question asked growers to identify the period over their farming history during which their nitrogen fertilizer use per acre was highest. Averaged over all subregions, the period of highest use was 1986-90, and 1981-85 was a similar high-use period for the Western and Central subregions (Table 4). When asked if a significant reduction (25% or more) in N fertilizer had been made relative to the period of highest use, about 40% of the farmers responded positively. The lowest frequency of reduction was for the Western region (28% positive) and the highest for W. Latah (58% positive).

Approximately 3 to 6% of the respondents said they planned to significantly reduce N rates within the next three to five years in all subregions except W. Latah, where over 16% indicated a planned significant reduction. This may indicate the awareness of more opportunity to improve N use efficiency in Idaho, possibly due to the highly visible soil fertility research and extension efforts at the University of Idaho.

Table 4. Period of highest nitrogen fertilizer use.

5-year Period	Precipitation Subregion Western	Central	Eastern	W. Latah
	- - - - - - - % of responses - - - - - - -			
1986-1990	33	31	42	50
1981-1985	29	32	29	13
1976-1980	16	12	17	15
1971-1975	0	6	5	6
1966-1970	0	3	0	2
1965 or before	22	15	8	15

Soil Testing

The survey asked a series of questions about soil testing and fertilizer recommendations. Soil testing is a vital component of a sound fertility management program. But it is not always a precision process, and many farmers have stopped using soil tests due to bad experiences in the past. Soil tests for nitrogen tend to be more reliable in the drier areas, where weather conditions have less dramatic influences on nitrogen release and loss in the soil. This relationship is modestly suggested by the survey data in Table 5. While soil testing is least used in the high precipitation W. Latah subregion, it is also used by less than half the sample farmers in western Whitman County, the driest subregion.

Table 5. Use of soil testing for fertilizer recommendations by subregion.

Subregion	Use test	No test	No answer	No. farms
	- - - % of responses - - -			
Western	47	51	2	47
Central	71	29	0	68
Eastern	53	46	1	68
W. Latah	36	61	3	56
Palouse average	53	45	2	239

By determining both residual soil nitrogen and available soil moisture prior to planting, a grower can make a better estimate of the proper amount of fertilizer to add. Preliminary data from WSU farm field tests and soil test surveys in the drier cropping zones indicate numerous fields with high residual soil nitrogen, in some cases enough to supply the needs of the following crop. About 90% of the growers in the Palouse survey who indicated that they used soil testing also tested for residual nitrogen. The average depth of the residual nitrogen test steadily decreased from 5.2 feet in the Western subregion to 3.9 feet in the W. Latah subregion.

When those using soil testing were asked about the intensity of their soil testing, the responses were as follows, averaged over all subregions: very extensive, 2%; extensive, 20%; moderate, 45%; and minimal, 34%. The Central and Eastern subregions indicated the highest intensity of soil testing. Over 75% of those using soil tests have samples taken by a fieldman for a fertilizer company, and over 60% of the samples were analyzed by a private testing lab. The presence of a soil testing lab at the University of Idaho likely accounted for some 30% of samples being run at a university facility in the W. Latah subregion.

Over 90% of the fertilizer recommendations for winter wheat were provided by fertilizer company representatives, farmers, and private consultants. Twice as many recommendations came from fertilizer representatives than from farmers or consultants (Table 6). No growers reported receiving fertilizer recommendations from the Extension Service. The level of confidence in fertilizer recommendations was mixed, with the following breakdown: very little, 10%; fair amount, 39%; quite a bit, 33%; great deal, 18%. There was no pronounced variation across subregions.

Table 6. Source of fertilizer recommendations for winter wheat by subregion, 1989.

Source	Precipitation Subregion Western	Central	Eastern	W. Latah	Average
	- - - - - - - - - % of responses	- - - -	- - - -		
Farmer	24	15	21	28	21
Fertilizer Co.	38	54	59	9	44
Consultant	20	19	11	57	24
Extension	0	0	0	0	0
Other	15	12	7	6	10
No answer	3	0	2	0	1
Sample size	(34)	(48)	(56)	(32)	(170)

Average soil pH values reported by growers dropped from 6.6 in the Western subregion to 5.8 in West Latah. This is consistent with the climatic gradient and pH results reported in other research. Some 39-56% of the respondents in the Whitman County subregions reported that the pH has not changed over the past 10 years (Table 7). In contrast, only 27% reported no change and a roughly equal proportion reported lower pH in western Latah County.

Table 7. Trend in soil pH over the past 10 years by subregion.

Change in pH	Precipitation Subregion Western	Central	Eastern	W. Latah
	- - - - - - - % of responses	- - - -	- - - -	
Higher	4	18	18	16
Lower	13	13	16	25
Same	56	44	39	27
Unknown	27	25	27	32

In the higher rainfall Eastern Whitman and W. Latah subregions, soil testing is less reliable and more difficult to interpret. But crop rotations are also more complex, thus increasing the need for fertility evaluations after various crops. Fertilizer company representatives are the most frequent source of fertilizer recommendations. A greater percentage of farmers feel there is an opportunity to reduce N fertilizer rates in the higher rainfall regions.

The data indicate little accounting for the previous crop in determining nitrogen rates for winter wheat. Farmers reported less variations in nitrogen fertilization rates on winter wheat than might be expected across subregions of the Palouse, given the substantial precipitation and crop yield differences among subregions. Overall, nitrogen fertilizer use per acre does not appear to have declined to any great degree on the Palouse farms represented in this survey.

Summary

A few generalizations may be made from the survey results. Only about half the sampled growers use soil testing. Fertility management appears to be most developed in the Central subregion, where the extent and intensity of soil testing are both highest.

SUSTAINABLE AGRICULTURE IN DRYLAND CEREAL/LEGUME CROPPING: PROJECT SUMMARY

David Granatstein

Sustainable agriculture is a term used frequently today. It represents a goal, not a set of farming practices, in which economic, environmental, and social concerns relating to agriculture are all addressed. The project described below, funded by the USDA Sustainable Agriculture program, is evaluating current and historical farming practices for their potential to make dryland farming in the Northwest more sustainable.

Dryland cropping regions in the northwestern U.S. share the common problems of economic instability and resource deterioration. Major constraints to change include chronic moisture deficits, soil degradation, export dependence, and government farm programs. The limited moisture conditions often result in poor yields and minimize the number of production options that growers can choose from. In the driest areas, summer fallow is a standard practice used to economically produce a crop, but it also plays a role in soil deterioration, erosion, and saline seep. The wetter areas have more agronomic options, but choices are often limited by the provisions of government farm programs. Finding farming practices that can maintain or enhance both profitability and natural resources is particularly difficult in dryland regions.

In addition to the biophysical constraints on dryland agriculture, growers face the loss of important production inputs, such as certain fertilizers and pesticides. The recent proposal to classify anhydrous ammonia as a hazardous substance, although rejected, threatened to greatly restrict transport of this material, which is the cheapest and most widely used nitrogen source in the region. Registration of the herbicide Dinoseb was canceled in 1987, thus limiting the weed control options in peas and lentils grown in rotation. Cases of weed resistance to herbicides have been documented. The fungus that causes strawbreaker footrot (an important cereal disease) is becoming resistant to certain fungicides. The lack of incentive for the pesticide industry to maintain or develop materials for use in minor crops accentuates the need for alternative pest control methods so growers can diversify their crop rotations.

For these reasons, researchers, extension workers, and growers involved with dryland farming in Washington, Idaho, Oregon, Montana, Wyoming, and Utah initiated a cooperative project in the fall of 1988. The project has focused on identification of historical and current information on cropping alternatives in cereal-based systems, dissemination of the information to user groups, and prioritization of future research needs and extension activities. The second phase of the project emphasizes continued regional communication, development of on-farm testing and documentation, and in-depth research into soil quality, soil biology, and the benefits of rotational systems.

A comprehensive review of the historical and current literature on dryland cropping systems alternatives was completed during the first phase of the project. This information has been used by Washington State University (WSU) cooperators to develop a computer citation database that is now available to the public. The highlights of the review are being compiled in a six-state resource guide on dryland farming. A regional newsletter called the Sustainable Farming

Quarterly is published by the project and features articles on historical studies, current research, and innovative farmers.

A project publication from Oregon State University (OSU) summarizes the findings of 50 years of consistent research on plots near Pendleton, Oregon. These plots are the oldest continual dryland research plots in the Northwest, and they offer a unique chance to measure long-term changes due to crop and soil management in the region. Numerous other publications and presentations have been developed by project cooperators as part of the educational effort.

Project cooperators have been involved in several surveys. In Wyoming, a survey of dryland farmers found that 60 percent of farmers currently used no fertilizer, and 20 percent used no herbicide, indicating that many farmers in this marginal area are indeed low-input. A group of eastern Washington and northern Idaho farmers using alternative practices and rotations were surveyed through detailed interviews in an attempt to learn what alternatives were actually in use on a commercial scale. This information is summarized in a WSU publication and is being used in an associated project of economic and policy modelling.

Several major conferences have been organized by project cooperators, including a Soil Building Cropping Systems conference in Montana and four dryland Farming for Profit and Stewardship conferences in northern Idaho and eastern Washington.

Project cooperators are involved in many on-going research efforts. Oregon scientists are examining the effects of long-term management on soil microbiology factors, including microbial diversity and soil-borne plant pathogens. Management effects on soil quality factors are being studied by Washington researchers. In Idaho, a combine-mounted yield mapping system is being developed for use in field management of variable landscapes. Montana and Wyoming cooperators are focusing on replacement of summer fallow with low-water use legumes to conserve soil and reduce nitrogen fertilizer needs. Alternative rotations are being tested by Utah researchers, and expanded use of the Miranda protein pea is one significant outcome.

Project activities are expanding into on-farm testing as well. Farmer-initiated research, demonstration, and information exchange have been highly successful in the Midwest. Similar strategies have not been widely used in the dryland regions of Washington, Oregon, and Idaho. The great environmental diversity among locations in the dryland region makes it difficult to transfer information from a single experiment station to a given farm.

On-farm testing is important for several reasons. Much of the historical information compiled to date was generated prior to semi-dwarf wheat varieties and widespread use of N fertilizer. Growers need to test this information in the context of today's practices and soil conditions. It is not possible to initiate rotational studies and generate valid results with short-term funding. But data can be collected from existing rotational systems on farms to determine some of the long-term effects. Many alternative practices are being used by farmers, and documentation of their performance is needed in order to extend the information to others. Growers are concerned about impending increases in regulation and loss of production tools, and view on-farm testing as a way for them to quicken the introduction of alternative practices.

On-farm tests supported by the project include tillage, variety, fertility, and green manure comparisons. Also, soils from a series of paired farms with contrasting management histories are being analyzed to document any measurable differences in soil condition due to farming practices. Farm tours have been held to view alternative practices, and more are planned for the future.

To date, the project has had a significant educational impact in the dryland region. The most promising areas for enhancing sustainability include soil quality improvement, use of rotation effects, variable landscape management, and fallow replacement. At present, few alternatives to herbicides exist for weed control, and moisture management strategies are limited in many areas. Economic data for evaluating alternatives are sorely lacking as well. By continuing the research activities, maintaining a high level of farmer involvement, and emphasizing regional communication, the project cooperators are optimistic about making dryland farming more sustainable in the Northwest.

<u>Selected Project Publications</u>

Long-term Management Effects on Soil Productivity and Crop Yield in Semi-arid Regions of Eastern Oregon. OSU Station Bulletin 675, Corvallis, OR (November 1989).

Farming for Profit and Stewardship Conference Proceedings - Post Falls, ID. Dept. of Crop & Soil Science, WSU, Pullman, WA (June 1990).

Protecting Groundwater from Agricultural Chemicals: Alternative Farming Strategies for Northwest Producers. AERO, Helena, MT (1990).

Prospects for Sustainable Agriculture in the Palouse: Farmer Experiences and Viewpoints. WSU Expt. Sta. Bulletin XB1016 (1990).

Northwest Dryland Cereal/Legume Cropping Systems Database (CROPSYS). MCP011, Cooperative Extension Publications, WSU, Pullman, WA (1991).

Managing small-seeded annual legumes for hay and green manure. Montana State Univ. Research Report, Bozeman, MT (1990).

Sustainability of dryland cropping in the Palouse: An historical view. <u>Journal of Soil and Water Conservation</u> 45:75-80 (1990).

Sustainable Farming Quarterly newsletter. AERO, Helena, MT. Available at County Extension and SCS offices.

WASHINGTON STATE UNIVERSITY EXTENSION PUBLICATIONS RELATING TO CEREAL AND EDIBLE LEGUME PRODUCTION

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Uniform Combine Residue Dist. for Successful No-Till and Minimum Tillage Systems	PNW0297	.50
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3. General Pests and Pesticides:		
Concepts of Integrated Pest Management in Washington	EB0753	.25
Pacific Northwest Pest Control Handbook	MISC0045	14.00
Pest Management Study Manual for Pest Control Operators	MISC0096	10.00
4. Plant Diseases:		
Diseases of Cereal Crops	EB0559	.75
Cephalosporium Stripe Disease of Cereals	EB1434	.50
Ergot of Cereals and Grasses	EB1091	.25
Plant Diseases	EB1239	.75
Pacific Northwest Plant Disease Control Handbook	MISC0048	17.25
5. Insects:		
Identification of Aphids on Small Grains	EB0993	.25
Aphid Control on Small Grains	EB1001	.50
Greenbug	EB1003	.25
Grasshoppers in Washington	EB1392	.50
Grasshopper Control	EB1454	.25
Russian Wheat Aphid	EB1486	.25
Pacific Northwest Insect Control Handbook	MISC0047	17.25

Fertilizer Guide: Winter Wheat for Central Washington	FG0031	.25
Fertilizer Guide: Dryland Wheat Nitrogen Needs for Eastern Washington	FG0034	.25
Fertilizer Band Location for Cereal Root Access	PNW0283	.50
6. Conservation:		
Yields of Four Spring Wheat Varieties in Conv., Min., and No-Tillage Systems	EB1094	.25
Crop Residue Management in No-Tillage Winter Wheat in Precip. Over 18 In./Yr.	EM4576	.25
7. Irrigation:		
Irrigated Winter Wheat Production	EB0916	.25
Irrigated Spring Wheat in Washington	EB1111	.25
Wheat Irrigation	EM3048	.25
8. Miscellaneous:		
Wheat Seed Quality	EB1309	.25
Frost Damage on Wheat	EC0398	.25
Postharvest Dormancy of Wheat	EM3890	.25
Growing Winter Wheat in Western Washington	EM4618	.25

BARLEY

1. Varieties:		
Boyer Winter Barley	EB0678	.25
Blazer Spring Malting Barley	EB0679	.25
Advance Barley	EB0720	.25
Andre Spring Barley	EB1249	.25
Showin Winter Barley	EB1394	.25
Cougbar Spring Barley	EB1476	.25
Vanguard Barley	EC0385	.25
Steptoe Barley	EC0392	.25
2. Soils and Fertilizer:		
Fertilizer Guide: Winter Wheat and Barley for Western Washington	FG0017	.25
Fertilizer Guide: Spring Wheat, Barley and Oats for Western Washington	FG0048	.25
Spring Barley in Eastern Washington--Fertilizer Trial Results	EB1260	.25
Fertilizer Guide: Barley for Eastern Washington	FG0029	.25
3. Conservation:		
Yields of Four Spring Barley Varieties in Conv., Min., and No-Tillage Systems	EB1093	.25

TRITICALE

1. Varieties:		
Flora: A Winter Triticale	OR/EC1244	.50
Triticale	PNW331	.25

OATS

1. Varieties:

Cayuse Oats	EC0358	.25

2. Soils and Fertilizer:

Fertilizer Guide: Spring Wheat, Barley and Oats for Western Washington	FG0048	.25

PEAS, LENTILS AND CHICKPEAS:

1. Varieties:

Garfield and Tracer Alaska Type Peas	EB0699	.25
Brewer Lentils	EB1408	.25

2. Insects:

Pea Leaf Weevil: Its Biology and Control	EB0903	.50
Insects of Peas	PNW0150	.50

3. Soils and Fertilizers:

Fertilizer Guide: Peas and Lentils for Eastern Washington	FG0025	.25

4. Miscellaneous:

Description and Culture of Lentils	EB0957	.50
Description and Culture of Chickpeas	EB1112	.50
Dry Pea and Lentil Production in the Pacific Northwest	ID/B578	.25