Cooperative Extension

Washington State University

Department of Crop and Soil Sciences

Technical Report 95-3

Dedicated to Dr. Clarence J. Peterson

1995 Field Day Proceedings: Highlights of Research Progress

Dryland Research Unit, Lind
June 15, 1995

Palouse Conservation Research Station, Pullman
June 29, 1995

Spillman Farm, Pullman
July 6, 1995

Baird Miller, Editor

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

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DEDICATION TO CLARENCE J. PETERSON, JR.

Dr. Clarence J. "Pete" Peterson, Jr. retired from the Crop and Soil Sciences Department of Washington State University in October 1994, after 29 years with ARS and seven years with WSU as the soft white winter wheat breeder stationed at Pullman.

Pete grew up on a dairy farm in the Boise Valley. He obtained his B.S. in Agronomy (1956) and M.S. in Plant Pathology (1959) from the University of Idaho. Dr. Orville Vogel hired Pete in 1959 as his technician, forming one of the top USA wheat breeding teams. Pete received his Ph.D. from Oregon State University in 1970. In 1973 he was selected by O. A. Vogel to replace him as leader of the breeding program.

C. J. Peterson was a highly successful breeder. He developed 10 varieties, a triticale, and several germplasm lines. In 1994, his varieties accounted for nearly 600,000 acres in Washington alone. Like Orville, Pete used a "hands-on approach" to breeding and was involved in every phase of the operation. Pete's laboratory was the field, and he was a master at exploiting diverse field situations to develop varieties with unique attributes. Included among these were high coldhardiness (Daws, Eltan), durable stripe rust resistance (Lewjain, Luke), tolerance to Cephalosporium stripe (Lewjain), multiple gene resistance to dwarf bunt (Luke and Lewjain), and outstanding soft wheat quality (Lewjain, Kmor).

Pete was a gifted innovator and made numerous inventions and modifications to nursery equipment, computerized breeding procedures, and other ways to improve efficiency. Among these were a versatile three-way conventional, deep furrow, and no-till drill. He and his brother invented a one-operation wheat head thresher and planter, which saves 70% in time and labor. He and his colleagues developed the widely used computerized, user-friendly pedigree system. With others he wrote several highly original research documents. These included pioneering research on adapting wheats to reduced tillage, developing triticales for the Pacific Northwest (PNW), and assessing impact of wheat cultivar improvement in the PNW.

Pete had a close working relationship with farmers. They had complete trust in his judgement because of his unique balance in all phases of crop improvement and production. He enjoyed extension activities and never turned down a chance to interact with growers. Each year he conducted over 20 field plot tours for PNW farmers.

C. J. Peterson was active in ASA and CSSA and contributed to technical sessions and organized and participated in symposia. He served on ARCPACS Board of Directors and helped develop the original certification exam.

He received numerous awards including the O. A. Vogel Washington State Crop Improvement Award, Honorary Life Member of Washington State Crop Improvement Association, and a special recognition plaque from the Washington Association of Wheat Growers.

Pete and Pat, his wife of 39 years, have retired on Lake Coeur d' Alene, Idaho. When they are not visiting their children and grandchildren, their friends are welcome to visit them.

COOPERATIVE PERSONNEL AND AREA OF ACTIVITY

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J. R. Carlson . . . . Director of Research, College of Agriculture & Home Economics
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Cereal Breeding, Genetics and Physiology

R. E. Allan, J. A. Pritchett, L. M. Little, USDA . . . . Wheat Genetics
E. Donaldson, B. Sauer, Dry Land Res. Unit, Lind . . . . HRW, HWW Wheat Breeding
K. K. Kidwell, M. A. Davis, Gary Shelton . . . . Spring Wheat Breeding & Genetics
S. E. Ullrich, C. E. Muir, J. A. Clancy, J. S. Cochran . . . . Barley Breeding & Genetics
A. Kleinhofs, C. M. Stiff, D. Kudrna . . . . Barley Genetics
S. S. Jones, D. F. Moser, V. L.DeMacon, L. Weller, S. Lyon . . . . SWW, HWW Wheat Breeding
R. L. Warner, A. Kleinhofs . . . . Barley Evaluation Laboratory
B. C. Miller, P. E. Reisenauer . . . . Cereal Cropping Systems
M. K. Walker-Simmons, E. Cudaback, S. Verhey, L. Holappa, E. Storlie, USDA . . . . Cereal Physiology
P. Chevalier . . . . Cereal Physiology
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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, and C. J. Simon, USDA

Weed Management

A. G. Ogg, F. L. Young, USDA, and E. P. Fuerst

Fertility Management and Conservation Systems
D. McCool, , R. I. Papendick, K. Saxton, J. Smith, USDA,
S. L. Oberle, W. L. Pan

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
Richard Johnson

Spillman Farm Manager
R. G. Hoffman

Dry Land Research Unit Farm Manager
Bruce Sauer

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George Young	Starbuck
Bob/Don Zimmerman	Almira

HISTORY OF THE DRY LAND RESEARCH UNIT

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

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

The first superintendent was the late Dr. M. A. McCall. McCall was a gifted researcher given somewhat to philosophy in his early reports. In a 1920 report he outlined the fundamental reasons for an outlying experiment station. He stated: "A branch station, from the standpoint of efficiency of administration and use of equipment, is justified only by existence of a central station". For 70 years this station has followed this policy of studying the problems associated with the 8 to 12 inch rainfall area.

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

The present facilities include a small elevator which was constructed in 1937 for grain storage. A modern office and attached greenhouse were built in 1949 after the old office quarters were burned. In 1960 a 40' x 80' metal shop was constructed with WSU general building funds. In 1964 an addition to the greenhouse was built with a Washington Wheat Commission grant of $12,000 to facilitate breeding for stripe rust resistance. In 1966 a new deep well was drilled, testing over 430 gallons per minute. A pump and irrigation system were installed in 1967. The addition of a 12' by 60' trailer house, and improvements in 1966 and 1967 amounted to over $35,000, with more than $11,000 of this from Wheat Commission funds and the remainder from state funds. In 1983 a new seed processing and storage building was completed, at a cost of $146,000. The Washington Wheat Commission contributed $80,000 toward the building, with the remaining $66,000 coming from the Washington State Department of Agriculture Hay and Grain Fund. A machine storage building was completed in 1985, at a cost of $65,000, funded by the Washington Wheat Commission. The old machine storage, built shortly after the station was established, was removed in 1985.

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

Since 1916 an annual field day has been held to show farmers and interested businessmen the research on the station. This year marks the 79th field day. Visitors are welcome at any time, and their suggestions are appreciated.

HISTORY OF SPILLMAN FARM

In the fall of 1955, 222 acres of land were acquired from Mr. and Mrs. Bill Mennet at the arbitrated price of $420 per acre. The money for the original purchase came as the result of a fund drive which raised $85,000 from industry and wheat growers. In addition, $35,000 came from the Washington State University building fund, $11,000 from the State Department of Agriculture, and another $10,000 from the 1955-57 operating budget. The dedication of the new facility took place at the Cereal Field Day July 10, 1957. In 1961 the Agronomy Farm was named Spillman Farm after the distinguished geneticist and plant breeder at Washington State University in the late 1880s.

Through the dedicated efforts of many local people and the initiative of Dr. Orville Vogel, arrangements were made to acquire an additional 160 acres north of the headquarters building in the fall of 1961. This purchase was financed jointly by the Wheat Commission and Washington State University. The newly acquired 160 acres were fenced and the wetland drained; it became an integral part of the Agronomy Farm, now consisting of 382 acres.

The headquarters building, which is 140 feet long and 40 feet wide, was completed in 1956. A 100 by 40 feet addition was built in 1981. In 1957 a well that produced 340 gallons per minute was developed. In 1968 the Washington Wheat Commission provided funds for a sheaf storage facility that was necessitated by the increased research program on the farm. At the same time the Washington Dry Pea and Lentil Commission provided $25,000 to build a similar facility for the pea and lentil materials. The facilities of the Spillman Agronomy Farm now range in value well over a half million dollars.

The Spillman Agronomy Farm was developed with proper land use in mind. A conservation farm plan which includes roads, terraces, steep slope plantings, roadside seedings, and a conservation crop rotation including alfalfa and grass has been in use since the farm was purchased.

Dick Hoffman was appointed farm manager in 1994.

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

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

	MONTHLY AVERAGE TEMPERATURE				PRECIPITATION (IN)			
	1994		30 YEAR AVE		30 YR	MONTHLY	ACCUM	DEVI-
MONTH	MAX	MIN	MAX	MIN	AVE.	1994	1994	ATION
JANUARY	45	31	35	22	1.11	1.29	1.29	0.18
FEBRUARY	40	26	44	28	0.83	0.33	1.62	-0.50
MARCH	58	31	53	30	0.71	0.20	1.82	-0.51
APRIL	66	39	62	34	0.68	1.02	2.84	0.34
MAY	73	44	72	41	0.81	1.52	4.36	0.71
JUNE	80	46	81	47	0.65	0.29	4.65	-0.36
JULY	92	55	90	53	0.27	0.20	4.85	-0.07
AUGUST	88	53	88	52	0.42	0.00	4.85	-0.42
SEPTEMBER	82	48	79	45	0.49	0.22	5.07	-0.27
OCTOBER	61	35	65	37	0.75	1.47	6.54	0.72
NOVEMBER	43	21	46	30	1.18	1.55	8.09	0.37
DECEMBER	39	27	38	25	1.31	1.30	9.39	-0.01
		1995				1995		
JANUARY	40	26	35	22	1.11	1.87	1.87	0.76
FEBRUARY	50	32	44	28	0.83	1.06	2.93	0.23
MARCH	54	32	53	30	0.71	2.21	5.14	1.50

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

Table 2. **Temperature and precipitation at Palouse Conservation Field Station, Pullman, 1994**

Month	Monthly Avg. Temperature(F) Max.	Min.	Precipitation (in) 30-Yr Avg.*	Monthly	Total Accum.	Deviation from Avg. Monthly	Accum.
1994							
January	43.2	33.0	2.89	1.87	1.87	-1.02	-1.02
February	37.5	24.4	2.09	.47	2.34	-1.62	-2.64
March	54.0	32.0	1.96	.62	2.96	-1.34	-3.98
April	59.2	40.2	1.58	1.50	4.46	- .08	-4.06
May	67.1	44.7	1.52	1.77	6.23	+ .25	-3.81
June	72.7	45.2	1.49	.90	7.13	- .59	-4.40
July	87.2	52.4	.53	.10	7.23	- .43	-4.83
August	85.2	51.0	.95	.10	7.33	- .85	-5.68
September	80.2	45.5	.99	.35	7.68	- .64	-6.32
October	60.0	35.9	1.61	3.21	10.89	+1.60	-4.72
November	37.2	28.3	2.64	5.33	16.22	+2.69	-2.03
December	25.9	29.0	3.07	2.38	18.60	- .69	-2.72
TOTAL	59.1	38.5	21.32		18.60		-2.72
1995							
January	37.9	27.8	2.89	2.57	2.57	- .32	- .32
February	45.8	30.4	2.09	1.49	4.06	- .60	- .92
March	47.7	31.9	1.96	2.04	6.10	+ .08	- .84
TOTAL			6.94		6.10		-.84
1994 CROP YEAR Sept. 1993 thru June 30, 1994			19.84		10.90		-8.94

*Thirty year average for precipitation, 1951-1980

WINTER WHEAT BREEDING AND GENETICS

S. Jones, E. Donaldson, T. Murray, D. Moser, M. Cadle, L. Weller
V. DeMacon, S. Lyon, A. Yildirim, X. Cai, E. Krohn and H. Remengesau
(and C.J. Peterson, retired)

New Variety:

Hiller - Winter club wheat Hiller was approved for release in 1995. Hiller was developed by C. J. Peterson, Jr. at Washington State University. Hiller has good resistance to stripe rust, partial resistance to leaf rust and powdery mildew. The variety is a semidwarf and is adapted to club wheat production areas of the PNW. In 27 site tests (1989 -1995) Hiller outyielded Hyak, Rhode and Tres. The end-use quality of Hiller is excellent compared to current club wheats and is considered similar to high quality wheats Elgin and Omar.

New Directions:

The winter wheat breeding program will be going through many changes (or additions) over the next few years. A greater emphasis is being placed on end-use quality and on reducing the time required to produce a variety. We are also putting a large effort into incorporating footrot resistance into all of our lines. True resistance to Cephalosporium stripe is also getting closer. We have combined vigorous laboratory and greenhouse programs with Dr. Peterson's existing field program. We now make crosses essentially every day of the year and can select for end-use quality on 1/4 of a teaspoon of flour. We are maintaining or increasing efforts into regional problems such as snow mold, dryland footrot, deep emergence and stand establishment.

All winter wheat breeding is now housed at Pullman for early generation production. The early generations in a breeding program are used primarily as increase generations with a minimum of selection. After three generations hard wheats will be grown at Lind and other low rainfall locations for the final selection processes. The main selection sites for the soft wheats will continue to be Pullman and the other off-station locations. Hard white wheats with very promising quality have been identified and in 1995 will be in their second year of field testing.

Dr. Peterson's wheat breeding program was a very successful one. He left a strong foundation from which we plan to produce the types of varieties that will not only be profitable in the short term but that will also help to strengthen the demand for our wheats in the world markets.

USDA-ARS WHEAT GENETICS AND BREEDING

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

New Variety Candidates. We have six ARS SWW selections in the 1995 Western Regional Tests. The bearded club line WA7752 has been approved for preliminary increase. WA7752 has strawbreaker foot rot resistance similar to Madsen. The main advantage of WA7752 is that it has club wheat flour and baking quality superior to Hyak and Rohde. It has excellent flour yield and milling score, even better than Paha. WA7752 has high yield potential generally outyielding other clubs by 4 to 10% in state and regional tests. It has better tolerance to Cephalosporium stripe than existing club varieties. Although WA7752 has the same gene for strawbreaker foot rot resistance that occurs in Hyak it may sustain more loss than Hyak when the disease is severe. If future tests verify that the quality of WA7752 is satisfactory it will be released in 1997. We have three other clubs in regional tests. WA7770 has combined resistances to strawbreaker foot rot, powdery mildew, and the three rusts. WA7795 is a new club multiline that has partial foot rot resistance with better rust resistance and higher yield potential than Rely. WA7793 has multiple gene resistance to leaf rust, stripe rust, and powdery mildew; it outyielded Rely and Rohde by 15 to 20% in 1994 ARS Tests.

Two SWW common selections (WA7794 and WA7796) have higher strawbreaker foot rot resistance than Madsen and quality equal to or better than Madsen. The SWW sel WA7690 was not approved for release. Even though it was superior to Madsen for emergence ability and resistance to strawbreaker foot rot, Cephalosporium stripe, and Septoria leaf blotch, it had only average quality and less coldhardiness than Madsen. It will be registered as a parental line.

Combining Resistances to Rusts and Other Diseases. A major goal of our ARS wheat breeding and genetics program is to exploit wheat's resistance and tolerance to the main diseases that limit wheat production in the Pacific Northwest. Good progress has been made in obtaining resistance or tolerance to individual diseases. Combining these resistances together into adapted wheat varieties is a top priority. Most of our currently grown soft white winter (SWW) wheat varieties lack resistance to one or more of the important diseases common to our region. Madsen, developed by this project, has the best overall disease resistance of our SWW varieties. Madsen has combined resistances to leaf rust, stripe rust, stem rust, powdery mildew, Septoria leaf blotch, common bunt and strawbreaker foot rot, yet it is susceptible to other important diseases such as Cephalosporium stripe.

Last year we evaluated 110 advanced and 130 F_5 lines in the field for their resistance or tolerance to Cephalosporium stripe. Level of Cephalosporium stripe was moderate. Based on disease symptoms, 15 advanced and 17 F_5 lines expressed resistance comparable to WA7437, our resistant check. WA7437 is a wheat line that has one chromosome from tall wheat grass that gives it high Cephalosporium resistance.

Many of our advanced lines have multiple rust resistance that is conditioned by three closely linked genes on chromosome 2AS. The genes are *Yr*17 (stripe rust), *Lr*37 (leaf rust), and *Sr*38 (stem rust). So far, these genes have remained resistant to the existing rust biotypes of our region.

This highly effective complex of rust resistance genes was apparently derived from *Aegilops ventricosa*, which is a weedy relative of wheat.

Using two stripe rust races, seedling reactions were determined on 110 advanced SWW club and common lines and 130 F_5 lines. About 50% of the advanced lines and 80% of the F_5 lines expressed resistance to both races. The combined virulences of the two races attack 8 genes for resistance including those of Hyak, Tres and Paha. Among this germplasm, 40% of the advanced lines and 25% of the F_5 lines had combined resistances to both stripe rust races and to strawbreaker foot rot.

A few club lines deriving unique stripe rust resistance from wild Emmer performed well in 1994. Several lines had yields equal to Rely and Tres, and four had club wheat flour quality equal to Rely. Genetic studies have shown that, in addition to the unique gene from wild Emmer, some of our lines have up to three other genes for stripe rust resistance. A few lines also have resistance to Septoria leaf blotch.

Breeding Tall Club Wheats for the Low Rainfall Areas. The main goal of this project is to develop varieties that are superior to Moro for quality, yield potential, and disease resistance yet with the excellent emergence characteristics of Moro. Our research has conclusively proved that the main semidwarfing genes of *Rht1* and *Rht2* adversely affect emergence. Extensive testing has shown that when these genes are present it is impossible to attain emergence potential equal to Moro. Hence we began looking at other sources of semidwarfism. Our tests have shown that the Balkan semidwarf gene *Rht8* has promise as a source of semidwarfism that does not adversely affect emergence. About 30% of our lines with the *Rht8* gene had emergence rates and final stands comparable to Moro. One of our club lines was 12% shorter than Moro, had excellent emergence, and equaled it for yield potential. Two tall non-semidwarf lines (ARS94481, ARS94484) were also equal to Moro for emergence. ARS94481 has club wheat quality equal to Tres. ARS94484 is a line genetically similar to Nugaines but its *Rht2* semidwarf gene has been replaced with a non-semidwarf gene. We also have several non-semidwarf club F_5 lines that are in our preliminary yield tests for the first time. these lines have strawbreaker foot rot resistance and a few of them carry genes for resistance to all three wheat rusts. Nearly 25% of our 1995 head rows are either non-semidwarf or contain the *Rht8* gene instead of the *Rht1* or *Rht2* genes.

Plans call for expanding emergence tests to low-rainfall areas. This will be a cooperative effort involving W. Schillinger, and E. Donaldson. It will give us an opportunity to determine the emergence potential of the Balkan semidwarfs under adverse stand establishment conditions. The ARS wheat genetics and breeding programs are committed toward developing winter wheats for adaptation to the dryland regions.

Winter Versus Spring Growth Habit. Emphasis on studying the influence of winter versus spring growth habit has increased. One goal of this research is to convert several winter wheats to spring wheats. This year we have 5600 head rows planted in a program to change Tres, Nugaines, Stephens, Daws, Wanser, and several other wheats to spring types. These are BC3 to BC6 lines in which were have backcrossed four different spring growth habit genes (*Vrn1, Vrn2, Vrn3* and *Vrn4*) into these winter wheats. In addition, we have finished converting Marfed spring wheat into a winter wheat by substituting the winter wheat allele of *Vrn1* for its spring allele. We have used these winter versus spring near isolines (NILs) in five fall sown trials. One 1993 test experienced significant cold injury. In that test the spring NILs had 43% survival while the winter NILs had 80% survival. These results confirmed reports from Europe and Canada that the *Vrn1* locus is linked to a gene for coldhardiness. In the four fall-sown tests that without cold injury, we found no differences between the winter and spring NILs for grain yield, heading date, seedling vigor and several other important agronomic traits. The *Vrn1* and *vrn1* NILs were also similar for most quality parameters except for flour absorption and kernel hardness.

A practical application of converting winter wheats to spring growth habits is for facilitating reseeding winter-damaged fall planting. Spring versions of winter wheats will speed up improving winter wheats by backcross breeding. Because spring wheats do not require vernalization, they could be used as recurrent parents for several cycles of backcrossing prior to recovering winter growth habit in the final cross.

These genetic stocks will help answer other important questions. The winter/spring NILs can be used in seeding date tests to precisely determine the vernalization requirement of winter wheats. Such tests would help determine the cut-off date for seeding winter wheats in late winter or early spring. The NILs will be especially useful in determining whether quality differences between spring and winter wheats are due to their inherent genetic differences or caused by environmental differences. The answer to this question would help in defining true end-use quality differences among our wheat market classes. Much of this research on winter and spring growth habit of wheat is a cooperative effort between our ARS program and the WSU spring and winter wheat breeding programs.

Impact of Varieties Developed by ARS in Cooperation with WSU. Wheat varieties developed by ARS Wheat Genetics, Quality, Physiology and Disease Research unit had major impact on Washington's 1994 crop. Madsen was grown on 781,000 acres and made up 41% of the common SWW acreage. Rely became the second leading club variety after Moro. Rely was grown on 89,800 acres. Our ARS club wheats accounted for 65% of the total club wheat grown in Washington.

1994 STATE/EXTENSION WINTER WHEAT

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

The 1993/94 wheat variety evaluation trials were established at 12 winter locations in 8 eastern Washington counties. A total of 29 winter wheats were evaluated. Varieties in the testing program included all significant released public varieties, those being considered for release and private varieties entered on a 'fee for entry' basis. All varieties evaluated in this testing program were also evaluated in the WSU breeders testing programs.

Early fall planting conditions were good, with sufficient moisture for stand establishment at the time of planting. The later plantings were seeded shallow and timely rains allowed sufficient growth period to produce vigorous stand establishment. The winter was characterized by an early cold spell in November followed by mild temperatures and light snowfall. There was some leaf burn due to the cold winds but no winterkill. The St. John nursery showed a slight Cephalosporium stripe infections, but yield differences were not nearly as distinct as 1993.

Statewide average winter wheat yields in the trials ranged from 19 to 171 bu/acre, with test weights ranging from 50 to 64 lbs/bu. The top yielding winter wheat varieties included Rod, Madsen, Rohde and Cashup.

1994 WSU WINTER WHEAT VARIETY TRIALS
YIELD (BU/A)

VARIETY NAME	DUSTY	COULEE CITY	HARRINGTON	POMEROY	FAIRFIELD	ASOTIN	RITZVILLE	PULLMAN LATE	BICKLETON	CRESTON	CUNNINGHAM	MAYVIEW	LAMONT	ST.JOHN	FARMINGTON	REARDAN	DAYTON	LIND IRR.	MOSES LAKE	AVERAGE**
SOFT WHITE CLUB																				
HYAK	22.7	45.9	.	50.8	56.4	62.8	69.4	66.3	65.8	70.1	100.8	72.8	76.5	86.0	79.3	92.5	84.4	104.9	143.0	76.7
RELY	20.7	46.4	.	50.7	62.2	67.2	75.3	67.3	64.2	82.5	72.1	73.4	67.9	89.3	88.7	100.7	96.7	118.5	150.4	79.3
ROHDE	32.5	44.3	52.6	59.7	60.5	73.1	74.7	66.4	67.1	80.2	71.0	81.5	82.4	95.4	91.4	94.1	94.3	117.7	171.4	83.1
TRES	24.0	.	.	58.4	53.5	64.6	72.8	64.5	63.2	77.1	63.4	63.5	84.0	88.2	91.4	98.0	90.2	123.4	145.0	78.0
WA7622	19.0	41.4	69.1	48.8	54.9	63.7	68.9	64.0	65.4	75.3	108.3	69.2	86.1	83.9	85.7	94.7	85.1	105.6	135.3	77.3
WA7697	30.1	.	42.4	58.2	61.4	68.8	66.5	60.1	70.9	78.3	77.3	78.5	85.1	88.6	89.3	91.6	109.7	115.7	153.4	81.4
SOFT WHITE COMMON																				
BASIN	25.6	.	44.2	53.9	61.4	68.3	66.1	66.8	60.5	73.5	55.3	69.6	72.0	78.8	80.6	90.6	110.4	75.4	154.9	74.3
CASHUP	23.5	.	65.3	49.2	63.0	64.8	69.4	70.8	68.2	80.5	65.7	85.2	74.8	96.4	88.6	90.6	104.2	98.1	166.4	80.0
DAWS	21.9	44.8	44.9	52.0	87.7	57.9	62.8	58.4	60.3	70.0	54.9	71.5	70.1	79.2	82.1	89.2	98.2	122.3	139.2	75.2
DURHEIMS PRIDE	24.2	.	49.7	46.6	54.1	57.5	69.0	67.9	60.3	69.4	56.3	63.6	56.4	73.6	72.4	81.5	93.8	116.7	135.8	70.5
ELTAN	27.2	48.8	53.1	49.7	62.2	71.8	67.7	69.6	65.4	75.2	56.9	83.5	79.3	86.1	88.0	103.1	85.6	98.7	135.8	76.8
GENE	23.6	37.5	.	61.4	46.0	67.9	59.7	65.8	80.1	69.1	87.5	68.7	54.0	67.5	68.9	76.1	107.9	86.7	144.6	72.7
HILL 81	31.3	.	.	55.3	60.6	63.5	68.3	70.4	64.3	75.3	62.3	76.6	80.6	89.5	92.0	91.7	103.4	93.8	148.7	78.1
KMOR	23.7	41.6	52.4	59.9	58.1	67.4	62.1	62.3	67.0	67.2	56.4	83.7	65.8	83.1	82.1	92.0	87.8	101.1	118.5	72.8
LAMBERT	31.1	42.0	37.6	56.9	56.1	70.4	67.8	66.3	67.6	77.6	76.9	72.9	74.8	85.5	87.6	91.9	106.3	91.1	155.1	78.6
LEWJAIN	24.2	41.6	55.3	50.4	59.1	61.6	63.2	56.4	63.8	66.8	61.7	84.3	82.5	76.1	79.7	93.1	90.7	98.6	137.8	73.5
MACVICAR	25.8	39.6	43.0	67.5	63.1	71.7	65.9	60.7	73.7	68.5	82.1	70.5	73.9	78.5	88.9	98.0	105.5	98.8	152.6	79.2
MADSEN	24.4	40.7	66.2	49.3	61.4	63.1	67.5	72.1	67.8	75.4	120.5	77.3	80.6	86.9	87.9	91.2	99.9	109.9	163.3	82.3
MALCOLM	25.7	.	.	55.0	62.0	64.4	66.7	60.8	66.0	66.7	75.1	62.6	71.6	77.5	84.5	89.3	107.4	93.9	147.6	75.1
NUGAINES	22.7	42.5	54.6	56.3	58.3	57.3	61.3	65.3	55.9	64.7	42.0	64.6	77.5	86.6	84.1	81.9	84.5	101.2	131.9	70.4
ROD	32.0	46.2	55.7	58.5	62.2	72.4	74.1	77.1	65.1	80.8	68.9	87.3	84.7	91.4	95.3	100.1	106.9	121.8	156.4	84.4
STEPHENS	27.3	36.7	.	60.0	53.7	69.6	56.4	65.7	70.4	70.1	79.0	75.1	71.4	68.6	85.0	83.1	113.8	104.2	152.5	76.8
W-301	28.3	41.2	55.1	61.3	49.3	64.1	65.1	65.0	72.4	68.3	79.2	70.3	68.7	63.3	85.7	80.8	108.3	102.2	158.0	75.9
WA7663	28.7	43.8	55.0	62.2	57.7	68.7	74.9	73.4	73.6	82.3	81.6	88.5	74.1	92.6	96.4	99.1	107.8	150.5	162.1	86.7
WA7686	27.3	45.9	.	56.0	59.7	63.6	66.2	72.7	63.1	80.4	105.5	84.6	82.9	102.9	92.1	97.1	106.3	101.2	165.1	83.9
WPB 583	21.2	.	42.8	54.1	52.2	57.6	35.4	58.4	70.7	60.6	.	58.7	54.2	64.0	73.6	62.0	88.2	85.9	147.1	.
WPB BANNER	30.0	.	61.9	59.2	53.2	74.0	63.3	70.5	75.8	68.3	.	75.8	67.9	67.4	85.5	82.5	111.4	102.8	166.4	.
HARD RED AND WHITE																				
HATTON	26.1	.	.	.	55.7	51.2	.	.	50.2	59.8	.	50.4	61.5	62.2	66.5	71.9	81.3	.	118.9	.
WA7679	28.8	45.1	.	48.1	57.5	66.0	63.3	64.6	60.4	70.4	43.3	65.0	69.0	69.4	89.8	79.1	75.2	.	139.6	.
NURSERY AVERAGE	26.0	42.9	52.7	55.3	58.7	65.3	65.9	66.1	66.2	72.6	73.2	73.4	73.5	81.3	84.9	89.2	98.1	106.9	148.2	
CV %	18.6	11.3	17.1	17.3	20.6	7.2	8.5	15.2	12.9	8.2	14.9	7.2	20.5	14.4	9.1	7.9	11.3	11.2	9.1	
LSD @ .10	5.7	5.1	14.1	10.0	14.4	5.5	5.8	10.5	10.0	7.0	11.4	6.2	17.7	13.7	9.1	8.3	13.0	13.4	15.8	

** AVERAGE NOT INCLUDING COULEE CITY AND HARRINGTON

1994 WSU WINTER WHEAT VARIETY TRIALS
TEST WEIGHT (LBS/BU)

VARIETY NAME	DUSTY	COULEE CITY	HARRINGTON	POMEROY	FAIRFIELD	ASOTIN	RITZVILLE	PULLMAN LATE	BICKLETON	CRESTON	CUNNINGHAM	MAYVIEW	LAMONT	ST.JOHN	FARMINGTON	REARDAN	DAYTON	LIND IRR.	MOSES LAKE	AVERAGE**
SOFT WHITE CLUB																				
HYAK	51.7	59.1	.	54.7	55.0	57.6	58.8	56.0	58.5	56.7	59.9	57.4	58.6	58.9	56.8	58.7	57.3	60.2	57.8	57.3
RELY	49.8	59.9	.	54.6	56.1	59.0	59.1	57.7	58.1	57.8	54.4	57.6	58.5	59.1	58.5	60.1	57.5	61.1	59.9	57.6
ROHDE	56.7	61.0	62.4	58.7	59.3	60.9	61.6	57.7	60.0	59.8	57.6	60.2	61.8	59.5	61.0	60.2	58.7	62.0	60.6	59.8
TRES	51.7	.	.	57.6	57.1	59.6	58.6	58.4	59.0	59.3	55.3	58.1	59.5	58.6	60.2	61.2	57.5	61.4	60.6	58.5
WA7622	50.8	58.2	59.3	55.6	56.5	58.8	58.2	56.5	57.5	57.7	59.6	56.8	58.5	58.2	58.3	59.1	56.6	59.7	57.9	57.4
WA7697	55.0	.	61.4	57.2	58.6	60.3	58.7	57.5	60.8	60.3	57.7	59.2	61.7	59.9	59.2	60.7	59.6	61.4	60.5	59.3
SOFT WHITE COMMON																				
BASIN	54.3	.	59.5	58.2	58.6	59.5	59.5	57.4	60.2	60.1	54.7	59.6	60.0	58.9	58.9	60.4	59.3	60.4	60.3	58.8
CASHUP	51.8	.	60.8	56.6	58.0	59.7	59.5	56.8	60.3	57.7	54.6	59.2	60.0	60.3	59.3	60.1	59.6	60.1	60.7	58.5
DAWS	52.2	59.7	60.3	57.2	58.4	57.9	58.3	57.0	60.4	58.9	54.3	59.2	59.1	58.9	58.5	59.5	57.4	60.8	58.6	58.0
DURHEIMS PRIDE	51.8	.	59.9	56.7	56.8	57.8	59.5	58.3	60.6	58.4	54.3	59.3	56.0	59.3	57.5	59.6	58.2	61.2	59.4	57.9
ELTAN	52.8	59.8	60.5	57.2	57.7	59.7	59.6	56.4	57.7	57.9	52.9	58.8	58.7	59.0	59.1	58.7	57.7	59.1	58.9	57.8
GENE	53.0	58.1	.	56.1	54.0	56.0	58.6	55.5	58.9	57.1	59.3	55.9	58.1	57.4	55.2	57.7	57.0	57.1	57.6	56.7
HILL 81	53.4	.	.	57.5	57.1	59.4	60.5	56.9	59.5	59.5	56.7	59.6	59.7	59.9	59.4	60.5	60.0	60.9	61.2	58.9
KMOR	51.5	59.1	60.7	55.6	55.6	58.3	58.0	55.1	58.7	56.9	53.5	58.7	56.2	57.3	56.7	58.5	56.8	58.9	58.0	56.7
LAMBERT	51.9	59.2	56.0	56.2	56.8	58.9	59.9	56.0	59.8	58.7	57.8	57.4	59.3	58.5	59.6	59.7	59.5	54.1	59.5	57.9
LEWJAIN	53.4	59.9	59.9	58.4	57.0	60.6	59.8	56.7	60.6	58.5	56.5	60.0	60.0	59.0	58.4	60.3	58.4	61.3	60.1	58.8
MACVICAR	52.5	59.0	55.0	56.5	57.1	57.5	59.1	55.0	60.5	58.3	56.4	58.3	58.6	57.4	57.9	59.3	57.0	33.9	57.6	56.1
MADSEN	51.9	59.3	59.1	57.1	57.1	58.6	60.5	56.8	60.2	59.1	60.5	58.8	59.7	59.3	58.9	59.2	58.2	59.2	60.9	58.6
MALCOLM	51.5	.	.	57.9	56.9	57.4	59.3	54.9	59.8	57.5	56.0	57.7	57.9	57.4	58.2	59.4	58.1	58.6	57.1	57.4
NUGAINES	54.9	60.7	62.5	61.0	58.9	60.3	61.8	59.4	62.4	61.3	57.0	60.6	62.4	59.7	60.2	61.9	60.2	62.5	60.4	60.3
ROD	52.0	58.0	60.3	55.9	55.3	57.9	56.4	55.7	58.9	56.7	54.0	57.5	57.3	57.8	57.7	58.1	57.3	59.3	58.8	56.9
STEPHENS	52.8	58.1	.	55.5	54.9	57.3	58.1	54.7	60.0	58.2	57.6	57.3	57.9	58.5	57.3	57.8	59.4	58.7	58.8	57.3
W-301	52.8	58.8	56.8	55.7	54.9	56.6	58.2	54.8	60.0	58.0	56.3	56.8	58.6	58.0	57.7	59.4	58.4	58.3	58.5	57.2
WA7663	50.8	56.2	58.6	55.0	54.4	56.1	56.9	55.4	57.9	55.9	54.9	56.9	55.6	56.5	57.0	56.0	55.6	58.6	57.5	55.9
WA7686	51.6	58.7	.	54.5	56.6	57.4	57.9	55.4	58.4	58.8	58.7	58.2	58.4	59.2	57.6	59.0	57.4	58.4	60.0	57.5
WPB 583	51.9	.	58.0	56.2	55.3	57.3	58.9	56.0	60.5	57.8	.	56.6	58.1	58.2	56.1	58.2	55.0	58.5	58.8	.
WPB BANNER	53.2	.	57.3	54.7	54.2	57.4	58.3	55.8	59.5	58.1	.	56.6	58.5	57.2	57.5	58.5	58.5	58.7	58.9	.
HARD RED AND WHITE																				
HATTON	56.1	.	.	.	61.3	62.7	.	.	62.5	62.0	.	61.6	63.0	61.4	61.6	62.4	63.2	.	63.8	.
WA7679	53.5	60.8	.	55.8	58.7	61.3	60.6	56.8	61.4	61.1	56.8	59.4	60.8	59.7	60.8	59.3	60.3	.	62.5	.
NURSERY AVERAGE	52.7	59.1	59.4	56.6	56.8	58.7	59.1	56.5	59.8	58.6	56.4	58.4	59.0	58.7	58.5	59.4	58.3	58.3	59.5	.
CV %	3.7	1.2		2.8	1.9	1.6	2.6	2.0	1.2	1.4	30.0	1.1	2.4	1.7	1.6	1.0	2.2		1.6	
LSD @ .10	2.3	0.7		1.6	1.3	1.1	1.7	1.2	0.9	1.0	1.8	0.7	1.6	1.2	1.1	0.7	1.5		1.1	

** AVERAGE NOT INCLUDING COULEE CITY AND HARRINGTON

1994 WSU WINTER WHEAT VARIETY TRIALS
PROTEIN (%)

VARIETY NAME	DUSTY	COULEE CITY	HARRINGTON	POMEROY	FAIRFIELD	ASOTIN	RITZVILLE	PULLMAN LATE	BICKLETON	CRESTON	CUNNINGHAM	MAYVIEW	LAMONT	ST.JOHN	FARMINGTON	REARDAN	DAYTON	LIND IRR.	MOSES LAKE	AVERAGE
SOFT WHITE CLUB																				
HYAK	15.3	.	11.0	.	.	12.0	.	.	7.4	9.7	.	13.0	10.7	12.0	13.0	.	11.9	13.8	.	11.9
RELY	15.3	.	11.6	.	.	12.0	.	.	7.6	9.8	.	13.2	10.7	12.0	13.2	.	12.4	13.3	.	12.0
ROHDE	14.3	.	10.3	.	.	12.1	.	.	7.9	9.1	.	12.8	11.2	12.1	12.8	.	12.3	13.3	.	11.8
TRES	15.3	.	11.4	.	.	11.8	.	.	7.4	10.2	.	12.9	10.7	12.4	12.9	.	12.7	13.2	.	12.0
WA7622	15.0	.	9.8	.	.	12.3	.	.	7.3	9.9	.	12.7	10.3	11.7	12.7	.	12.1	14.1	.	11.8
WA7697	15.5	.	12.4	.	.	12.4	.	.	7.4	10.2	.	13.1	11.3	12.1	13.1	.	12.4	13.8	.	12.1
SOFT WHITE COMMON																				
BASIN	13.9	.	12.5	.	.	11.9	.	.	7.7	10.6	.	12.7	11.5	12.0	12.7	.	11.4	12.6	.	11.7
CASHUP	14.9	.	11.9	.	.	12.7	.	.	7.6	10.5	.	12.7	11.5	12.4	12.7	.	12.6	13.0	.	12.1
DAWS	14.4	.	11.7	.	.	12.4	.	.	7.9	9.9	.	12.7	10.6	12.0	12.7	.	12.2	13.1	.	11.8
DURHEIMS PRIDE	14.4	.	12.1	.	.	12.8	.	.	8.4	11.0	.	13.5	11.8	12.2	13.5	.	12.1	12.9	.	12.3
ELTAN	14.7	.	11.1	.	.	12.1	.	.	6.9	10.2	.	12.8	11.7	12.7	12.8	.	12.8	14.2	.	12.1
GENE	14.6	.	13.3	.	.	12.3	.	.	8.1	10.3	.	13.5	12.4	12.3	13.5	.	12.3	15.1	.	12.4
HILL 81	14.8	.	11.3	.	.	12.9	.	.	7.8	10.7	.	12.7	12.2	12.6	12.7	.	12.6	14.3	.	12.3
KMOR	14.4	.	10.6	.	.	12.4	.	.	7.4	9.9	.	13.4	11.7	12.7	13.4	.	12.3	13.3	.	12.1
LAMBERT	14.1	.	13.2	.	.	12.0	.	.	7.8	9.9	.	12.9	11.0	11.9	12.9	.	12.3	13.2	.	11.8
LEWJAIN	15.0	.	12.5	.	.	12.5	.	.	7.4	10.2	.	13.7	10.9	12.9	13.7	.	13.0	13.1	.	12.2
MACVICAR	14.2	.	14.1	.	.	12.3	.	.	8.1	9.8	.	13.0	11.4	12.0	13.0	.	12.1	14.0	.	12.0
MADSEN	15.5	.	12.4	.	.	12.9	.	.	8.5	10.6	.	12.8	10.8	12.5	12.8	.	13.1	14.4	.	12.4
MALCOLM	14.0	.	12.8	.	.	12.6	.	.	8.1	10.5	.	13.1	11.8	12.2	13.1	.	11.8	13.7	.	12.1
NUGAINES	14.1	.	11.3	.	.	13.1	.	.	8.2	10.0	.	13.1	10.0	12.1	13.1	.	12.0	12.5	.	11.8
ROD	13.6	.	11.1	.	.	12.1	.	.	7.2	9.2	.	12.3	11.3	11.9	12.3	.	12.0	13.6	.	11.6
STEPHENS	14.8	.	12.6	.	.	13.0	.	.	7.9	11.1	.	13.3	11.4	12.4	13.3	.	12.1	14.4	.	12.4
W-301	15.3	.	13.3	.	.	13.0	.	.	8.0	11.3	.	13.3	12.2	12.6	13.3	.	12.5	13.3	.	12.5
WA7663	13.7	.	9.6	.	.	11.7	.	.	7.3	9.7	.	12.4	11.5	11.5	12.4	.	12.2	13.2	.	11.6
WA7686	16.4	.	11.3	.	.	12.9	.	.	8.4	10.5	.	13.0	11.7	12.4	13.0	.	12.8	14.4	.	12.6
WPB 583	14.8	.	13.5	.	.	12.8	.	.	8.0	11.2	.	13.9	12.9	12.7	13.9	.	13.1	15.3	.	12.9
WPB BANNER	15.1	.	12.7	.	.	12.8	.	.	7.9	10.5	.	13.5	12.4	12.7	13.5	.	12.5	13.2	.	12.4
HARD RED AND WHITE																				
HATTON	14.2	.	.	.	.	13.8	.	.	8.5	12.3	.	14.7	12.5	13.5	14.7	.	12.9	.	.	.
WA7679	14.4	.	.	.	.	11.9	.	.	7.4	10.1	.	13.2	11.5	12.7	13.2	.	13.0	.	.	.
NURSERY AVERAGE	14.7	.	11.9	.	.	12.5	.	.	7.8	10.3	.	13.1	11.5	12.3	13.1	.	12.4	13.7	.	
CV %	3.4					7.0			7.6	5.6		4.9	10.7	3.1	4.9		8.4			
LSD @ .10	0.6					1.0			0.7	0.7		0.8	1.4	0.5	0.8		1.2			

IMPROVING SPRING WHEAT VARIETIES FOR THE PNW NEW DIRECTIONS, NEW IDEAS

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

Spring wheat plays an important role in wheat production in the Pacific Northwest by serving as a safety net for winter wheat when the fall sown crop is lost to winter kill. Even though spring wheat is better adapted to conservation tillage systems than winter types, the higher yield potential of winter wheat entices many growers to plant winter varieties. The economic benefits of producing spring wheat can be improved by developing high yielding varieties with superior end-use quality that carry genetic resistances to stripe, leaf and stem rusts, the Hessian fly insect and the Russian wheat aphid. Breeding procedures for spring wheat improvement are being modified to improve efficiency and to emphasize selection for the ability to germinate and grow aggressively at low temperatures, superior quality characteristics, and beneficial disease and pest resistances. By focusing on these traits, we will be able to develop superior spring wheat varieties that overcome the limitations of contemporary cultivars.

Improving Efficiency

We have improved the efficiency of the breeding program by rapidly advancing early generation (F_1, F_2) plant materials in the greenhouse. Seed production is limited to one generation per growing season in the field, whereas at least three generations can be produced in a single year in the greenhouse if properly managed. Last winter, we advanced F_1 seed from the 1994 field crossing block to the F_2 generation in the greenhouse. Within a ten month period, we accomplished what it usually takes two years to complete in a field based breeding program. We also have initiated a backcross breeding program in the greenhouse to quickly move simply inherited triats into adapted spring wheat lines. By using greenhouse facilities to accelerate the process, sixth generation BC materials will be available for field testing within three years.

Grain Yield

For most contemporary spring wheat varieties, grain fill tends to occur during the warmest part of the growing season resulting in shrunken kernels and low test weights. To improve the yield potential of spring wheat, varieties must be developed that germinate well at low soil temperatures in order to benefit from early planting dates. Seedlings must have rapid early grow rates, and wheat plants must fill the canopy quickly to avoid competition from weedy species and to capitalize on the optimal growing conditions of late spring and early summer. By developing varieties that avoid the climatic stresses of late summer through aggressive earlier season growth rates, test weights and grain yields of spring wheats should improve.

Progress

A. Cold Temperature Gradient Plate Evaluation

To assess the level of variation among cultivars for the ability to germinate at low temperatures, sixteen contemporary spring wheat varieties were evaluated on a cold temperature gradient plate ranging from 0 to 12°C. Results indicated that the soft white common spring wheats germinated more quickly at low temperatures than either hard type, and the low temperature germination rates of the hard white varieties were superior to those of the hard red lines. Low temperature germination ability was highly variable within market class indicting that it may be possible to manipulate this trait through breeding and selection. We are currently investigating various methods for evaluating low temperature germination ability among breeding lines.

B. Characterization of Spring Growth Habit Genes

Recent reports indicated that certain spring growth habit gene combinations promoted earliness while providing optimal grain fill potential under stress conditions, and researchers predicted that genotypes carrying these gene combinations will have the highest grain yields. Currently, no information is available concerning which growth habit genes are carried by spring wheat varieties grown in the PNW. Genetic testers for spring growth habit genes are currently being crossed in the greenhouse to 59 spring varieties and breeding lines to determine which gene is carried by each line. This information will be used to identify parents to cross to recover offspring carrying superior spring growth habit gene combinations that promote earliness while providing tolerance to environmental stresses. This strategy will be used to develop high yielding varieties for all market classes of spring wheat.

End-Use Quality

End-use quality has become a major issue in varietal development of all market classes of wheat; however, spring wheat lines with enhanced end-use quality have been difficult to identify in traditional selection programs. Early generation evaluation of quality characteristics has been incorporated into the breeding program to improve selection efficiency for end-use quality. We are investigating the effectiveness of selecting for quality factors in early generation lines based on high-molecular weight (HMW) glutenin storage protein banding patterns and microsedimentation values.

Progress

A. HMW Glutenin Storage Proteins

Fifty-nine contemporary spring wheat varieties and advanced breeding lines will be assayed for HMW glutenin banding patterns this summer. Protein banding patterns of several soft common and hard white varieties from Australia also will be determined.

B. Microsedimentation test

Entries in the 1995 commercial, tri-state and preliminary spring wheat nurseries were evaluated in May. Microsedimentation tests of F_4 and F_5 breeding lines will be completed by the end of July. This method appears to be a simple, inexpensive, reliable method for assessing end-use quality of early generation materials. Results will be used to discard lines with unacceptable end-use quality and to identify superior combinations of parents to hybridize in the 1995 crossing block.

Insect Problems of Spring Wheat

The Hessian fly (HF) and the Russian wheat aphid (RWA) are the primary insect pests of spring wheat. Currently, only a few HF resistant varieties are available and all of these carry similar genetic resistance. Aside from Wakanz, Wawawai and WBP 926, all contemporary spring wheat varieties are susceptible to HF and no RWA resistant varieties have been developed. Several HF and RWA resistance genes have been identified in wheat, and these genes must be incorporated into adapted spring wheat varieties. Since genetic resistance to both of these pests is simply inherited, backcross breeding is being used to rapidly incorporate resistance genes from non-adapted germplasm into elite genotypes. By aggressively selecting for resistance in early generation plant materials via greenhouse and field screenings, we are assured of advancing lines that carry the resistance genes. Our long term goal is to combine resistances to RWA and HF into a single cultivar.

Progress

A. Hessian Fly

Eight different HF resistance gene sources provided by R. Sears (Kansas State University, KSU) are currently being used as parents in backcross and conventional crossing programs in the greenhouse to introduce novel combinations of resistance genes into PNW germplasm. F_1 and BC_1 seed from various crosses will be harvested in July, and early generation materials will be screened for resistance in greenhouse and/or field trials. Eventually, resistant, recombinant lines will be evaluated at multiple locations throughout eastern WA, and resistant lines with superior agronomic and quality characteristics will be considered for varietal release.

B. Russian Wheat Aphid

RWA resistant spring wheat lines developed by C. Baker (Oklahoma State University, OSU) have been planted at Spillman Farm in an observation nursery. Genotypes with superior agronomic characteristics will crossed to adapted varieties in the 1995 field crossing block, and early generation advancements will be made in the greenhouse in the fall of 1995. Seed from segregating materials will be sent to OSU for screening and selection. Resistant lines will be advanced through the program

New Variety Development Efforts

Developing superior soft white and hard red spring varieties for the PNW is still the first priority of the breeding program; however, efforts to develop adapted hard white and spring clubs varieties have increased.

A. Spring Clubs

Even though many growers would like to produce spring club wheat as a primary crop or use it to reseed when the fall sown crop is lost to winter injury, spring club varieties adapted to the growing conditions of eastern WA are not available at this time. The most efficient method for developing adapted spring club varieties is to convert adapted winter club wheats to spring types and to convert adapted soft white common spring wheats to spring club types. Since club head type and spring growth habit are simply inherited, these triats can easily be manipulated through backcross breeding. The first winter-spring crosses for this study will be made in the field crossing blocks this summer.

B. Hard White Spring Varieties

The hard white crossing program has been expanded, and additional germplasm sources have been incorporated into the breeding program. Several hard white spring accessions from Australia (courtesy of E. Souza, U of I) were included as parents in the 1995 field crossing block. Development of hard white spring varieties will be accelerated by rapidly advancing early generation materials in greenhouse, and emphasizing early generation selection for end-use quality based on results of microsedimentation tests.

Crop Production Studies

We are involved in several collaborative efforts investigating important crop production issues in spring wheat.

A. Integrated Crop Production of Spring Wheat in Arid Regions

A spring wheat trial was established at Lind to evaluate varietal responses to competition with Russian thistle, and to determine the effects of no-till vs. conventional plantings and altered row spacings on weed competition and grain yield in an annual cropping situation. A fertility trial was established at Ralston to determine optimal fertilizer rates and placements for hard red and soft white spring wheat varieties.

B. Optimizing Seeding Rates and Row Spacing For Spring Wheat

A preliminary field trial was established at Spillman Farm in Pullman to investigate improving spring wheat performance by optimizing row spacing and seeding rates.

C. Hessian Fly Seed Mixture Trial

A variety seed mixture trial was established at four locations (3 with and 1 without a Hessian fly history) to determine whether mixing seed of different varieties can be used to improve the performance of Hessian fly resistant varieties Wakanz and Wawawai.

Collaborators

Several interdisciplinary research teams have been assembled to address important issues in spring wheat breeding and/or crop production. Each of the following individuals has made a significant contribution to this work and their efforts are greatly appreciated: R. Allan, C. Baker (OSU), Z. Czuchajowska, S. Jones, H. Leung, R. Line, B. Miller, C. Morris, S. Oberle, A. Ogg, W. Pan, K. Pike, W. Schillinger, R. Sears (KSU), S. Seefeldt, D. Young and F. Young.

1994 STATE/EXTENSION SPRING WHEAT VARIETY TRIALS

K.K. Kidwell, M.A. Davis, G.B. Shelton, B.C. Miller and P.E. Reisenauer

Twenty-one spring wheat varieties, including 11 soft whites, 3 hard whites, 6 hard reds and 1 club line, were evaluated at thirteen locations in eastern Washington during the 1994 growing season. Limited moisture and high summer temperatures resulted in below normal grain yields and reduced grain quality at many locations. Droughty conditions caused plants in most of the non-irrigated spring wheat nurseries (Tables 1-3) to mature 1 to 4 weeks earlier than expected resulting in low grain yields, low test weights and high protein levels. At several locations, rain showers in early May provided adequate moisture to promote normal plant development, and average grain yields of varieties grown at these sites were similar to those obtained in previous years. In general, data from 1994 spring wheat variety trials grown in low rainfall areas must be interpreted with caution due to the adverse effects of drought stress on plant growth at many locations.

Locations With Less Than 16 Inches Of Average Annual Rainfall

Lind: This nursery was planted on fallowed ground on March 8th. At the time of planting, the moisture level in the top 3 feet of soil was 3.9 inches. Based on the results of soil fertility tests, a starter fertilizer (4# N, 15# P_2O_5) was applied with the seed and a base fertilizer (13# N, 29# S) was banded 2 inches below the seed during planting. This site received 3.2 inches of precipitation during the growing season. In general, plants in this trial developed normally and grain yields were slightly higher than expected (Table 1).

Bickleton: This nursery was seeded into excellent moisture (5 inches in the top 4 feet of soil) on April 14th. The stand emerged well; however, the trial was inadvertently over-fertilized. This, coupled with the hot, dry growing conditions, created a stressful environment for crop growth and development. Yields, test weights and protein levels of all varieties grown at this site were poor (Table 1).

Lamont: This site was seeded into 3.7 inches of moisture in the top 4 feet of soil on March 25th and received 3.9 inches of precipitation during the growing season. Although average yields of varieties were comparable to those obtained at Lind, grain yields were substantially lower than expected at this location (Table 1).

Dusty: The field trial was planted on March 11th into 4.0 inches of moisture in the top 4 feet of soil, and the cooperator applied a base fertilizer (50# N, 10# S) at the time of planting. Only 2.2 inches of rain fell at this site during the growing season resulting in low grain yields, low test weights and high protein levels for all varieties evaluated in this trial (Table 1).

Varietal Performance

Generally, Edwall, Vanna, ID377S and WPB 926 were among the highest yielding varieties in the four trials grown in areas with an average annual rainfall of less than 16 inches (Table 1). Soft white varieties Centennial, Alpowa and ID448 were high yielding at Lind and Lamont, and test weights for these varieties were relatively high compared to other varieties. Among the hard white varieties, ID377S and WA7778 were agronomically superior to Klasic at every location except Bickleton. However, Klasic has superior milling and flour properties compared to both the ID and the WA hard white lines. WPB 926 was among the highest yielding hard red varieties grown at these locations, and this variety also is resistant to the Hessian fly.

Locations With 16 To 20 Inches Of Average Annual Rainfall

Reardan: On April 10th, this nursery was planted in a field that had been sown to winter wheat the previous year. Prior to planting, the cooperator applied a base fertilizer (60# N, 10# S). During the growing season, 4.1 inches of rain fell at this location. Due to droughty conditions, yields and test weights of varieties grown in this trial were low (Table 2).

Mayview: This nursery was planted on April 1st in a field that had previously been used to produce winter wheat. The moisture in the top 3 feet of soil was excellent (6.1 inches) at this location. The cooperator applied a base fertilizer (70# N, 15# S) prior to planting, and the nursery received 4.1 inches of rainfall during the growing season. Heavy residue from the previous crop hindered emergence, and this, coupled with an extremely dry season, reduced yields and test weights of all varieties grown at this location (Table 2).

St. John: This nursery was seeded into 6.4 inches of moisture in the top 4 feet of soil on March 31st; however, only 2.5 inches of precipitation accumulated at this site after planting. In spite of this, grain yields averaged nearly 55 bu/ac at this location (Table 2). The highest grain yields recorded in the 11 non-irrigated spring wheat variety trials planted in 1994 were harvested from this site.

Dayton: This trial was seeded on March 29th into 4.7 inches of moisture in the first 4 feet of soil. High temperatures and limited rainfall (2 inches after planting) hindered plant development in this nursery. As plants were starting to head, a hail storm severely shredded the flag leaves. Grain yields were extremely low at this location compared to yields from other areas in the same rainfall zone (Table 2).

Varietal Performance

Low average test weights (Table 4) of grain harvested from varieties grown in the 16 to 20 inch rainfall zone may have been caused by drought stress. Edwall, Wakanz, Alpowa and ID377S were high yielding across environments, and Alpowa had higher test weights and lower protein contents than most other varieties. Klasic had comparable yields to the other hard white lines (ID377S and WA7778) at all locations except for St. John. The hard red varieties tended to be lower yielding (8% on average) than the soft and hard white varieties at all locations. No single hard red variety was the highest yielding at all locations; however, WPB 926 had reasonable test weights and high protein contents across locations.

Locations With More Than 20 Inches Of Average Annual Rainfall

Pullman: This nursery was planted on March 29th into 6.5 inches of moisture in the top 3 feet of soil. During planting, a starter fertilizer (10# N, 34# P_2O_5) was applied with the seed and a base fertilizer (63# N, 15# S) was banded 2 inches below the seed. Pullman received 4.8 inches of precipitation after planting, and average grain yields were slightly lower than expected due to lack of moisture during the growing season (Table 3).

Fairfield: This trial was planted on April 19th with 6 inches of moisture in the first 3 feet of soil. A base fertilizer (62# N, 8# P_2O_5, 6# S) was applied during planting. After planting, 5 inches of rain fell at Fairfield. Yields and test weights were greatly reduced as a result of drought stress (Table 3).

Farmington: Soil moisture conditions were excellent (7 inches) when this nursery was planted on April 16th. The cooperator applied a base fertilizer (60# N, 13# S) prior to planting. The site only received 2.6 inches of moisture after planting; therefore, grain yields and test weights were much lower than those obtained at other locations in this rainfall zone (Table 3).

Varietal Performance

Alpowa was the highest yielding variety at two locations, and was among the top yielding entries in the third trial in this rainfall zone (Table 3). Alpowa had higher test weights and lower protein contents than a majority of the other soft white varieties evaluated in these trials. All three hard white lines had high grain yields at Pullman; however, Klasic had higher test weights than ID377S and WA7778 at all locations. Again, none of the hard red varieties was high yielding across locations. Hard red varieties with early maturity (Butte 86, WPB 926 and WPB 936) were generally higher yielding than hard red lines that matured late (Spillman and Wampum).

Irrigated Nurseries

The irrigated nursery at **Royal Slope** was planted on March 13th. Prior to planting, a base fertilizer (240# N, 30# P, 30# S, 100# K, 1# B) was applied to the field. The irrigated nursery at **Moses Lake** was planted on March 11th. Warm temperatures resulted in outstanding yields and test weights among varieties in both irrigated locations (Table 4).

Varietal Performance

The soft white experimental line ID448 was far superior in yield to any other variety grown in these trials. Its test weights were lower than the trial averages; however, test weights for all varieties evaluated under irrigation were above 60 lb/bu. ID448 also had the lowest protein content of any line evaluated at both locations. Soft white lines Centennial, Edwall, Vanna and Alpowa also were high yielding under irrigation. In terms of grain yield, test weight and protein, Express, WPB 926 and WPB 936 were the superior hard red varieties under these conditions. Butte 86 was the lowest yielding variety in both of the irrigated trials. The hard white experimental lines ID377S and WA7778 were superior to Klasic in total grain yield; however, their milling and flour properties were inferior to those of Klasic.

Status Of New WSU Varieties

Alpowa (WA7677, PI566596) is a single gene semidwarf, soft white common spring wheat with excellent yield stability across environments. Typically, Alpowa has a higher grain yield and test weight than most other entries in spring wheat variety trials planted at various locations. Milling and baking properties of Alpowa are similar to or slightly lower than those of Penawawa. Alpowa appears to carry adult plant resistance to stripe rust and leaf rust; however, this variety is susceptible to stem rust when conditions favor the development of the fungus. Alpowa also is susceptible to the Hessian fly and the Russian wheat aphid. Registered seed of this variety will be increased in 1995.

Calorwa (WUC657) is a soft white spring club variety that was developed at the University of California in Davis. Grain yields of Calorwa tend to be slightly lower than the average yields of other spring wheat varieties. This cultivar carries at least one semidwarfing gene and is slightly shorter in height than Penawawa. Calorwa appears to carry resistance to local forms of stripe, leaf and stem rusts as well as powdery mildew. Calorwa is a pastry wheat with weak mixing properties similar to those of superior soft white winter club wheats. Several reports indicated that the kernel characteristics of Calorwa when grown in different environments did not consistently meet the classification requirements for club wheat. Seed increase of Calorwa has been stalled at the Foundation level until the seed type of this variety is confirmed to be club.

Wawawai (WA7712, PI574538) is a single gene semidwarf, soft white common spring variety that carries the H_3 resistance gene to the Hessian fly insect. Tests weights of Wawawai typically exceed those of Penawawa and Wakanz, and the grain yield potential of Wawawai is similar to that of Penawawa. Wawawai carries adult plant resistances to local races of stripe rust and stem rust and is also moderately resistant to leaf rust. Wawawai has milling and baking quality properties equivalent or superior to those of Penawawa, and Foundation seed of this variety will be increased in 1995.

Table 1. Grain yields, test weights and protein contents of spring wheat varieties evaluated in field nurseries receiving less than 16 inches of average annual rainfall: Lind, 9.5"; Bickleton, 12.5"; Lamont, 15"; Dusty, 16".

			Yield (bu/ac)					Test Weight (lb/bu)					Protein (%)				
Class	Variety	Seed Status*	Lind	Bick-leton	Lamont	Dusty	Avg	Lind	Bick-leton	Lamont	Dusty	Avg	Lind	Bick-leton	Lamont	Dusty	Avg
SWS	Centennial	AV	28.1	15.6	24.4	7.4	18.9	59.5	53.8	55.2	47.0	53.9	13.1	16.5	15.3	15.9	15.2
	Edwall	"	26.8	17.2	28.4	7.0	19.9	55.8	50.0	50.7	43.3	50.0	12.7	16.2	14.9	14.9	14.7
	Penawawa	"	23.9	15.8	15.6	3.9	14.8	58.8	52.3	50.8	38.6	50.1	12.9	17.2	15.3	14.7	15.0
	Sprite	"	25.7	11.5	29.9	8.2	18.8	57.8	54.6	50.7	43.2	51.6	13.1	16.7	15.2	16.1	15.3
	Vanna	"	29.0	17.1	25.7	7.6	19.9	57.0	49.4	49.8	41.7	49.5	12.6	17.5	15.3	16.5	15.5
	Wakanz	"	29.4	9.8	20.8	3.6	15.9	57.3	50.8	52.8	40.0	50.2	12.6	18.2	15.5	15.3	15.4
	Alpowa	FS	26.7	15.6	24.3	6.9	18.4	59.2	55.1	53.7	47.0	53.8	12.2	16.7	15.6	15.9	15.1
	Wawawai	BS	26.8	13.0	22.1	5.2	16.8	59.1	51.7	54.1	43.0	52.0	12.8	17.1	15.3	16.1	15.3
	ID392	EXP	27.2	12.9	17.6	5.7	15.9	59.8	53.0	53.5	44.9	52.8	12.5	16.9	15.3	15.4	15.0
	ID448	"	27.6	13.8	25.3	5.5	18.1	58.5	53.9	54.9	46.8	53.5	12.8	17.1	15.2	16.0	15.3
	Wadual 94	"	26.0	13.6	22.9	5.5	17.0	56.2	53.2	52.6	45.3	51.8	12.7	17.4	16.5	16.6	15.8
HWS	Klasic	AV	13.9	20.2	24.0	10.7	17.2	62.1	52.4	53.8	47.4	53.9	13.1	16.6	15.9	15.1	15.2
	ID377S	EXP	27.1	18.2	22.8	8.9	19.3	59.7	53.7	53.3	45.5	53.1	13.7	17.2	16.3	15.6	15.7
	WA7778	"	30.1	16.1	24.1	8.0	19.6	56.5	51.1	52.7	47.6	52.0	13.4	17.1	16.0	15.9	15.6
HRS	Butte 86	AV	23.9	19.5	22.2	7.0	18.2	60.2	52.6	52.4	45.5	52.7	14.2	17.7	17.4	16.9	16.6
	Express	"	22.6	16.5	27.0	10.0	19.0	60.2	53.7	54.2	47.6	53.9	14.0	17.6	16.7	15.9	16.1
	Spillman	"	28.0	15.3	21.6	6.2	17.8	56.5	50.5	51.3	44.5	50.7	13.9	17.7	18.0	16.3	16.5
	Wampum	"	26.5	14.2	24.9	5.2	17.7	57.6	47.9	54.0	44.6	51.0	13.2	17.7	16.7	17.0	16.2
	WPB926	"	23.3	19.0	23.7	13.9	20.0	60.3	54.5	53.8	48.9	54.4	14.3	17.8	17.6	15.5	16.3
	WPB936	"	25.5	15.3	27.2	9.0	19.3	60.1	52.3	54.7	48.1	53.8	14.7	17.7	17.5	16.5	16.6
Club	Calorwa	FS**	24.7	14.2	22.9	6.4	17.1	60.6	48.9	49.0	39.9	49.6	12.3	16.3	15.6	16.0	15.1
		Mean	25.8	15.4	23.7	7.2	18.0	58.7	52.2	52.8	44.8	52.1	13.2	17.2	16.0	15.9	15.6
		CV (%)	11.7	19.1	31.6	14.5											
		LSD @.10	3.6	3.5	8.8	1.2											

*AV=Available, FS=Foundation Seed, BS=Breeder Seed, EXP=Experimental Seed

** Calorwa will remain at the FS level until its seed type is confirmed to be club.

Table 2. Grain yields, test weights and protein levels of spring wheat varieties evaluated in field nurseries receiving from 16 to 20 inches of average annual rainfall: Reardan, 17"; Mayview, 18"; St. John, 18"; Dayton, 19.6".

			Yield (bu/ac)					Test Weight (lb/bu)					Protein (%)				
Class	Variety	Seed Status*	Rear-dan	May-view	St. John	Dayton	Avg	Rear-dan	May-view	St. John	Dayton	Avg	Rear-dan	May-view	St. John	Dayton	Avg
SWS	Centennial	AV	28.4	22.6	54.6	14.3	30.0	52.0	54.0	58.9	54.3	54.8	13.8	13.3	12.2	16.2	13.9
	Edwall	"	26.5	24.0	60.2	12.7	30.9	48.2	50.9	56.0	53.3	52.1	13.6	13.0	11.7	16.2	13.6
	Penawawa	"	24.3	21.4	54.3	14.5	28.6	50.4	52.4	59.2	55.6	54.4	14.1	14.1	12.0	16.4	14.2
	Sprite	"	28.1	19.3	58.4	16.1	30.5	48.9	51.3	57.0	52.6	52.5	14.8	13.6	12.5	16.3	14.3
	Vanna	"	28.0	21.5	58.5	15.8	31.0	49.1	50.9	57.2	51.5	52.2	13.6	14.3	11.5	16.4	14.0
	Wakanz	"	29.0	23.2	61.9	14.5	32.2	49.8	50.6	58.1	52.7	52.8	13.8	13.8	11.7	16.0	13.8
	Alpowa	FS	33.5	26.5	65.6	17.1	35.7	52.9	56.1	60.6	55.6	56.3	13.6	12.2	10.5	16.3	13.2
	Wawawai	BS	26.5	19.1	44.1	12.9	25.7	52.3	50.2	59.1	55.8	54.4	13.8	14.8	12.2	16.5	14.3
	ID392	EXP	27.1	20.6	57.5	15.0	30.1	52.3	54.4	60.3	55.7	55.7	13.1	13.1	11.0	15.9	13.3
	ID448	"	21.8	15.3	60.4	14.8	28.1	50.6	54.2	58.3	56.4	54.9	14.2	14.0	11.8	16.2	14.1
	Wadual 9	"	28.0	20.4	66.3	8.9	30.9	51.3	51.9	59.6	53.8	54.2	15.0	15.6	12.9	17.2	15.2
HWS	Klasic	AV	33.6	20.4	40.0	16.8	27.7	55.0	53.0	59.0	54.7	55.4	13.1	13.8	13.3	16.5	14.2
	ID377S	EXP	30.6	22.0	60.6	13.4	31.7	52.8	54.1	59.6	54.8	55.3	15.0	15.2	12.3	16.8	14.8
	WA7778	"	28.2	24.5	50.9	14.2	29.5	48.9	53.5	57.3	53.0	53.2	15.1	14.1	12.6	16.0	14.5
HRS	Butte 86	AV	29.1	21.1	53.1	9.6	28.2	53.7	54.1	59.9	53.4	55.3	15.2	14.9	13.9	17.7	15.4
	Express	"	24.7	22.8	44.0	14.4	26.5	50.2	53.0	58.3	54.1	53.9	14.6	15.3	13.8	17.3	15.3
	Spillman	"	25.1	17.7	47.3	11.8	25.5	48.2	49.2	56.9	52.6	51.7	15.5	16.1	13.9	17.4	15.7
	Wampum	"	27.8	17.1	57.3	11.8	28.5	50.1	51.7	57.8	54.3	53.5	14.6	14.5	13.4	17.4	15.0
	WPB926	"	24.8	25.5	47.3	16.0	28.4	52.7	53.7	57.7	54.9	54.8	15.1	16.6	14.9	18.5	16.3
	WPB936	"	27.8	21.9	59.9	10.7	30.1	51.4	51.2	58.4	52.8	53.5	15.3	15.3	13.9	17.8	15.6
Club	Calorwa	FS**	26.9	19.1	51.6	13.4	27.8	51.3	51.0	57.8	52.2	53.1	14.1	14.1	12.5	17.1	14.5
		Mean	27.6	21.3	54.9	13.7	29.4	51.1	52.4	58.4	54.0	54.0	14.3	14.4	12.6	16.8	14.5
		CV (%)	13.9	12.3	17.7	26.7											
		LSD @.10	4.6	3.9	11.5	4.4											

*AV=Available, FS=Foundation Seed, BS=Breeder Seed, EXP=Experimental Seed

**Calorwa will be held at the FS level until its seed type is confirmed to be club.

Table 3. Grain yields, test weights and protein contents of spring wheat varieties evaluated in field nurseries receiving more than 20 inches of average annual rainfall: Pullman, 20.5"; Fairfield, 21"; Farmington, 22".

			Yield (bu/ac)				Test Weight (lb/bu)				Protein (%)			
Class	Variety	Seed Status *	Pull-man	Fair-field	Farm-ington	Avg	Pull-man	Fair-field	Farm-ington	Avg	Pull-man	Fair-field	Farm-ington	Avg
SWS	Centennial	AV	50.0	31.6	51.2	44.3	58.6	54.7	56.0	56.4	13.0	12.8	11.8	12.5
	Edwall	"	45.5	27.7	49.0	40.7	54.0	49.0	52.2	51.7	13.6	13.2	11.6	12.8
	Penawawa	"	49.6	24.0	46.5	40.0	57.3	50.7	53.0	53.7	12.9	13.1	12.7	12.9
	Sprite	"	52.2	30.5	52.8	45.2	53.8	50.6	53.0	52.5	14.5	13.0	12.9	13.5
	Vanna	"	49.1	28.0	54.0	43.7	54.4	48.6	52.4	51.8	13.6	13.3	11.9	12.9
	Wakanz	"	56.2	26.5	52.7	45.1	57.3	49.9	51.9	53.0	12.7	13.3	12.7	12.9
	Alpowa	FS	58.6	30.8	56.9	48.8	58.8	52.4	55.2	55.5	12.7	13.5	12.1	12.8
	Wawawai	BS	48.1	23.5	51.8	41.1	57.6	50.9	55.1	54.5	12.8	13.7	12.5	13.0
	ID392	EXP	47.2	28.2	39.6	38.3	57.8	53.2	53.6	54.9	13.1	13.1	13.0	13.1
	ID448	"	52.5	26.3	46.8	41.9	57.7	53.0	54.6	55.1	12.4	13.3	12.6	12.8
	Wadual 9	"	50.4	29.7	54.7	44.9	56.9	51.7	54.3	54.3	14.4	14.5	13.6	14.2
HWS	Klasic	AV	54.4	32.8	47.4	44.9	58.3	55.6	57.0	57.0	13.5	14.1	12.1	13.2
	ID377S	EXP	54.7	28.1	46.0	42.9	57.4	53.2	56.0	55.5	14.4	14.9	12.1	13.8
	WA7778	"	56.0	26.5	50.6	44.4	55.9	49.6	53.9	53.1	14.8	15.0	11.6	13.8
HRS	Butte 86	AV	46.5	29.7	47.8	41.3	57.6	54.6	58.1	56.8	15.4	15.0	13.4	14.6
	Express	"	53.9	25.6	41.2	40.2	56.8	51.3	54.7	54.3	14.9	14.5	13.8	14.4
	Spillman	"	44.0	23.1	41.7	36.3	53.3	50.0	53.1	52.1	15.6	15.6	13.5	14.9
	Wampum	"	46.9	24.6	44.1	38.5	56.8	49.8	52.7	53.1	14.0	15.5	13.1	14.2
	WPB 926	"	53.0	29.2	48.9	43.7	57.6	54.5	56.9	56.3	15.9	15.1	12.9	14.6
	WPB 936	"	53.0	29.6	49.9	44.2	55.6	54.4	57.7	55.9	15.2	14.8	12.4	14.1
Club	Calorwa	FS**	50.1	26.7	45.1	40.6	56.5	51.9	53.2	53.9	13.4	13.1	12.5	13.0
		Mean	51.0	27.7	48.5	42.4	56.7	51.9	54.5	54.4	13.9	14.0	12.6	13.5
		CV (%)	8.4	17.5	8.7									
		LSD @.10	5.0	5.8	5.0									

*AV=Available, FS=Foundation Seed, BS=Breeder Seed, EXP=Experimental Seed

**Calorwa will be held at the FS level until its seed type is confirmed to be club.

Table 4. Grain yields, test weights and protein contents of spring wheat varieties evaluated in irrigated field trials in 1994.

			Yield (bu/ac)			Test Weight (lb/bu)			Protein (%)		
Class	Variety	Seed Status*	Royal Slope	Moses Lake	Avg	Royal Slope	Moses Lake	Avg	Royal Slope	Moses Lake	Avg
SWS	Centennial	AV	127.4	157.0	142.2	64.8	63.0	63.9	10.7	11.5	11.1
	Edwall	"	126.7	150.5	138.6	62.5	61.4	62.0	10.8	11.7	11.3
	Penawawa	"	140.4	137.8	139.1	64.9	62.6	63.8	11.4	11.7	11.6
	Sprite	"	122.1	146.0	134.1	64.5	62.6	63.6	11.1	11.6	11.4
	Vanna	"	136.8	164.1	150.5	64.2	62.6	63.4	10.8	11.2	11.0
	Wakanz	"	131.8	145.3	138.6	63.4	61.9	62.7	11.1	11.7	11.4
	Alpowa	FS	130.3	159.1	144.7	65.2	63.4	64.3	11.2	11.6	11.4
	Wawawai	BS	133.9	144.3	139.1	65.0	62.5	63.8	11.2	12.1	11.7
	ID392	EXP	128.1	154.8	141.5	64.1	63.0	63.6	10.8	11.2	11.0
	ID448	"	154.9	164.7	159.8	60.8	61.5	61.2	10.5	11.2	10.9
	Wadual 9	"	117.8	147.1	132.5	63.7	62.7	63.2	12.4	13.2	12.8
HWS	Klasic	AV	117.3	134.3	125.8	66.0	63.7	64.9	12.9	13.5	13.2
	ID377S	EXP	132.2	164.2	148.2	65.5	63.8	64.7	12.1	12.8	12.5
	WA7778	"	140.2	164.1	152.2	62.0	61.3	61.7	11.6	12.2	11.9
HRS	Butte 86	AV	107.2	116.0	111.6	64.1	62.5	63.3	14.5	15.5	15.0
	Express	"	126.9	134.3	130.6	64.2	62.8	63.5	14.1	15.1	14.6
	Spillman	"	120.4	149.9	135.2	62.4	61.8	62.1	13.4	14.2	13.8
	Wampum	"	126.3	161.8	144.1	63.5	61.6	62.6	12.2	13.4	12.8
	WPB926	"	111.0	126.5	118.8	63.9	62.5	63.2	13.9	15.3	14.6
	WPB936	"	128.6	131.3	130.0	64.5	62.7	63.6	13.6	15.1	14.4
Club	Calorwa	FS**	115.0	135.7	125.4	63.9	61.6	62.8	11.2	11.7	11.5
		Mean	127.4	147.1	137.3	64.0	62.5	63.3	12.0	12.7	12.4
		CV (%)	4.8	9.0							
		LSD @.10	7.2	15.6							

*AV=Available, FS=Foundation Seed, BS=Breeder Seed, EXP=Experimental Seed

**Calorwa will be held at the FS level until its seed type is confirmed to be club.

INTEGRATED CROP PRODUCTION OF SPRING WHEAT IN ARID REGIONS

Frank Young, Alex Ogg, Jr., Kim Kidwell,
Steve Oberle, and Bill Pan

The major crop rotation in Washington's arid region is winter wheat-summer fallow. This system is characterized by weeds such as downy brome and jointed goatgrass and diseases such as take-all in the growing crop. Severe wind erosion during the summer-fallow season increases human health hazards and reduces soil quality and the long-term sustainability of the region's agriculture. Continuous cropping of spring wheat or rotating spring wheat with winter wheat or other spring crops would reduce the number of fallow fields, increase residue cover on fields in the summer and fall, and reduce the potential for wind blown dust in these regions. In the arid regions of Washington, spring wheat is used primarily as a crisis crop when winter wheat is killed by severe winters or when it is infested severely by weeds, diseases, or insects. In these circumstances spring wheats typically yield about 2/3 of the expected winter wheat crop and therefore is unprofitable for growers. Most growers would not consider planting spring wheat as a primary crop until profitable varieties are available and successful production management systems are established.

At the present time, a profitable crop management system for spring wheat in conservation tillage has not been identified. There are no nutrient management guides for spring wheat in conservation production systems in eastern Washington and there are no spring wheat cultivars/genotypes identified/developed that germinate, emerge and grow in low temperatures. Low temperature growth and development would increase crop competition against summer annual broadleaf weeds such as Russian thistle and kochia. Cultural practices such as close row-spacings, early planting, competitive varieties, and proper fertility management need to be developed for optimum weed management strategies and economic spring wheat production systems.

A team of research scientists from USDA-ARS and WSU has been assembled to evaluate the best management practices for economical spring wheat production in conservation tillage systems. Presently five scientists from the disciplines of weed science, agronomy, soils, and plant breeding are involved. Current research includes 1) evaluating the germination response of several classes of spring wheats to temperatures, 2) best management practices for Russian thistle control including row spacing, competitive crops, and new sprayer technology, and 3) developing economical and site-specific nutrient management plans for spring wheat.

In the future, a long-term, large-scale field study will be initiated in the 10 to 12 inch rainfall area of eastern Washington. This replicated, on-farm test for best spring wheat management practices will be established in the fall of 1995 to make direct comparisons among continuous spring wheat (or spring crop rotation), spring-wheat fallow, and winter wheat-fallow systems. This study will emphasize conservation tillage practices to reduce wind erosion and improve management practices to minimize the need for off-farm inputs and to maximize profitability of spring wheat production. This study will be conducted concurrently with the research satellite studies previously described. The research team includes scientists from the disciplines already mentioned as well as entomology, pathology, agricultural economics and statistics. Hopefully this study can be conducted for 4 years (two complete cycles of each 2-yr crop rotation), with every crop grown every year.

BARLEY IMPROVEMENT RESEARCH

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

Cultivar Development/Variety Testing

The latest WSU winter barley cultivar release is *Hundred*, which is a high yielding semi-dwarf 6-row type. Hundred has had consistently high yields across eastern Washington (Table 1). The newest WSU barley cultivar is *Crest*, a 2-row spring malting type with high yield (Table 2), good kernel quality, and good feed quality. Pre-release breeder seed production is underway for a new 6-row hooded hay type (WA 7999-88) (Table 3) and a new 2-row hulless type (WA 11045-87) (Table 4).

Whereas winter and spring and 2-row and 6-row types are bred, emphasis is on spring types. This emphasis is due to northwest barley breeding program collaboration. For spring barley in 1994, 172 crosses were made. In 1995, plants will be selected from 183 segregating F_3 populations (50-100/population) from previous years' crosses. In addition, there are 102 F_2 populations in the field and 72 F_3 single seed descent populations in the greenhouse. Lines will be selected from approximately 12,000 head and plant rows including homozygous doubled haploid (from anther culture) plant rows. There are 37 24-entry preliminary yield trials planted at Spillman Farm this year; the entries of which mostly came from 1994 head/plant rows. The more advanced lines are tested in 22 30-entry major yield trials at Spillman and throughout eastern Washington. In addition, there are seven spring barley yield trials conducted by Baird Miller and Pat Reisenauer and there are 25 grower-conducted on-farm tests in 10 counties in 1995.

The winter barley program is much smaller in scope with reliance on the Oregon State University program for new breeding line evaluation in Washington. In 1994-95, there are about 1,000 winter barley plots and about 7,500 spring barley plots in total. Carl Muir and Judy Cochran are field research technologists working with the program. Barley performance in 1994 was presented in the March 10, 1995 Green Sheet for small plot trials and in the April 1995 Wheat Life for on-farm tests.

Grain quality evaluations of breeding lines and cultivars are conducted on field-grown samples. Basic kernel quality characteristics, such as test weight and kernel plump-thin percentages, are measured in our laboratory. Malting quality is evaluated at the USDA-ARS Cereal Crops Research Unit at Madison, Wisconsin. Feed quality evaluations are conducted in the Department of Animal Sciences primarily by John Froseth.

While yield and grain quality are always important selection criteria, pest resistance is moving up in priority. Crossing, screening and selection for Russian wheat aphid, barley stripe rust and soil borne pathogen resistance is underway. The Russia wheat aphid is a relatively new pest in the Pacific Northwest (PNW) and has the potential to inflict serious damage to the barley crop. Reaction screening is carried out at the USDA-ARS Insect Laboratory at Stillwater, Oklahoma. Barley stripe rust is a new disease to the PNW and little resistance exists in currently grown barley cultivars. Rollie Line is collaborating on monitoring and testing for this disease. We have had germplasm screened for barley strip rust reaction the past several years in Bolivia, Texas, and now at WSU. Soil borne pathogens probably affect barley production more than we realize. A new effort was initiation in 1994 through Vadim Jitkov's M.S. research project in collaboration with Jim Cook to screen for reaction to soil borne pathogens in the field and growth chamber.

Application for Biotechnology

Anther culture techniques have been used to develop doubled-haploid lines (DHL) from F_1 plants from crosses in the breeding program. This is a rapid (~1 year) method for developing homozygous (true breeding) breeding lines. Traditionally near homozygous lines are developed after several years of allowing the progeny of crosses to segregate from F_2 through $F_{5\text{-}8}$. The advantages of DHLs are rapid development of breeding lines for selection and testing and early initial selection and testing of true breeding lines (non-segregating lines) vs. selection of lines still segregating. Cultivar development time can be cut by 1/3-1/2 using HDLs. In 1994, 1400 DHLs from 20 crosses were in the field for selection and DHL production from F1s of 20 new crosses is culminating with 500 DHL field plots in 1995. Z. Huang was a visiting scientist in charge of DHL production in the program, but lack of funding has terminated his efforts on barley.

Collaboration in the North American Barley Genome Mapping Project involves work on several fronts with Andy Kleinhofs, Janet Clancy, and Feng Han. The first comprehensive map developed from Steptoe/Morex is being applied to quantitative trait locus (QTL) analysis and molecular marker assisted selection uses relevant to cultivar development. We are verifying QTL identified and developing markers suitable for selection in the breeding program. Initially, we are concentrating on the dormancy trait in Steptoe and several malting quality traits in Morex. The availability of a detailed genome map allows us for the first time to begin to understand the genetics of complex economically important agronomic (yield, lodging, maturity) and quality (feed, kernel, malting) traits through QTL analysis. With the identification and location of specific genes, marker-assisted selection strategies can be developed to allow more directed breeding of these important economic traits.

Table 1. Winter Barley Yield Averages through 1994, Lb/A (% of Boyer).

Variety	Pullman 11 Yr	Pomeroy 9 Yr	Walla Walla 9 Yr	Lind Irr 5 Yr	Extension 71 LOC-Yr
Hundred	6100 (112)	4775 (103)	4940 (96)	4760 (114)	4535 (105)
Hesk	6085 (111)	4885 (106)	4875 (94)	4530 (109)	4490 (103
Boyer	5460 (100)	4620 (100)	4140 (100)	4160 (100)	4335 (100)
Showin	5335 (98)	4570 (99)	5070 (98)	4355 (105)	4265 (98)
Kamiak	4915 (90)	3835 (83)	4580 (89)	2680 (64)	3935 (91)

Table 2. Spring barley yield averages through 1994.

Variety	Pullman 14 Yr	Pomeroy 14 Yr	Walla[2] 11 Yr	Lincoln Co. 10 Yr	Connell 8 Yr	Lind 10 Yr	Fairfield 4 Yr	Mean-63 LOC-Yr
		Lb/A (%)						
Crest	4845(101)	3215(98)	3530(96)	3530(96)	2750(105)	1920(107)	3275(97)	3460(99)
Steptoe	4810(100)	3260(100)	3690(100)	2615(100)	1790(100)	1820(100)	3390(100)	3510(100)

Table 3. Agronomic performance of barley forage types, five year means.

			---------- *Forage Yield**		------------		----- *Yield* -----	
Variety	Plant Height	Lodging	Green T/A	Rel. %	Dry T/A	Rel. %	Grain T/A	Rel. %
7999-88	37	4	12.7	112	4.4	113	1.8	128
Belford	40	16	11.3	100	3.9	100	1.4	100

*Harvested at early soft dough stage (~35% DM).

Table 4. Hulless barley performance, Pullman.

	--------------- *Grain Yield*			--------------	--- *4-Year Means*	---
Variety	4 Yr Lb/A	Rel. %	6 Yr Lb/A	Rel. %	TW Lb/Bu	Plant Ht. In.
11045-87	4050	119	4090	111	59.4	35
Scout	3410	100	3685	100	57.1	38
Condor	3485	102	---	---	61.8	34

1994 STATE/EXTENSION WINTER BARLEY

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

The 1994 winter barley variety evaluation trials were conducted at 6 locations in eastern Washington. Twenty winter barleys were evaluated at all locations. In cooperative efforts with the WSU breeders all varieties evaluated in this testing program were also evaluated in the WSU breeder's testing program.

In general, the earlier fall planting moisture conditions were good, with sufficient moisture for stand establishment at the time of planting. The later plantings were seeded shallow and timely rains allowed a sufficient growth period to produce vigorous stand establishment. The winter was characterized by an early cold spell in November followed by mild temperatures and light snowfall. The extreme cold and high winds killed the winter nurseries at Dusty and Fairfield. The Walla Walla site was abandoned due to poor emergence and stand establishment. The remaining sites survived the winter without injury.

Rainfall throughout the growing season was abnormally low. This condition coupled with an above average temperature provided a potential for extremely poor yields and grain quality. The winter barley however, was able to mature before these weather conditions did too much damage, resulting in near normal yields and good grain quality.

Statewide average winter barley yields in the trials ranged from 3075 to 8138 lbs/acre, with test weights ranging from 41.9 to 50.8 lbs/bu. The top yielding winter barley varieties were Kold and Hesk.

1994 WSU WINTER BARLEY VARIETY TRIALS

YIELD (LBS/A)

VARIETY	ASOTIN	BICKLETON	POMEROY	LIND IRR.	PULLMAN	AVERAGE
1794-89	3860	4085	4792	4244	5594	4540
1869-89	4024	3999	4507	5205	7402	4980
1872-89	3830	3803	4353	4485	7703	4791
1975-86	4220	4901	4656	6081	7978	5484
1996-87	3609	5349	4352	4305	7811	5018
1997-87	3803	4708	5160	5654	6589	5181
2006-89	4253	3688	4517	4428	7546	4908
2063-89	3624	4467	3785	4962	7048	4687
2667-89	3047	4554	4181	5278	8027	4960
2677-89	3570	4454	4788	4737	8132	5105
BOYER	3816	4502	4875	4446	6911	4926
EIGHT-TWELVE	3925	4108	4940	5012	6492	4899
GWEN	3538	3721	4270	2585	5753	4014
HESK	4198	4886	5272	5398	7391	5415
HUNDRED	3373	4750	4795	5490	7160	5101
KAMIAK	3075	3732	3136	3012	5578	3651
KOLD	4228	5179	4284	4239	8138	5127
O1900119	3614	4157	4480	4559	7484	4824
O1900130	4214	3882	4128	3337	6492	4409
SHOWIN	3803	5263	5122	4981	6890	5204
NURSERY MEAN	3781	4427	4520	4622	7106	4865
CV %	13.7	14.8	9.6	16.3	8.1	11.9
LSD @ .10	612	824	416	890	677	290

1994 WSU WINTER BARLEY VARIETY TRIALS

TEST WEIGHT (LBS/BU)

VARIETY	ASOTIN	BICKLETON	POMEROY	LIND IRR.	PULLMAN	AVERAGE
1794-89	44.8	46.0	45.3	49.3	50.3	45.9
1869-89	45.9	47.6	45.7	50.6	50.5	46.8
1872-89	46.2	46.5	46.4	50.1	50.6	46.9
1975-86	41.1	44.8	40.2	48.9	48.1	42.6
1996-87	44.5	47.1	43.1	49.8	49.7	45.3
1997-87	47.2	47.1	46.5	50.3	50.5	47.3
2006-89	46.2	46.0	44.4	50.3	48.5	45.9
2063-89	42.8	44.2	44.6	48.5	48.2	44.5
2667-89	40.5	46.0	39.0	47.9	46.8	41.9
2677-89	40.5	45.4	41.4	47.3	47.4	42.9
BOYER	44.8	45.6	43.0	47.8	47.4	44.6
EIGHT-TWELVE	48.3	47.3	45.1	50.9	49.0	47.0
GWEN	48.5	45.3	47.9	49.6	50.6	47.8
HESK	44.6	46.7	43.2	49.2	48.1	45.1
HUNDRED	38.8	42.3	41.9	49.0	48.0	42.0
KAMIAK	47.5	48.9	49.7	49.9	50.6	49.0
KOLD	46.8	49.0	44.4	51.3	50.8	46.9
O1900119	43.2	44.8	44.7	48.3	47.4	44.8
O1900130	47.6	46.5	44.5	51.0	48.2	46.4
SHOWIN	46.3	45.0	45.5	48.5	47.2	45.9
NURSERY MEAN	44.8	46.1	44.3	49.4	48.9	45.5
CV %	2.4	2.5	3.2			2.8
LSD @ .10	1.3	1.4	1.4			0.8

1994 STATE/EXTENSION SPRING BARLEY

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

The 1994 spring barley variety evaluation trials were conducted at 7 locations in eastern Washington. Twenty-six spring varieties, twelve 6-row and fourteen 2-row, were included in the evaluation trials. Four additional varieties were included at the irrigated Moses Lake site. As a cooperative effort all varieties evaluated in this testing program were also evaluated in the WSU breeder's testing program.

Spring planting was completed earlier than normal due to the warm early spring. Planting conditions were unusually warm, this resulted in the rapid establishment of stands. The rainfall throughout the remainder of the growing season was abnormally low. This condition coupled with an above average temperature resulted in extremely poor yields and grain quality with no incidence of disease.

Statewide average spring barley yields in the trials ranged from 322 to 10024 lbs/acre, with test weights ranging from 31.4 to 54.1 lbs/bu. The top yielding 6 row varieties were Steptoe, Colter and Marana. The top yielding 2 row variety was Baronesse.

1994 WSU SPRING BARLEY VARIETY TRIALS

YIELD (BU/A)

VARIETY	DUSTY	BICKLETON	DAYTON	LIND DRY	LAMONT	MAYVIEW	REARDAN	FAIRFIELD	PULLMAN	ST. JOHN	FARMINGTON	MOSES LAKE	AVERAGE
2-ROW													
16277-85	673	832	1328	1609	1781	1675	1781	2132	4213	4306	3700	8635	2722
7758-89	807	1018	1447	1750	1949	2042	1997	2192	4136	3998	4248	8141	2697
9035-84	778	957	1514	1723	2213	1854	1681	2099	3744	3976	4176	8082	2733
9448-83	599	725	1245	1601	1617	1585	1764	1867	3859	3847	4123	8378	2601
BARONESSE	891	1189	1473	1653	1830	2448	2118	1767	4002	4434	4186	8951	2912
CAMELOT	955	1269	1471	1717	2010	2226	2186	2212	3935	4389	3791	7639	2714
CRYSTAL	322	571	894	1474	997	1695	1797	1826	3757	1352	2740	7259	2057
GALLATIN	725	1467	1295	1518	2027	2042	2009	1880	3721	4297	3671	7483	2678
HARRINGTON	772	817	1424	1686	1958	1788	1941	1968	3917	3721	3959	8619	2714
ID810274	654	1043	1182	.	2160	.	.	.	.	3869	3698	8124	.
LEWIS	836	1349	1232	1599	2017	1979	2295	2121	3976	3974	4100	8632	2842
MELTAN	817	1379	1429	1603	2099	2027	2465	2301	3843	4375	4015	8551	2909
TARGHEE	788	1127	1135	1617	1861	1877	2007	2116	3633	3570	3643	8357	2644
6-ROW													
306-B	.	.	.	.	.	.	.	.	.	.	.	9144	.
307-B	929	1503	1352	1485	1710	1621	2578	2371	2650	3374	4144	8153	2656
9589-87	452	823	998	.	1088	.	.	.	.	3879	3650	7876	.
9593-87	371	779	1002	1373	920	1592	2296	2024	3071	3961	3694	8030	2426
9605-87	536	951	1005	1307	1226	1812	2615	2140	2744	3646	4105	8489	2548
9908-89	669	1116	1101	1645	1404	1497	2147	2269	3165	3427	3932	7766	2512
COLTER	908	1382	992	1447	1727	1511	2396	2501	2574	3172	4180	9750	2733
COLUMBIA	.	.	.	.	.	.	.	.	.	.	.	9054	.
ID22322	694	1037	1213	.	1283	.	.	.	.	3384	3436	7976	.
MARANNA	890	977	1146	1322	1361	1482	1673	2245	2588	3525	4160	10024	2616
MEDALLION	.	.	.	.	.	.	.	.	.	.	.	9879	.
MOREX	782	1320	1043	1413	1356	1663	2002	1851	2760	3426	3860	6330	2317
NANCY	.	.	.	.	.	.	.	.	.	.	.	8429	.
RUSSELL	901	1455	1077	1176	1829	1560	2335	2390	2899	3613	3927	7679	2570
STANDER	759	1312	1071	1204	1715	1250	2147	2273	2903	3393	4028	7714	2497
STEPTOE	932	1500	1020	1719	1539	1898	2626	2405	2868	3861	4362	9218	2829
NURSERY MEAN	734	1110	1207	1535	1667	1789	2129	2130	3432	3703	3898	8334	
CV (%)	13.8	17.5	16.4	12.3	25.2	20.5	9.2	12.0	10.3	20.5	10.4	8.7	
LSD @ .10	119	228	233	223	501	433	232	300	418	894	477	869	

1994 WSU SPRING BARLEY VARIETY TRIALS

TEST WEIGHT (LBS/BU)

VARIETY	DUSTY	BICKLETON	DAYTON	LIND DRY	LAMONT	MAYVIEW	REARDAN	FAIRFIELD	PULLMAN	ST. JOHN	FARMINGTON	MOSES LAKE	AVERAGE
2-ROW													
16277-85	41.1	44.9	38.6	47.1	41.5	47.9	47.5	44	51.3	50.1	48.5	52.1	45.6
7758-89	41.8	46.9	40.1	47.4	43.5	46.9	47.6	44.6	50.3	49.8	49.4	53.4	46.3
9035-84	43.3	46.6	40.8	47.6	42.7	47.2	48.4	46.2	50.2	50.4	49.4	52.2	46.7
9448-83	41.8	44.7	38.3	45.6	41.8	46.1	45.6	43.3	49.0	48.2	47.2	52.3	45.1
BARONESSE	44.8	48.8	41.9	48.1	43.0	52.0	47.6	44.8	50.4	50.2	50.4	53.5	47.7
CAMELOT	45.9	47.6	43.6	49.2	45.9	50.4	50.5	46.5	52.3	52.5	51.7	54.0	48.7
CRYSTAL	41.4	46.9	38.8	47.3	44.2	48.8	47.6	45.5	49.7	52.0	49.2	54.0	46.8
GALLATIN	42.4	45.6	39.0	48.4	43.8	49.8	48.5	47.7	51.8	52.7	51.6	53.9	47.3
HARRINGTON	42.2	45.2	39.1	46.1	41.8	47.4	45.3	43.0	49.4	49.4	50.0	52.7	45.8
ID810274	41.4	45.1	37.6	.	40.9	.	.	.	.	50.3	48.9	52.1	.
LEWIS	44.3	47.5	41.3	48.7	45.1	49.8	51.5	47.8	52.1	51.3	51.6	54.1	48.2
MELTAN	45.1	47.0	39.0	49.6	42.0	47.8	51.5	44.4	51.3	50.9	50.6	53.6	47.2
TARGHEE	41.6	44.6	39.4	47.7	43.1	48.1	49.7	43.9	50.3	49.3	50.0	53.2	46.2
6-ROW													
306-B	.	.	.	.	.	.	.	.	.	.	.	49.3	.
307-B	41.3	41.8	37.4	49.0	41.8	45.6	49.4	46.0	46.2	47.5	48.4	49.8	44.5
9589-87	36.7	39.3	30.5	.	35.5	.	.	.	.	44.8	44.0	49.0	.
9593-87	36.7	39.9	31.4	41.6	35.6	41.0	42.5	38.8	44.1	44.5	43.3	49.0	40.3
9605-87	36.7	41.2	33.1	44.1	36.1	42.4	46.8	42.4	42.9	45.0	46.1	49.1	41.4
9908-89	37.1	41.8	34.0	44.4	37.1	44.8	47.0	41.1	45.1	46.2	48.2	48.8	42.3
COLTER	38.8	38.2	33.3	45.2	38.6	41.3	47.3	41.0	45.4	45.3	47.6	50.3	42.2
COLUMBIA	.	.	.	.	.	.	.	.	.	.	.	48.5	.
ID223222	41.2	41.3	38.9	.	37.2	.	.	.	.	46.7	47.0	50.4	.
MARANNA	40.7	41.7	35.3	43.3	38.6	43.5	42.3	38.9	42.5	43.9	45.4	50.8	42.3
MEDALLION	.	.	.	.	.	.	.	.	.	.	.	51.5	.
MOREX	39.5	40.9	34.2	45.6	36.0	45.0	44.3	45.4	46.3	47.7	48.9	50.5	42.9
NANCY	.	.	.	.	.	.	.	.	.	.	.	53.1	.
RUSSELL	41.7	38.9	35.0	48.4	39.3	45.7	49.9	42.3	45.1	47.9	48.5	50.3	43.6
STANDER	41.6	41.6	35.0	48.6	39.0	43.9	49.5	43.9	44.9	49.3	49.5	51.6	44.4
STEPTOE	39.3	38.1	34.0	45.0	39.2	39.3	42.5	42.4	43.6	44.2	44.9	48.9	41.4
NURSERY MEAN	41.1	43.5	37.2	46.7	40.6	46.2	47.5	43.9	48.0	48.5	48.5	51.5	
CV (%)	4.5	3.0	4.0	-	4.0	-	-	-	-	2.5	2.0	0.9	
LSD @ .10	2.2	1.5	1.8	-	1.9	-	-	-	-	1.4	1.1	0.6	

1994 SPRING BARLEY ON-FARM VARIETY TESTING RESULTS

Baird Miller, Agronomist
Steve Ullrich, Plant Breeder

The spring barley on-farm variety testing program was successfully continued in 1994. The success of this program has depended on the active participation from growers, industry and Washington State University (see Table 1 for a list of participants). This past year more than 30 growers seeded the variety strip trials and 29 trials were harvested. Chuck Goemmer, with Washington State Crop Improvement Association, and Keith Bailey, with Great Western Malting Company, acquired the certified seed for the trials. The certified seed was donated by Whitman County Grain Growers, Spectrum Crop Development, W.F. Wilhelm and Sons, Oakesdale Grain Growers, Rosalia Producers, and Great Western Malting Co. The seed was distributed by the Ritzville Warehouse. Larry Morrow, from Nu Chem, provided complementary soil testing for interested growers. The county coordinators from 10 counties coordinated the seed delivery, data and grain sample collection, and distribution of results. Ron McClellan and several county NRCS and county agents spent a tremendous amount of time sampling the trials to document the straw production of the individual varieties. Baird Miller, Steve Ullrich, Pat Reisenauer, and David Hooks, from Washington State University, handled the grain processing (test weight, protein, plump and thins), data analysis and summary. Mary Palmer-Sullivan, representing the Washington Barley Commission, was responsible for the overall coordination and communication of the program.

Five standard varieties were included at all testing sites: Steptoe, Crest, Camelot, Harrington, and Baronesse. Each county had the option of adding varieties of their choice. Great Western Malting provided several malting varieties to interested participants.

The growers participating in this program were asked to establish the drill strips so that the strips traversed (or ran perpendicular to) the natural variability (soils and terrain) in the field. This way all the varieties would uniformly include the variability in the field and approximate the average conditions of a given field. It was also critical that the placement of varieties in the field did not favor or penalize a particular variety. For example, it was recommended that the drill strips not border a weedy fenceline or bottomland area. The drill strips were typically wider than the combine header width and ran from 800 to 2,500 feet in length. The drill strips were harvested with the grower's combine and weighed individually with weigh wagons or portable weigh scales. A grain sample from each variety was taken for processing at WSU.

The grain yield, test weight, and grain protein from this year is summarized in tables 2-4. The grain yield, test weight, and grain protein is summarized for the past five years of the program in tables 5-7. The statewide averages for the straw production and residue:grain ratios is shown in table 8. For the results of the individual counties, contact your local county coordinator or county agent.

The spring barley on-farm variety testing program will continue in 1995. The statewide leadership and coordination will remain the same. This year's varieties will be Steptoe, Crest, Harrington, Camelot, Baronesse, and Colter plus the county choices. Great Western Malting will provide seed of the malting varieties for interested growers. Larry Morrow of Nu Chem will provide soil tests for interested growers. NRCS also has agreed to assist us with the collection of straw samples.

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

Table 1. 1994 Spring Barley On-Farm Variety Testing Participants.

Statewide Organization:

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

Contributors of Certified Seed:

BARONESSE:	Keith Becker, Whitman County Grain Growers, Inc.
CAMELOT:	Curtis Hennings/Andy Thostenson, Spectrum Crop Development Corp.
CREST:	Edgar Wilhelm, W.F. Wilhelm & Son, Inc.
HARRINGTON:	Mark Johnson, Oakesdale Grain Growers, Inc.
STEPTOE:	Dan Curtis, Rosalia Producers, Inc.
MALTING:	Keith Bailey, Great Western Malting Company

Storage and Distribution of Seed: Gale Gordon and Gary Reilly, Ritzville Warehouse Co.

Soil Testing: Larry Morrow, Nu Chem

County Coordinators:

Adams:	Curtis Hennings
Asotin:	Frank Johnson
Columbia:	Roland Schirman
Garfield:	Dave Bragg and David Ruark
Kittitas:	Tom Hoffman
Klickitat:	John Fouts
Lincoln:	Tom Schultz and Fred Fleming
Spokane/ Stevens:	Jerry Scheele and Paul Peterson
Whitman:	Keith Becker

Grower Cooperators:

Adams:	Curtis Hennings, Allen Jones
Asotin:	Frank Johnson, Carroll Johnson, Pat Wolf
Columbia:	Jay Penner, Broughton Land Co. (George Wood), Jay Takemura
Garfield:	David Ruark, Scott Seed Farm, Tom Herres, Gary Houser, Roger and Mary Dye
Kittitas:	Pat Clerf
Klickitat:	Tex and Neal Brown, Dale and Glenda Bowdish, A.C. Goddard, Bud Story, Stephen Naught
Lincoln:	Tom Schultz, Dale Dietrich, Cliff Carstens
Spokane/ Stevens:	Gerald Scheele, Hal Meenach, Maurice Piersol, Dennis Miller, Dick Christensen, Don Berger, Gary Gibson, Glenn Wolf, Merrill Ott, Ed Machtemes
Whitman:	Mark Hall, Pete Swannack, Joe Schmick, Schroetlin Bros.

Table 2. Yield performance for the 1994 spring barley on-farm variety trials, summarized among production zones.

Variety	Production Zone (lbs/acre) < 2000	2000-3000	>3000	Average
	Yield (lbs/acre)			
Baronesse	1486	2612	4328	2029
Camelot	1451	2406	3887	1913
Crest	1350	2361	3656	1817
Harrington	1238	2345	3595	1737
Steptoe	1464	2441	4329	1967
Average	1398	2433	3959	1892
# Locations	16	7	2	25

Table 3. Test weight for the 1994 spring barley on-farm variety trials, summarized among production zones.

Variety	Production Zone (lbs/acre) < 2000	2000-3000	>3000	Average
	Test Weight (lbs/bu)			
Baronesse	45.7	46.7	51.9	46.5
Camelot	47.0	47.6	52.5	47.7
Crest	45.5	48.2	52.8	46.8
Harrington	44.0	45.9	50.5	45.2
Steptoe	40.7	42.5	47.6	41.8
Average	44.5	46.2	51.0	45.6
# Locations	14	7	2	23

Table 4. Grain protein for the 1994 spring barley on-farm variety trials, summarized among production zones.

Variety	Production Zone (lbs/acre) < 2000	2000-3000	>3000	Average
	Grain protein (%)			
Baronesse	15.6	12.4	11.2	14.2
Camelot	16.1	12.6	11.9	14.7
Crest	15.7	12.1	12.0	14.2
Harrington	16.0	12.7	12.6	14.7
Steptoe	13.7	10.9	10.2	12.6
Average	15.4	12.1	11.6	14.1
# Locations	14	7	2	23

Table 5. Historical yield performance for the spring barley on-farm variety testing program.

Variety	1994	1993-94	1992-94	1991-94	1990-94
	Years				
	Yield (lbs/acre)				
Baronesse	2029	.	.	.	.
Camelot	1913	2804	2589	2754	2717
Crest	1817	2569	2429	2608	.
Harrington	1737	2726	2514	2660	2631
Steptoe	1967	2765	2627	2817	2812
Average	1893	2716	2540	2710	2720
# Locations	25	52	78	118	152

Table 6. Historical test weight for the spring barley on-farm variety testing program.

Variety	1994	1993-94	1992-94	1991-94	1990-94
	Years				
	Test weight (lbs/bu)				
Baronesse	46.5*	.	.	.	.
Camelot	47.6	50.1*	49.7*	50.8**	50.4**
Crest	46.9	49.0*	48.6*	50.1*	.
Harrington	45.1	48.1	47.9	49.2	48.7
Steptoe	41.9	44.3	44.2	45.8	45.5
Average	45.4	46.2	46.1	47.5	47.1
# Locations	24	51	77	117	151

* - # of observations is 1 less than shown
** - # of observations is 2 less than shown

Table 7. Historical grain protein for the spring barley on-farm variety testing program.

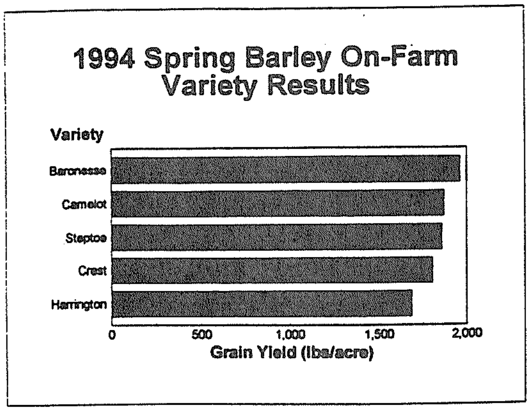
Variety	1994	Years 1993-94	1992-94
	Grain protein (%)		
Baronesse	14.2*	.	.
Camelot	14.8	12.8*	13.0**
Crest	14.2	12.5*	12.8*
Harrington	14.8	12.7	12.8
Steptoe	12.6	10.9	11.2
Average	14.1	11.8	12.0
# Locations	24	50	74

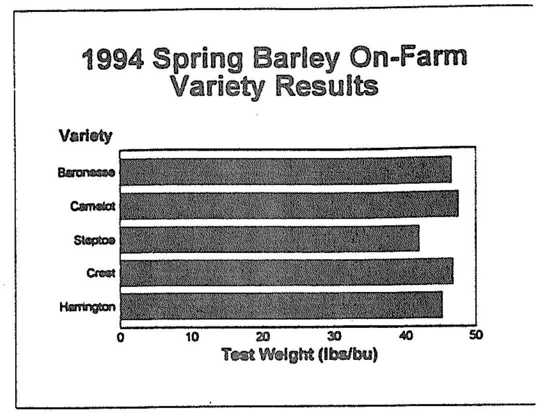
* - # of observations is 1 less than shown

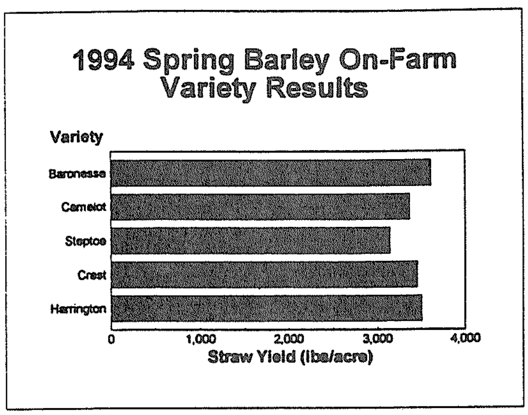
** - # of observations is 2 less than shown

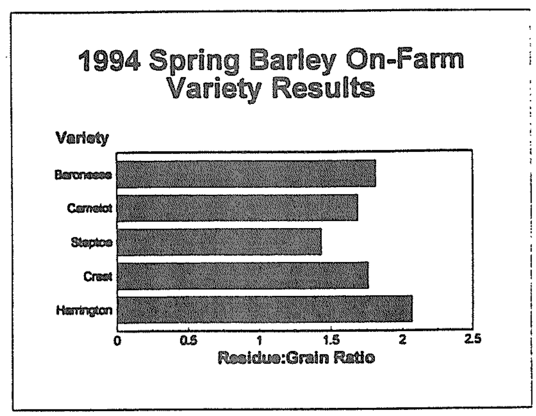
Table 8. Residue production summary for the 1994 spring barley on-farm variety trials.

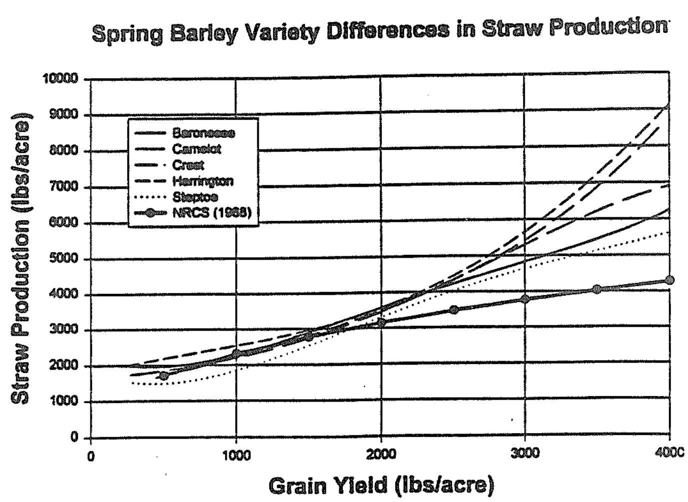
Variety	Straw Yield	Harvest Index	Residue: Grain
	lbs/acre	ratio	ratio
Baronesse	3607	0.39	1.65
Camelot	3406	0.39	1.67
Crest	3415	0.39	1.68
Harrington	3522	0.37	1.86
Steptoe	3161	0.44	1.37
Average	3422	0.39	1.64
Samples	125	125	125


1994 Spring Barley On-Farm Variety Results
Variety
Baronesse
Camelot
Steptoe
Crest
Harrington
0
500
1,000
1,500
2,000
Grain Yield (lbs/acre)


1994 Spring Barley On-Farm Variety Results
Variety
Baronesse
Camelot
Steptoe
Crest
Harrington
0
10
20
30
40
50
Test Weight (lbs/bu)


1994 Spring Barley On-Farm Variety Results
Variety
Baronesse
Camelot
Steptoe
Crest
Harrington
0
1,000
2,000
3,000
4,000
Straw Yield (lbs/acre)


1994 Spring Barley On-Farm Variety Results
Variety
Baronesse
Camelot
Steptoe
Crest
Harrington
0
0.5
1
1.5
2
2.5
Residue:Grain Ratio


Spring Barley Variety Differences in Straw Production
Straw Production (lbs/acre)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Baronesse
Camelot
Crest
Harrington
Steptoe
NRCS (1988)
0
1000
2000
3000
4000
Grain Yield (lbs/acre)

Yield (lbs/acre) Summary for the Spring Barley On-Farm Variety Testing Program

ADAMS COUNTY

VARIETY	1994	1993-94	1992-94	1991-94	1990-94
ALEXIS	1266	.	.	.	.
B-1202	1294	.	.	.	.
BARONESSE	1528	.	.	.	.
CAMELOT	1505	2073	1706	1959	1828
COLTER	1684	.	.	.	.
CREST	1226	1625	1328	1697	.
CRYSTAL	1131	.	.	.	.
DERKADO	1177	.	.	.	.
GALENA	1355	.	.	.	.
HARRINGTON	1402	1923	1446	1744	1644
MT140523	1437	.	.	.	.
STEPTOE	1779	1878	1560	1933	1805
AVERAGE	1399	1875	1510	1833	1759
#LOCATIONS	1	4	6	9	10

ASOTIN COUNTY

VARIETY	1994	1993-94	1992-94	1991-94	1990-94
B-1202	1441	.	.	.	.
BARONESSE	1739	2757	.	.	.
CAMELOT	1472	2420	.	.	.
COLTER	1528	2472	.	.	.
CREST	1666	2501	.	.	.
GALENA	1499	.	.	.	.
HARRINGTON	1408	2443	.	.	.
MT140523	1611	.	.	.	.
STEPTOE	1592	2612	.	.	.
AVERAGE	1551	2534			
#LOCATIONS	3	6			

COLUMBIA COUNTY

VARIETY	1994	1993-94	1992-94	1991-94	1990-94
BARONESSE	1893	.	.	.	.
CAMELOT	2038	3201	2799	2913	.
CREST	1804	2713	2616	2728	.
HARRINGTON	1626	3160	2773	2850	.
STEPTOE	1674	2902	2808	3038	.
AVERAGE	1807	2994	2749	2882	
#LOCATIONS	2	4	7	9	

GARFIELD COUNTY

VARIETY	1994	1993-94	1992-94	1991-94	1990-94
BARONESSE	1864	.	.	.	.
CAMELOT	1707	2486	2317	2641	2763
CREST	1574	2357	2153	2532	.
GALLATIN	1720	.	.	.	.
HARRINGTON	1577	2425	2213	2537	2582
STEPTOE	1835	2641	2487	2832	2929
AVERAGE	1713	2477	2293	2636	2758
#LOCATIONS	5	9	13	18	21

KLICKITAT COUNTY

VARIETY	1994	1993-94	1992-94	1991-94	1990-94
BARONESSE	1345	.	.	.	.
CAMELOT	1200	2233	1981	1788	1828
COLTER	1304	2124	.	.	.
CREST	1224	2042	1790	1672	.
HARRINGTON	1052	1951	1696	1515	1594
STEPTOE	1333	2294	2063	1851	1882
AVERAGE	1243	2129	1883	1707	1768
#LOCATIONS	4	8	10	14	19

LINCOLN COUNTY

VARIETY	1994	1993-94	1992-94	1991-94	1990-94
B-1202	1464	.	.	.	.
BARONESSE	1888	2584	.	.	.
CAMELOT	1770	2404	2123	2499	2356
CREST	1696	2269	1987	2346	.
CRYSTAL	1500	.	.	.	.
HARRINGTON	1422	2209	1848	2283	2178
MT140523	1726	2514	.	.	.
STEPTOE	1939	2559	2202	2552	2427
AVERAGE	1676	2423	2040	2420	2320
#LOCATIONS	3	5	8	14	22

SPOKANE COUNTY

VARIETY	1994	1993-94	1992-94	1991-94	1990-94
BARONESSE	2467	.	.	.	.
CAMELOT	2341	3172	2674	2779	2804
CREST	2204	2895	2480	2598	.
HARRINGTON	2273	3173	2692	2720	2754
STEPTOE	2216	2777	2395	2565	2726
AVERAGE	2300	3004	2560	2666	2761
#LOCATIONS	5	9	14	21	29

WHITMAN COUNTY

VARIETY	1994	1993-94	1992-94	1991-94	1990-94
BARONESSE	3741	4677	4495	.	.
CAMELOT	3740	4149	3881	3836	3709
CREST	3365	3722	3789	3694	.
HARRINGTON	3409	4176	3984	3892	3799
STEPTOE	3931	4092	4150	4058	4020
AVERAGE	3637	4163	4060	3870	3843
#LOCATIONS	2	6	11	21	28

BREEDING DIMENSIONS OF PALOUSE GRAIN LEGUME CROPS

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

The Grain Legume Breeding Program is focused on producing new improved cultivars of dry pea. lentil, chickpea and Austrian winter pea. Industry is demanding a wide range of types within each crop. These types must be environmentally adapted, high yielding, and market acceptable. Meeting these demands has necessitated accelerating the breeding process. An increased use of greenhouse screening techniques of early generation breeding material coupled with intense field screening of selected material has resulted in dramatically reducing the overall time from initial parental selection and cross pollinations through to cultivar release. The breeding efforts directed at each of these crops are described below.

Dry Peas:

Dry peas are an important rotational crop to the cereals in the Palouse region of eastern Washington and northern Idaho. The crop provides an alternative to the cereal grains and is considered necessary in order to break disease cycles, improve weed control and fertility status of the soils. The crop is attacked by a number of diseases of which root rots, wilts, viruses and powdery mildew can be of epidemic proportions. Currently, the dry pea crop is made up of 80% round smooth seeded green types (typical of "Alaska" peas). The remainder is made up of smaller seeded green types ("small sieves") and large yellow-seeded types. The principal quality factor for the smooth green types is good color retention and resistance to seed bleaching. Cultivars are needed which will retain their dark green cotyledon color even though moist conditions known to be conducive to seed bleaching may occur. Progress has been made under previous industry supported projects in the development of dry pea lines with multiple disease resistance, particularly to root rot, wilt, powdery mildew and viruses (mainly bean leaf roll and pea enation mosaic).

Progress is also being made in developing lines with greater resistance to seed bleaching and with darker green seed coats. The method currently in use in the greenhouse and laboratory to identify good color qualities of the seed coats and cotyledons is working exceptionally well. Selections made using those techniques have shown marked improvement in color qualities. Those lines, and additional lines to be identified using that screening procedure, will provide the industry the quality and disease resistance needed to remain competitive in world markets.

An improved yellow pea variety is needed to replace Umatilla because of the problems that have developed with seed coat cracking in some years. Lines with good seed size and color and with resistance to diseases, including powdery mildew, Fusarium wilt and viruses, have been identified and are currently being tested. Those lines, and additional lines to be identified in the crosses now being evaluated in the breeding program, will provide the industry the needed varieties of yellow peas. During the recent tour of markets in the Orient, it was determined that there is a demand for exceptionally large seeded yellow peas. The direction of the breeding program has gone toward the development of larger seeded types.

The dry pea and lentil industry is in need of marrowfat varieties of dry peas that can be grown in the Palouse region of eastern Washington and northern Idaho. The marrowfat type is typified by large green flattened seeds that weigh at or above 30 grams per 100 seeds. The type is in demand in markets in the orient where they are used to make snack items that have become popular in that region. Marrowfats are also used for canning and for sprouting. A market assessment visit to the Orient sponsored by the USA Dry Pea and Lentil Council was made in the fall of 1994, and at that time it was clear that there is a growing demand for marrowfat types in that region. In addition to the present demand, the potential in Indonesia for marrowfats could greatly expand with the increasing population and a growing demand for snack items. As a result of the findings of that visit, the following recommendations were made concerning marrowfat types: 1) Develop marrowfat germplasm and varieties for use in the Palouse region that have exceptionally large seeds. Place greater emphasis on seed size than on color, because that region can add artificial color during processing. 2) Investigate harvesting procedures that will ensure good color and a minimum of mechanical damage.

During the 1994 field season, advanced green pea selections were compared, in replicated yield trials, to standard cultivars at Pullman and Farmington, WA, and at Genesee, ID. Yields of green pea selections in the trials were depressed because of the extremely hot and dry conditions during the past spring and summer. The advanced yield trial contained 13 breeding lines and 5 check varieties. Of the 13 breeding lines, five (PS210308, PS110028, PS010376, PS210377 and P5810106) were significantly higher yielding over the three locations when compared to the checks. These five lines had resistance to powdery mildew and Fusarium wilt race 1. Because of the hot and dry conditions, virus diseases were not serious in 1994, possibly due to poor survival of aphid vectors. The most promising of the five lines appeared to be PS210308 because of relatively high yields and earliness. Quality evaluations indicated that PS210308 has large seeds (100 seeds weigh about 22g compared to 19.4g for Columbian). Other quality traits of PS210308 indicate a high percentage water uptake, low hard seed percentage, a fast cooking time, and good color when compared to the check. Another line that performed well was PS010376 for both yield and quality. PS810106 had performed very well over the past three years, and we had increased the line in anticipation of release this year; however the line did not perform well in the hot and dry season of 1994, and consequently, we will need to reevaluate the line and whether or not to proceed with a release. The most promising line (PS210308) appears to be significantly superior to PS810106 for yield, earliness, and color to warrant proceeding with that line instead of PS810106. Single plant selections of PS210308 and PS110028 are available.

The preliminary yield trial for green pea selections contained 17 breeding lines and 3 check varieties and was planted only at Pullman. All of the lines had resistance to powdery mildew except for the three checks. Of the 17 breeding lines, two were significantly higher yielding when compared to the three check varieties. The highest yielding line (PS210246) had good resistance to bean leaf roll virus; however ,the quality evaluations indicated that the color of the line was fairly light. The other line (PS210370) that was significantly higher yielding when compared to the checks had good green color and was also significantly larger seeded. The preliminary screening nursery contained 72 green pea selections that were being evaluated for the first time. Of those 72 lines, 32 were higher yielding when compared to the Alaska 81 check. Also, there was a considerable number of the lines that appeared to have resistance to bean leaf roll virus in the plots at Kimberly. Because of the hot and dry season in 1994, many of the lines in the nursery will need to be reevaluated in 1995. Early generation material was selected in the greenhouse and laboratory for resistance to powdery mildew, earliness, and resistance to seed bleaching and other seed quality traits. Early generation breeding lines were screened at Corvallis, OR for resistance to pea enation mosaic virus and at Kimberly, ID for resistance to bean leaf roll virus. Resistance to Fusarium wilt was determined in the wilt nursery at Spillman Farm. Evaluations for resistance to common root rot were conducted by John Kraft at Prosser.

Two marrowfat type lines (PS210333 and PS210332) were tested in the preliminary yield trial in 1994. The lines were selected for adaptation to Palouse conditions and for good marrowfat type and good color. The lines were significantly lower yielding when compared to the checks, and it appears that they were adversely affected by the hot and dry conditions in 1994. An expanded crossing program for the marrowfat type was initiated in the summer of 1994 with the objective of developing a marrowfat variety for the Palouse. These additional crosses and the marrowfat crosses made in 1993 are being evaluated and selected in the greenhouse this winter to provide selections for evaluation in the field in 1995.

Advanced yellow pea selections were compared to standard cultivars in 1994 at Pullman and Farmington, WA, and at Genesee, ID. Two of the lines (PS010603 and PS010598), which appeared to be excellent candidates to replace Umatilla in 1993, did not perform as well as expected. Both lines have resistance to powdery mildew, a disease which was especially prevalent throughout the Palouse in 1993. PS010603 was the largest seeded of the lines in the trial. Several lines performed well in the hot and dry season in 1994 including PS110374, Rex, and Umatilla. Both Rex and Umatilla are susceptible to powdery mildew, and Rex is susceptible to Fusarium wilt. Quality evaluations indicate that PS110374 has larger size and good color when compared to the checks and PS010603. We have begun to develop breeder seed of PS010603 and PS010598, but we will need additional data on performance before either of the lines can be recommended for release. In addition to these two lines, we plan to develop breeder seed of PS110374 in the coming year. Single plant selections of PS010603, PS010598, and PS110374 are available.

The preliminary yield trial for yellow pea selections contained six breeding lines and two check varieties. Three of the lines were higher yielding, and two of the lines had good resistance to bean leaf roll virus. The six breeding lines had resistance to Fusarium wilt and powdery mildew; and they had good seed size and color. Two of the lines (PS210387 and PS210389) had the semi-leafless trait and were dwarf types. Nine yellow seeded lines were evaluated in the preliminary screening nursery in 1994, and of those lines, PS310584 was the highest yielding.

Emphasis in 1994 was placed on selecting green and yellow peas lines with resistance to powdery mildew and several viruses, particularly bean leaf roll and pea enation mosaic. Crosses and backcrosses were made between advanced lines of green and yellow peas with germplasm lines containing multiple virus resistance. The resulting hybrids were grown in the greenhouse and the progenies were screened in the field for resistance to pea enation mosaic and pea leaf roll viruses. The virus screening trials conducted at Corvallis, OR and Kimberly, ID this past season were successful in identifying a number of lines with multiple resistance to several viruses. Those lines have been increased in the greenhouse and will be evaluated in 1995.

PS110028 and PS210308 are the best candidates for release of an improved green dry pea with good dark green color and significantly higher yields. PS010603 and PS010598 yellow pea lines have performed well in previous years but it now appears that PS110374 has emerged as the most promising yellow pea line for possible release in the near future.

Lentils:

The lentil industry of the U.S. competes in the world market and must have cultivars that produce acceptable quality of the various market classes. For that reason, varieties with improved yields and crop quality are essential to maintaining and improving competitiveness. Until very recently, the Palouse region produced only one type of lentil, the so-called Chilean type ('Brewer') with large yellow cotyledons. Indications now are that several types can be produced and sold in various markets both domestically and world-wide. Indications are that an exceptionally large yellow seeded lentil with uniformly green seed coats is needed by the industry to compete in markets in the Mediterranean region. In addition to a large yellow lentil variety, the industry would benefit from a small typically Turkish red type of lentil.

Recent priorities set by the industry with respect to the different types of lentils are as follows:

1. Yield and Disease Resistance (highest priority) We are approaching this priority by first identifying resistance to two viruses that seem to be problems most seasons. These are pea enation mosaic virus and bean leaf roll virus. We have identified sources of resistance to pea enation and have begun to incorporate that resistance into breeding lines. Other than through virus resistance, lentil yields are not likely to increase unless we can significantly increase biomass. This is being approached through germplasm evaluations where we are looking for genetic types that will produce biomass at faster rates. Increased biomass should also help with the residue problem growers are faced

   with in meeting conservation compliance requirements. Increased yields will result from increased biomass and better resistance to viruses.

2. Larger Green Lentil (highest priority) Based on the trip to the Mediterranean area in 1993, it was apparent that we need to develop a large seeded lentil variety that will compete favorably with the Laird lentil from Canada. Therefore, we have made a series of crosses that are designed to lead to selections in the 7-8mm category. Quality characteristics need to be taken into account during development. An 8mm diameter lentil will likely be about 7 days later maturing than Brewer in order to produce the biomass and yields necessary to be competitive.

3. Turkish Red Lentils (high priority) Crosses for the development of a Turkish red lentil have been made using Turkish germplasm that was evaluated in the field in 1993. The development of a Turkish red lentil is well underway. Quality factors will be taken into account during the selection process.

4. Eston Type Lentil (high priority) We currently do not have any work underway toward development of an Eston type lentil although we have numerous crosses using Eston. Those crosses can be utilized for the selection of an Eston type.

5. Winter Lentil Variety (priority) We have work underway toward the development of winter lentils. Winter lentils would have to be sown into standing stubble or into a minimum tillage system in order to control soil erosion. Several hundred lines, which have been selected for desired seed types, are currently being evaluated in the field this winter. Lines with acceptable winter-hardiness will be evaluated for quality traits and also for yield. This area of work is being carried out at a low level of priority.

6. Brewer Lentil Type (strong maintenance program) We have been using the Brewer lentil in crosses designed to develop a replacement for that variety. Our objectives are to select a type in the Brewer size category but with better yields and better color.

7. Redchief Lentils (strong maintenance program) Currently, we are not working on a replacement for the Redchief lentil. We have used the line extensively in crosses, and it would be no problem to begin selection of lines for eventual replacement of that variety.

8. Small Spanish Browns (maintenance program) We have assisted in the development of a pure seed program for the Spanish Brown lentil. We have also made a series of crosses and selections for resistance to Ascochyta blight. Spanish Browns are highly susceptible to that disease, and the development of resistance should be a high priority for the industry.

9. Crimson Lentil (low priority) We have not been doing anything with the Crimson lentil except to use it as a check in the yield trials.

10. Emerald Lentil (low priority) This type has been a low priority for a long time. We are still carrying a few crosses that were made to increase the seed size and to develop an earlier maturing green cotyledon type variety.

11. Zero Tannin Lentil (low priority) This type of lentil has never been a high priority, but some effort has been placed on development of zero-tannin lines with either yellow, red or green cotyledons. In the future the industry may benefit from having zero-tannin varieties available for production.

One of the major yield constraints in lentil production is susceptibility to pod and seed shattering, which has been estimated to range from 15-50% throughout the region. Reducing seed shattering will have a major effect on improving yield and returns to farmers. Viruses are also a major problem in some years when populations of aphid vectors are favored by environmental conditions. Viruses such as pea enation mosaic and bean leaf roll can significantly reduce yields. Resistance to these viruses has been identified and is currently being incorporated into lentil breeding lines, but expanded effort in this area is needed.

During the 1994 field season, an advanced large yellow lentil yield trial of 20 selections and four standard cultivars as checks, was planted at Farmington and Pullman, Washington and at Genesee, Idaho. The hot and dry season depressed yields in all the trials. Eight of the lines were significantly higher yielding when compared to the Brewer check. One of these lines (LC060144) also performed well in 1993, and a preliminary increase of breeder seed was made in 1994. However, four other lines were higher yielding when compared to LC060144 and included LC960254, LC160008, LC960148 and LC060143. A decision will need to be made as to which of these lines to propose for increase of breeder seed. LC960254 is larger seeded when compared to the Brewer check and also was the highest yielding in 1993 and 1994. Cooking quality evaluations indicated no significant problems and that LC960254 and LC060144 cook in approximately the same time as Brewer, and the color after cooking was good in both 1993 and 1994. These two lines will be included in the 1995 trials in order to obtain additional data needed for a possible release proposal. The two lines will also be used in crosses designed to incorporate resistance to virus diseases. Evaluation of the lines in the Advanced Yield trial for residue production indicated the presence of genetic variation and that there is good potential for breeding for increased biomass production and increased residues.

Early generation selections were screened for tall upright plant habit, tolerance to viruses, biomass production, large uniform seed size with little or no mottling and blunt edged seeds. Fifty-four selections were included in the Preliminary yellow lentil yield trial that was planted only at Pullman. The 54 selections were compared to Brewer, Palouse, Emerald and Pardina. The hot and dry season made it difficult to evaluate the material in all the trials, and it will be necessary to carry forward many of the lines in the 1994 trial to 1995 to obtain a better assessment of performance. In spite of the difficult season, a number of the selections were promising for increased plant height, large seed size with the absence of mottling and high yield potential. The preliminary screening nursery had 107 selections of large yellow seeded types. Among the material were lines that had exceptionally high yields. These lines will be advanced to replicated yield trials this coming season. The lines were selected from progenies of various crosses and from material introduced from ICARDA. Most of the lines were selected for tolerance to viruses, large and uniform seed size and good color.

Work on red lentils was further reduced so that efforts could be concentrated on the more widely grown yellow lentil. However, a trial for red lentils consisting of six lines, inclusive of checks, was planted at Pullman. We have made progress in the development of a small red lentil which will be more like a Turkish small red. Of the small red lentil selections, LC660819 was significantly higher yielding when compared to Crimson and was about 7 cm taller. Also, LC660819 was about 10 days earlier to bloom when compared to Crimson. Work on the development of a small red Turkish type lentil will continue until such a line can be released.

Good progress was made in the development of a zero-tannin lentil, and samples of a number of selections have been distributed to potential users in order to obtain their reactions to this new type. It appears that a zero-tannin lentil will have a place in the canning industry because it will not darken as it ages or when it is canned. Selections have been made for large seed size and yellow cotyledons. Crosses have been made to develop zero-tannin lines with green and red cotyledons.

Two lines, LC960254 and LC060144, have performed very well in 1993 and 1994. LC960254 also performed well in 1992. These lines are being increased for possible release. LC960254 appears to have the highest yield potential and has good seed size and color. Quality evaluations have been conducted on both of these lines and they appear to be acceptable.

Chickpeas (Garbanzo Beans):

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

The international centers (ICARDA, ICRISAT) and other programs in places such as Morocco, Turkey, and Jordan have worked on Ascochyta blight resistance in chickpea and have developed, through breeding resistant germplasm. We have obtained most of the more promising accessions from those programs and have screened that material over the past six years. The material has excellent resistance to the disease and some of the lines have resistance to the pod infection phase; however, the accessions have mostly medium seed size and are later maturing. Yield potential of the resistant material is excellent and the yield improvements made with the releases of Sanford and Dwelley were significant. Hybridization of those lines, particularly those with resistance to pod infection is required in order to make full use of the germplasm.

Sanford, Dwelley and two other selections (CA188163 and CA188178) were compared to four check varieties and the germplasm sources of resistance to Ascochyta blight at three locations in 1994. The season was extremely hot and dry and the chickpea trials were adversely affected. Mean yields over all trials was only 668 kg/ha (about 600 pounds per acre) Sanford and Dwelley were significantly taller and higher yielding when compared to Surutato and the other check varieties. The improved plant height of Sanford and Dwelley is an added benefit and has made harvesting easier. Ascochyta blight was present in the yield trials at all three locations; and the checks, which are susceptible to the disease, were severely affected and yields were greatly reduced. The two selections in the trial performed very well and were similar in yield to Sanford and Dwelley. Dwelley was the largest seeded of the varieties and selections in the trials. Quality evaluations indicated that the hot and dry season affected the size of all the chickpea varieties in the trial. Dwelley however seemed to maintain seed size better than the others. Soakability and cooking times were good for both Sanford and Dwelley.

The desi trial of four lines including Sarah (also known as Tyson), Garnet, Myles and a line from ICRISAT in India was evaluated at three locations. Myles was higher yielding when compared to Sarah and Garnet and was larger seeded. Myles has significantly better resistance to Ascochyta blight and has excellent seed quality traits. Quality evaluations indicate that Myles cooks in approximately the same time as Sarah and Garnet.

Emphasis was placed on crosses and backcrosses designed to transfer resistance to Ascochyta blight to a large seeded Spanish White type suitable for the Spanish market. Those crosses were increased in the greenhouse and selected for size and shape of the seeds. The primary criteria in the selection process was for large and white seeds. The material is being increased to F_3 lines that will be evaluated in the Ascochyta blight nursery this coming spring. The main objective is to develop a white seeded Spanish White type with resistance to Ascochyta blight. Crosses were also made between Sanford and Dwelley, and germplasm which was identified as having good resistance to pod infection. Single plant progeny rows in the F_5 will be screened in the Ascochyta blight nursery at Spillman Farm in 1995. This past summer, over 1000 single plant rows of advanced (F_7 - F_8) material were included along with over 1000 earlier generation progenies. Ascochyta blight infected chickpea debris from the 1992 crop was uniformly distributed in the plot area as an inoculum source. Irrigation was provided to ensure good spread of the disease especially during the podding stage.

Myles desi type chickpea was released in 1994. Myles was obtained from ICRISAT and tested under the designation ICCX86047BP20HB. The line demonstrated excellent resistance to Ascochyta blight and has larger seeds. A good supply of seed should be available for planting in 1995.

Austrian Winter Peas:

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

In the fall of 1993, yield trials of Austrian winter pea selections were established at Spillman Farm at Pullman, WA. The advanced trial contained 10 breeding lines and four check varieties. All of the breeding lines in the advanced trial had the semi-leafless trait and improved standing ability. Most of the breeding lines were significantly higher yielding when compared to the checks. The highest yielding line, D258-1-2, was nearly 800 pounds greater than the Common or Melrose checks. D258-1-2 has been one of the highest yielding lines in the trials over the past 5 years, however, in 1993, yields were somewhat reduced possibly because of the unusually cold and wet season in 1993. D258-1-2 is a semi-leafless type that is taller than Melrose, Fenn or Glacier. Even though D258-1-2 is tall, the increased tendril number brought about by the semi-leafless trait provides good resistance to lodging along with increased air movement through the canopy and should provide an escape mechanism from Ascochyta blight and Sclerotinia white mold. Quality evaluations indicate that the hard seed percentage for D258-1-2 was lower than that of Glacier, Melrose, Fenn, and Common (for data see 1993 and 1994 reports). About 200 pounds of pre-breeder seed of D258-1-2 is available for planting in the spring of 1995 with anticipated release in 1995. Additional data on the winterhardiness of D258-1-2 should be available from the 1994-95 field trials.

Early generation Austrian winter pea breeding material was evaluated in the aphanomyces and Fusarium wilt nurseries at Spillman Farm in 1994. New selections were evaluated in the preliminary yield trial. Also, 50 new crosses were made in 1994 to add powdery mildew resistance, Aphanomyces resistance and virus resistance to Austrian winter pea types. These crosses have been increased in the greenhouse this past fall and will be further increased in the field in 1995. To improve the vine strength and standing ability of Austrian winter peas we have used 'Bohatyr' in the crossing program. Bohatyr, from Czechoslovakia, has exceptionally strong and woody stems that improve standing ability. The woody stem trait if combined with the semi-leafless trait should greatly improving standing ability and help avoid foliar diseases such as Sclerotinia white mold and Ascochyta blight and improve yields and crop quality. In addition, we have utilized sources of virus resistance in the crossing program in order to incorporate resistance to pea enation mosaic virus and bean leaf roll virus.

A small winter feed pea trial was conducted to evaluate two white flowered winter-hardy breeding lines for yielding ability when compared to Austrian winter pea varieties. The two lines in the trial had yields that were 250 to 400 pounds per acre higher than Melrose and Fenn. We have continued to select for white flowered winter pea types that could be used as a winter feed pea.

Winter lentils with good seed quality traits were selected from fall planted material. Those lines with good seed quality traits are being evaluated in nurseries planted this past fall.

D258-1-2, a semi-leafless type selection with good yield potential and with a plant structure that should improve standing ability has been released this winter. The improved standing ability should enable the variety to escape damage from foliar diseases such as Sclerotinia white mold and Ascochyta blight by allowing increased air movement throughout the canopy. The increased vine length should be an advantage for providing ground cover, green manure, and increased surface residues. Seed is being increased this summer.

WEED MANAGEMENT FOR INTEGRATED CROPPING SYSTEMS

Alex Ogg, Frank Young, and Steve Seefeldt of ARS-USDA
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Weeds such as downy brome, jointed goatgrass and Russian thistle are wide spread in Washington and each year they cost Washington farmers tens of millions of dollars in lost yield and control practices. Recently, kochia has begin spreading into the dryland regions of Washington. Although only a few fields are severely infested at this time, kochia has the ability to spread throughout all of the dryland wheat region and in 10 years may be one of the most troublesome weeds in spring grains and spring legumes.

Described below are some of the major weed science research projects we are conducting on these troublesome weeds.

DOWNY BROME

Downy brome (cheatgrass) is one of the most wide spread and troublesome weeds in winter wheat in Washington. It can increase rapidly on reduced tillage systems as its germination and seedling establishment are favored by straw lying on the soil surface. Depending on the environmental conditions, we estimate that 1,000,000 acres of winter wheat in Washington are infested with downy brome and that wheat yields are reduced 15% on an average of about 25% of the infested acres. Assuming a 50 bu/A average yield and a crop value of $3.50/bu, downy brome is costing Washington wheat producers $6.5 million annually in lost production and another $2.5 million in herbicide and application costs for a total of $9,000,000 per year.

Downy brome reproduces by seed only and the seed are relatively short-lived in the soil seldom surviving more than 2 to 3 years. Therefore, farming practices that enhance downy brome seed germination during fallow periods should reduce the soil seed bank and reduce competition with the next winter wheat crop. In 1994, we began a study to determine if postharvest tillage in August would enhance downy brome seed germination and/or decay during the fallow year in a winter wheat-fallow system. Tillages applied were shallow discing, spike-tooth harrowing, sweeps, and skewtreading. A no-till treatment was included for comparison. Soil in each treatment was sampled before and immediately after tillage in August and again in the spring just before the start of spring tillage. Emerged downy brome were counted in March and the plot area was sprayed with Roundup in early April. Standard farming practices will be used for summer fallow, making sure no downy brome are allowed to produce seed. After winter wheat is planted, downy brome will be counted in each post-harvest tillage treatment to determine the success of these practices in reducing the downy brome soil seed bank.

Although it is too early to make overall conclusions, we have made the following observations. Downy brome seed populations in the top 4.7 inches (12 cm) of soil ranged between 30 million and 100 million per acre. There were no significant differences in downy brome seedling populations during the fallow winter. The extremely dry fall in 1994 may have masked the effects of the tillage treatments. There was a significant amount of downy brome seed that persisted in the soil for more than one year. This study will be repeated in 1995-96 at a different site.

JOINTED GOATGRASS

Jointed goatgrass is another troublesome winter annual grass weed that infests an estimated 500,000 acres in Washington and is spreading in the dryland winter wheat producing region. It also reproduces only by seed, although seed can remain viable in the soil for 4 to 5 years in the drier regions. As few as 45 goatgrass plants per square yard can reduce winter wheat yields 25%. The current control recommendation for jointed goatgrass is to have three years of successive spring crops or fallow before planting winter wheat.

In 1993, we began following the population of jointed goatgrass in a heavily infested winter wheat field. Initially, there were an average of 8300 spikelets (joints) per square yard on the soil surface after wheat harvest. The field was burned in early September and the fire destroyed 93% of the joints lying the soil surface. The fire had no effect on the large number of joints buried in the soil. Following a full year of summer fallow (1994) there were 32 viable joints in the top 5 inches of a square yard, a population still large enough probably to reduce winter wheat yield significantly had winter wheat been planted. In February of 1995, there were 24 jointed goatgrass plants per square yard.

Based on the results of this monitoring study, field burning after a winter wheat crop followed by two years of spring crop/fallow can reduce jointed goatgrass seed viability by 99%. The field was sprayed, tilled and planted to spring wheat in March of 1995. The farmer plans to summer fallow before planting winter wheat. We will continue to monitor the field for jointed goatgrass joints in the soil and will count jointed goatgrass populations when winter wheat is planted in the fall of 1996.

Another jointed goatgrass study has been initiated (1992) to examine population dynamics of jointed goatgrass and subsequent interspecific competition between jointed goatgrass and no-till winter wheat. Two to 150 spikelets yd^{-2} were planted into no-till wheat following spring dry pea. To determine the rate of long-term increase of a jointed goatgrass infestation, data on weed population, biomass, spikelet production and spikelet shattering will be collected. Winter wheat yield and test weights will be measured. Total amount of jointed goatgrass spikelets produced in each density will be multiplied by the percent shattering that occurred. This shattered amount of spikelets for each area will be returned to that plot in the fall before planting the second year's winter wheat. With data from several populations of jointed goatgrass, a simulation model can be developed to predict economic thresholds or determine when growers should rotate to spring crops and avoid the large weed populations and subsequent poor yields of winter wheat. During the 1993-94 growing season when precipitation was 48% of the 30-year average, 4 jointed goatgrass yd^{-2} produced 335 spikelets whereas 85 plants yd^{-2} produced 5990 spikelets. Wheat yields were reduced $> 20\%$ when goatgrass populations were only about 12 plants yd^{-2}. High jointed goatgrass populations coupled with dry weather (1993-94) greatly reduced wheat yield when wheat followed wheat compared to when wheat followed pea.

COMPETITIVE WINTER WHEATS

In the fall of 1993, a study was initiated to evaluate the competitiveness of eight common winter wheat varieties against downy brome and jointed goatgrass. Crop and weed seed yield of each species will be determined as influenced by weed/crop interactions. The varieties Eltan, Madsen, Dusty, Lewjain, Basin, and Stephens (soft white winter wheats), Rhode (a club wheat), and Celia (a winter triticale) were selected based on their different morphological characteristics. All varieties were grown with and without high populations of downy brome and jointed goatgrass. The varieties were seeded at a constant density with a double disk drill. Weeds were hand sown in the blocks. After planting, growth and development of the wheat varieties and weeds were measured on a regular basis throughout the growing season. To be able to identify plant characteristics of a competitive wheat plant, data collected included leaf number, plant height, soil water removal, leaf area index, area biomass, yield components, and plant dry weight.

Results from the 1993-94 growing season, when precipitation was 52% less than the 30 year average, indicated that rapid early growth (height) combined with early maturation were important characteristics of competitive wheats. All of the varieties tested last year yielded similarly in the weed free treatment. Stephens, Madsen, Rhode and Celia were more competitive with downy brome than the other varieties. When competing with jointed goatgrass Stephens, Rhode, and Celia yielded two to three times more grain than the other varieties. When compared to the other varieties, Rhode and Celia reduced downy brome biomass the most and Celia reduced jointed goatgrass biomass the most.

RUSSIAN THISTLE

Russian thistle (Salsola iberica) is one of the most prevalent and expensive weeds to control in the intermediate and low-rainfall areas of eastern Washington. The weed infests an estimated 50% of the 2.2 million acres of wheat and costs over $3 million annually in lost crop yield and costs for control. Russian thistle is a problem in the growing wheat crop, following crop harvest, and during the summer-fallow year. In years with below-normal rainfall, Russian thistle can reduce crop yield more than 50% and generally reduces yield 30% in years with normal precipitation. A survey conducted in eastern Washington found that over half the sampled sites had Russian thistle plants resistant to chlorsulfuron and other sulfonylurea herbicides. Because of the widespread resistance to sulfonylurea herbicides, a new integrated weed management system for Russian thistle has been evaluated. The study utilized best management practices for in-crop, preharvest, and postharvest control of Russian thistle. A combination of in-crop and preharvest control almost eliminated weed competition and seed production.

An air-assisted sprayer is being evaluated presently for Russian thistle control. If successful, this technology will reduce herbicide use, carrier volume, and input costs. Very little research has been conducted with this technology in the PNW, especially in the drier regions where increased spraying efficiency and herbicide efficacy would be especially important.

KOCHIA

Kochia (*Kochia scoparia* (L.) Schrad.) is an aggressive annual weed which was introduced from Asia as an ornamental garden plant. It can produce over 20,000 seeds per plant and is capable of producing over 2 million seeds yd^{-2}. Kochia readily infests cultivated fields, roadsides, ditchbanks and other waste areas. This weed is well adapted to a wide range of climatic and environmental conditions and is known to compete with both irrigated and nonirrigated crops reducing significantly, yields at relatively low populations. Kochia competes effectively with crops for water, nutrients and light, but it also produces natural toxins which affect growth and development of crop plants. It has been a notorious problem in the Midwest and in the Rocky Mountain Region for several decades. It is prevalent in the irrigated areas of Idaho, eastern Oregon and the Columbia Basin of Washington, but has only been reported recently in the Palouse Region of Idaho and Washington.

This annual weed poses a great destructive potential in cereals, canola, peas, lentils and other crops grown in the Palouse Region. Mature plants can reach heights of 6 feet and cover a space of over a square yard. Kochia has the potential to grow, produce seed and extract soil moisture after a cereal crop has been harvested much like its close relative Russian thistle. Kochia is difficult to control with commonly used herbicides and has developed resistance to several sulfonylurea and triazine herbicides. The weed develops a high level of tolerance to phenoxy herbicides at a relatively early stage of growth. Growers and fieldmen should become familiar with the weed, eliminate existing infestations, clean combines after harvesting infested fields and plant clean seed to reduce spread to noncontaminated fields.

Weed scientists from the USDA-ARS, University of Idaho and Washington State University have initiated studies to both better understand the biology of the weed and to develop effective and economic control practices which can be integrated into cropping systems of the Palouse Region. Initially, herbicide treatments are being evaluated to determine rates and timing of applications, affect of herbicide treatments and kochia populations on crop yield / quality, and weed growth and seed production. Laboratory and greenhouse studies have been initiated to better understand the adaptability of kochia to the Palouse Region by determining environmental requirements, growth potential, and postharvest reproductive capability. In addition, the toxic effects of this annual weed on cereal crops is being studied.

While kochia is not a new weed in the United States, it is a relatively new introduction to the Palouse. Agriculturists should be concerned with this weed and begin to suppress the spread of this potential economically important plant while infestations are still manageable.

RUSSIAN WHEAT APHID MANAGEMENT IN DRYLAND WHEAT IN WASHINGTON

L. K. Tanigoshi, K. S. Pike and T. A. Murray

Mass Propagation, Release and Recovery of Russian Wheat Aphid Parasitoids

Cereal aphid predators and parasitoids play a role, sometimes a significant role , in controlling aphids in Washington. However, more often than not, the value of these natural enemies is not recognized at the farm level. Studies are in progress to document these natural enemies, their bio-effectiveness, and abundance across seasons and locations. The use biological agents to control cereal aphids, especially the Russian wheat aphid (RWA), in Washington and other western states has been of high interest and has led to numerous searches for aphid natural enemies in Old World environments. WSU has been especially active in the Middle East because of the low frequency of cereal aphid problems there, attributed in part, to biological control. Of the bioagents collected, mass propagated, and released, a majority have been parasitoids.

The biogeography and aphid-habitats that sustain beneficials year-round in the arid and semi-arid steppe grasslands and small grains of the Middle East and Morocco have been characterized as part of a joint effort between WSU, International Center for Agricultural Research in the Dry Areas (ICARDA, Syria), Cukarova University, Turkey, and Mid-American International Agricultural Consortium (MIAC, Morocco). Successful establishment and maximum impact of these exotic agents on target aphids in Washington is expected in areas that match, in part or in whole, original collection sites. Parameters of climate, latitude, habitat, precipitation, and temperature associated with Morocco, the lowlands and highlands of Jordan and Syria, and the Anatolian Plateau of south-central Turkey are, in many ways, comparable with the low rainfed agroecozones of eastern Washington. Scientific partnerships and continued discovery are needed to reference indigenous and introduced species with elevation, cropping and intercropping systems, noncropping habitats, and climate in Old and New World settings as a basis for finding ways to enhance current levels of biological control.

A new Northwest Biocontrol Insectary & Quarantine facility (NWBIQ), developed by WSU-Department of Entomology and College of Agriculture and Home Economics (CAHE) at Pullman, is affording opportunity to establish a large repository of RWA natural enemies for biological control use, and to expand research efforts on several biological fronts. The NWBIQ represents one of four main centers in the United States where RWA aphidophages are held live. Founder populations are available for research and applied use upon request.
This large gene pool of natural enemies maintained by NWBIQ and others represents not only a commitment by U.S. scientists to utilize a complex of beneficial species to control cereal aphids, but also a wide national and international collaborative exploration and collection effort.

Beginning in early 1987, NWBIQ has propagated nearly 3.5 parasitoids or micro-wasps representing species in the hymenopterous families Aphidiidae and Aphelinidae through 1994. During spring/summer of 1994, NWBIQ insectary propagated more than 451,000 parasitic wasps that commonly parasitize RWA. Respective field release levels included *Aphelinus albipodus*

(299,500), *A. asychis* (114,000), *Aphidius colemani* (12,000), and *A. matricarae* (26,000). A greater percentage of the 86 statewide releases in 10 Washington counties were concentrated into natural areas based on the rationale that the parasitoids would switch aphid hosts throughout the long winter and spring small grain growing season. Field site diversification for 1994 included winter wheat (27%), spring wheat (25%), barley (28%), club wheat (5%) and uncultivated natural areas/roadside vegetation (15%). *A. asychis* was recovered from near Dusty, Whitman County for the third year in a row and *A. albipodus* again near Anatone, Asotin County. *Diaeretiella rapae* was the dominant wasp parasitoid present, usually comprising more the 95% of the beneficial species. Its aphid-host range was expanded, pointing to new possibilities for developing alternate host-habitats for enhancing its presence and abundance. *Aphidius ervi* and *Lysiphlebus testaceipes*, also primary parasitids, were present, but uncommon in their attack on RWA.

Advances have been made with the Random Amplified Polymorphic DNA (RAPD-PCR) studies to separate closely allied species and strains of indigenous and exotic parasitoids for use in biological control of RWA. The goal
is to develop genetic markers to distinguish Asian strains of *Aphelinus albipodus* (China, Tashkent, Caucasus, Pakistan). Six random primers (Operon Technologies, A1-5, A13) indicated that similar scorable polymorphic bands exist for the four Asian populations of *A. albipodus*. Assessing the establishment of exotic *A. albipodus* is problematic at this time. Deficiencies in the taxonomic `state of the art' for this group are at issue. Presently the only reliable method to separate *A. albipodus* from *Aphelinus varipes* is by way of male antennal characters. Females of these two species can not be reliably separated from one another. There is much overlap in the color patterns between these species. Our ongoing RAPD project of exotic stock cultures and field recoveries will hopefully sort out this problem. There exists the possibility that we are recovering exotic material as well as hybrids between *A. albipodus* and the closely related indigenous species, *A. varipes*.

Isolation of Plant-Aphid Volatile Infochemicals that Elicit Responses from the RWA Parasitid, Aphelinus albipodus.

To understand the effectiveness of a biological control agent, some basic question must we asked; such as, how does the biological control agent find the pest insect in our large cultivated landscapes? When insects forage, a basic hierarchy is followed to narrow down suitable habitats available in a given area; this hierarchy includes the following steps: host-habitat selection, host location and host acceptance. For the first two steps, insects may use visual and olfactory cues to reach a suitable host. Our objective of this research is to explore the possible chemical cues that *Aphelinus albipodus* uses to locate RWA.

To study the responses of the parasitoid to different odor sources, we used a Y-tube olfactometer. This apparatus allows the wasps to make a decision between two odor sources. We found that the parasitoids are able to perceive green leaf volatiles from wheat plants and are able to distinguish wheat plants infested with aphids by olfaction alone. However, the wasps are not able to perceive any kairomone from the aphids; thus, the plants seem to play an important role in the parasitoid's foraging behavior.

Researchers have discovered a unique interaction between the crop plant, pest species and parasitoid. When a pest feeds on a plant, some plants can respond by producing noxious volatile chemicals to deter or kill the plant feeding insect; thus, plants are able to utilize a direct defense against attacking pests. Plants will only produce these chemicals when attacked by a pest. This allows for a reliable chemical cue for predators and parasitoids to find the pest species; thus, the plant also possesses an *indirect defensive mechanism.* We wanted to test the possibility of this type of interaction due to the ability of the parasitoids to distinguish between aphid-infested plants and non-infested plants. If the chemical cue originated solely from the aphid infested plant and not the aphids, the plant should remain attractive to the parasitoids from some time after the aphids are removed. This, however, was not the case; the wasps could not distinguish between a plant that was infested by aphids and a plant that had never been exposed to aphid feeding. This suggests that aphid induced wheat volatiles are not the only cue available to the wasps for foraging.

To determine the unique properties of the chemical profile of aphid-infested wheat, we are currently isolating chemical profiles from the wheat plants, aphids and aphid-infested plants. For now it appears that an aphid kairomone and a plant synomone are *acting together* to elicit a response from the parasitoid. The wasps will only respond to an aphid kairomone when it is perceived along with plant synomones. With this information, we may be able to enhance the direct and indirect defenses of wheat plants and compliment the actions of biological control agents.

MORECROP, AN EXPERT, ADVISORY SYSTEM FOR WHEAT DISEASE FORECASTING AND MANAGEMENT

Roland F. Line
USDA-ARS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

How to purchase MoreCrop. For details, contact Roland F. Line, Agricultural Research Service, U.S. Dept. of Agriculture, 361 Johnson Hall, Washington State University, Pullman, WA 99164-6430. Telephone: 509/335-3755 FAX: 509/335-7674.
To purchase the manual and program, contact Washington Cooperative Extension Bulletin Office, Cooper Publication Building, WSU, Pullman, WA 99164-5912. Ask for MCP22 MoreCrop. Cost of distribution is $40. Telephone: 509/335-2857 FAX: 509/335-3006.

WHEAT AND BARLEY ROOT DISEASE RESEARCH

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Take-all caused by *Gaeumannomyces graminis*, var. *tritici*, Pythium root rot caused by several *Pythium* species, and Rhizoctonia root rot caused by *R. solani* AG8 and *R. oryzae* occur in various mixtures in wheat and barley field soils of the Inland Northwest, and collectively cause major damage to these crops. Research over the past 20 years using soil fumigation as a tool gives some idea of the importance of root diseases: The average increase in yield of winter wheat in response to soil fumigation in commercial fields has been 70, 22, and 7%, respectively, in fields cropped every year, every other year, and every third year to wheat. Besides showing the importance of root diseases, these results also show the value of the 3-year crop rotation, which can be almost as effective as fumigation for root disease control. Soil fumigation is not an option, but neither is the 3-year rotation always acceptable in this area where the climate and soils of the region are so very suitable for wheat and barley at least every other year or two years in three. The poor performance of wheat and barley planted into wheat or barley residue typical of conservation tillage systems is also the result of root diseases, favored by the high soil moisture typical of soil covered with straw together with the lack of crop rotation. Root diseases must be controlled to achieve both the high yields and the fertilizer-use efficiency possible with conservation tillage and frequent cropping to small grains.

One-pass (or two-pass) planting systems, where the field is tilled, fertilized, and planted with one (or two) passes, offer one of the few if not only emerging technologies with the potential to reduce costs (because of fewer trips over the fields), increase yield (because of more water available for the crop), and save or even improve the soil (because of less erosion and more soil organic matter). However, ability to manage the root diseases of these crops is critical to the success of these new systems.

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

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

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

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

nutrients more accessible to diseased roots. Soil disturbance at the time of planting and within the seed row can also be beneficial in cases of seeding directly into stubble where Rhizoctonia root rot is important.

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

While mixtures of pathogens are the rule and not the exception, the importance of any one component in the mixture can vary with soil conditions and cropping practices. For example, the more acidic clay type soils typical of the very southeastern edge of Washington and adjacent northern Idaho favors *Pythium*, whereas the neutral-alkaline, lighter-textured soils favor *Rhizoctonia*. Barley in the rotation favors *Rhizoctonia*, wheat favors take-all, and peas favor *Pythium ultimum*. We have only recently begun to examine wheat after bluegrass where we find heavy pressure from both *Rhizoctonia* and *Pythium* but not take-all. A treatment designed to control just one component can sometimes favor another member in the mixture. Our research program is both a) continuing to find out more about how soil conditions and practices favor different mixtures of these pathogens and b) develop the means to control the entire mixture.

Seed treatment chemicals are available to control components and possibly all of the mixture responsible for seed infections and seed rot, but seed treatments do little to protect against root rots. For example, Apron controls *Pythium* attack of seeds, but can leave the germinating seed vulnerable to attack by *Rhizoctonia*. A combination of Apron + Terrachlor controls both pathogens on seeds and very young seedlings. Thiram and Captan control both pathogens on seeds only, although neither of these fungicides are as effective as Apron against *Pythium*. We are currently investigating the effects of Dividend on seed- and root-infecting fungi.

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

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

Field trials are currently in progress in eastern Washington and northern Idaho with these bacteria. In some 15 large-scale field trials carried out since 1982, the average response to seed inoculation in fields of wheat following wheat (no crop rotation), and where take-all was the dominant yield-limiting factor, has been 10.4% with a mixture of two strains having ability to produce one antibiotic and 15% with a different single strain that by itself produces three related antibiotics. In 1993 near Almota, wheat planted no-till after wheat averaged 25 bu/A greater yield (100 bu/A vs. 75 bu/A) in response to seed treatment with one of our most widely effective strains. We are very encouraged by these results in field trials. We have also had success with *Pythium* control; one strain tested in field plots near Pullman where Pythium root rot was the dominant root disease gave an average yield increase of 25%.

Future efforts will continue to concentrate on combining our best strains of root-associated biocontrol bacteria with the seed-treatment chemicals and cultural practices identified above to provide even better control than is possible with cultural practices or biological control alone. Our goal is to obtain yields of winter wheat in a two year rotation that now can only be obtained in three year rotations, and yields of winter wheat grown without crop rotation that now can only be obtained in a two-year crop rotation, all in combination with conservation tillage. Our research is supported by the Washington and Idaho Wheat Commissions, the Washington Barley Commission, the O. A. Vogel Wheat Research Fund, the USDA's National Research Initiative Competitive Grants Program, and many grower and agribusiness cooperators.

CONTROL OF STRIPE RUST, LEAF RUST AND STEM RUST, 1995

Roland F. Line
USDA-ARS

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

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

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

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

Stem rust is less frequently severe, but when present, it can cause major damage to both wheat and barley in specific areas. In 1980 to 1984, stem rust significantly damaged both wheat and barley in eastern Washington and Oregon and northern Idaho, especially in late maturing fields. In 1993, because of late planting of spring wheat and barley and unusually favorable weather, stem rust was very severe in those same regions. Spring crops were again planted late in 1995. Severity of the disease will depend upon weather in late spring and early summer.

Monitoring Rust. Races of *Puccinia striiformis*, the pathogen that causes stripe rust, are identified by the varieties that they attack, and new races of the pathogen frequently evolve to attack varieties that were previously resistant. Table 1 lists the races of *Puccinia striiformis* that have been detected in North America their virulence on differential varieties, and the year they were first detected. Fifty-five stripe rust races have been identified of which 44 have been detected in eastern Washington.

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

Most winter wheat varieties currently grown in the region are very susceptible to leaf rust. Since the current races can attack most winter wheat varieties and the resistance in spring wheat is now race specific, there is no major selective pressure for new races of leaf rust. Consequently, no significant new races of *Puccinia recondita*, the pathogen causing leaf rust, were detected in 1993.

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

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

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 that is 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 and location of genes for resistance has been obtained, and that information and material should be useful in developing new disease control programs, identifying races, and understanding how resistance works.

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

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

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

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

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

CDL Race	Virulence on[a] differentials	Year detected	CDL Race	Virulence on differentials	Year detected
1	1,2		29	1,3,4,5	1983
2	1,2,5	1963	30	1,4,6,8,12	1983
4	1,3	1964	31	1,3,5,11	1983
5	1,3,4	1968	32	1,4	1983
6	1,6,8,12	1972	33	1,3,9,12,13	1984
7	1,3,5	1974	34	1,3,4,5,12	1984
8	1,3,9	1974	35	1,10	1985
9	1,3,6,8,12	1975	36	1,3,4,9,12	1985
10	1,2,3,9	1976	37	1,3,6,8,9,10,11,12	1987
11	1	1976	38	1,3,11	1987
12	1,5,6,12	1976	39	1,2,4	1987
13	1,5,6,8,12	1976	40	1,4,14	1989
14	1,8,12	1976	41	1,3,4,14	1989
15	1,3,6,10	1976	42	1,3,11,12	1989
16	1,3,9,11	1977	43	1,3,4,5,12,14	1990
17	1,2,3,9,11	1977	44	1,4,5	1990
18	1,3,4,9	1977	45	1,3,12,13,15	1990
19	1,3,6,8,10,12	1977	46	1,3,6,9,10,11	1991
20	1,6,8,10,12	1977	47	1,6,8,12,13	1992
21	2	1978	48	1,6,8,12,13,14	1992
22	1,3,12	1980	50	1,3,4,5,14	1992
23	1,3,6,9,10	1981	51	1,3,4,12,13	1992
24	1,3,5,12	1981	52	1,4,8,12,14	1993
25	1,3,6,8,9,10,12	1981	53	1,4,6,8,10,12	1993
26	1,3,9,12	1982	54	1,3,4,8,10,12	1994
27	1,3,12,13	1983	55	1,3,6,10,11	1994
28	1,3,4,12	1983			

[a] 1=Lemhi, 2=Chinese 166, 3=Heines VII, 4=Moro, 5=Paha, 6=Druchamp, 7=Riebesel 47-51, 8=Produra, 9=Yamhill, 10=Stephens, 11=Lee, 12=Fielder, 13=Tyee, 14=Tres and 15=Hyak.

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

	Stripe Rust			Stripe Rust	
Variety	Seedling	Adult	Variety	Seedling	Adult
Soft White Winter Wheat			Hard Red Winter Wheat		
Rod	S	R			
Kmor	S	R			
Eltan	S	R			
Madsen	S	R	Buchanan	S	R
Stephens	S	R	Blizzard	S	MR-MS
Luke	S	R	Batum	S	R
Lewjain	S	R	Wanser	S	MR-MS
Dusty	S	R	McCall	S	MR-MS
Daws	S	R-MR	Century	S	MS-S
Hill 81	S	R-MR	Hatton	S	S
Malcolm	S	R-MR	Weston	S	S
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
			Wadual	S	R-MR
WA7797	S	R	Wakanz	S	MR-MS
Rohde	S	MR	Urquie	S	MR-MS
Hyak	S	MR-MS	Walladay	S	MS-S
Rely	R+S	R+S	Fielder	S	S
Crew	R+S	R+S	Fieldwin	S	S
Tres	S	MS-S	Twin	S	S
Moro	S	S	Dirkwin	S	S
Jacmar	S	S	Owens	S	S
Barbee	S	S			
Paha	S	S			
Tyee	S	S			

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

BARLEY STRIPE RUST IN THE PACIFIC NORTHWEST IN 1995

Roland F. Line and X.M. Chen
USDA-ARS, WSU

A new barley disease, barley stripe rust, has appeared in the Pacific Northwest and could cause wide-spread damage to barley in Washington and adjacent states. If the disease becomes wide-spread on barley, losses could be as severe as the losses that occurred in wheat during the early 1960's when there were no resistant cultivars and no other available methods of control. There is an urgent need for research aimed at preventing such a disaster.

Barley stripe rust is one of the many fungal diseases of cereals and grasses that are referred to as rusts. They get their names by the characteristic rust-like spores that are produced on the foliage of the plants. Stripe rust appears as golden-yellow, long, narrow stripes on the leaf surface and glumes. The stripes generally appear between the leaf veins but can sometimes cover the entire leaf. The spores produced on a leaf are carried by the wind to other leaves on the same plant, to other plants, and to plants in other fields. When the leaves are moist, the spores germinate, infect the leaves, and produce new spores. The cycle can be repeated many times in a growing season. Thus, the disease can start from a few infections and increase to completely cover the plant. The fungus can only infect and grow on living plants. Therefore, the presence of susceptible barley plants throughout the year contributes to the survival and spread of the pathogen. Barley stripe rust is similar to the well known wheat stripe rust; however, they are two different diseases. Wheat stripe rust (*Puccinia striiformis tritici*) can attack cultivars of barley as well as wheat, but it has never been observed to cause severe damage to fields of barley in the Pacific Northwest. In contrast, barley stripe rust (*Puccinia striiformis hordei*) is known to reduce barley yields by 30 to 70 percent and to greatly reduce the quality of the grain. Barley stripe rust is not known to damage wheat.

Barley stripe rust is a new disease in the United States. It was not known to be present in the United States until 1991. The disease is well known in Europe, and like wheat stripe rust, several races of the barley pathogen occur in that part of the world. Barley stripe rust was reported to be present in South America near Bogata, Colombia in 1975. It was postulated that the barley rust was introduced by people traveling from Europe, since the race that was detected in Columbia was the same as a race that was common in Europe. The rust soon spread to other South American countries and eventually to Mexico. It caused wide-spread devastating losses in each of the regions where it occurred. The disease was first detected in Texas in 1991. It appeared in Colorado in 1992, and in Arizona in the spring of 1993 where it again caused major yield losses and greatly reduced malting quality. By August 1993, it was detected in southern Idaho and Montana. There were reports of barley stripe rust in California in 1993 that were confirmed during the spring of 1994. It also appeared in Utah in 1994. There are reports, which have not yet been confirmed, that it is in northern California, southwestern Oregon, northern Idaho, and Washington. If barley stripe rust is not in Washington at this time, it will be in the state within the near future. When the weather is favorable for the disease, we expect it to be as destructive as it has been in other regions of the world and as destructive as wheat stripe rust has been in fields of susceptible cultivars in the Pacific Northwest.

Little is known about the specific environmental factors that contribute to severe barley stripe rust. Based on what we know about wheat stripe rust in this region, barley stripe rust in other regions, and controlled temperature tests in the greenhouse, we have determined that the environment in the Pacific Northwest will be highly favorable for the disease. Once barley stripe rust appears in Oregon, Washington, or northern Idaho, it will spread throughout the Pacific Northwest. Both field and controlled environmental research will be needed to clearly understand how weather and management contribute to severe epidemics of the rust.

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

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

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

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

Monitor your crop. The disease has not yet been positively detected in Washington and adjacent regions of Oregon and Idaho. Therefore, it may not develop until late in the spring, when damage is less severe. Being forewarned is half of the battle against the disease. Timely control is important. Fields should be examined frequently throughout the growing season. Look for small golden-yellow stripes on the leaves, contact your county agent, and verify that it is stripe rust. Barley and wheat stripe rust look alike. If it is stripe rust, send a sample to Roland F. Line, 361 Johnson Hall, WSU, Pullman, WA 99164-6430, to determine if it is barley stripe rust or wheat stripe rust on barley. Continue to monitor the field. If it begins to spread and become more severe, it is probably barley stripe rust.

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

Consider using foliar fungicides if the disease starts to spread and increase rapidly. Foliar sprays are not necessary unless severe rust is expected. Best control should be before the rust develops on the upper leaves. Bayleton and Tilt are systemic fungicides that control stripe rust. Old supplies of Bayleton may be used on barley, but new supplies will not be labeled for barley. Tilt cannot be used beyond the late jointing stage. Determine your economical benefits before using the foliar fungicide.

Some barley cultivars are also susceptible to stem rust. Stem rust is characterized by red pustules on stems and leaves. Stem rust was severe in 1993 in fields that were planted late because it appears later in the growing season. The cool, wet weather of 1993 was highly favorable for stem rust. Resistant cultivars and foliar sprays are possible controls for stem rust.

VIRULENCE AND POLYMORPHIC DNA RELATIONSHIPS OF *PUCCINIA STRIIFORMIS* F. SP. *HORDEI* TO RUSTS OF BARLEY, WHEAT, AND BLUEGRASS IN THE USA.

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WSU and USDA-ARS

Relationships of *Puccinia striiformis* f. sp. *hordei* (barley stripe rust) to *P. s. tritici* (wheat stripe rust) , *P. s. poae* (bluegrass stripe rust), *P. hordei* (barley leaf rust), *P. recondita* f. sp. *tritici* (wheat leaf rust), and *P. graminis* f. sp. *tritici* (wheat and barley stem rust) in the USA were determined by virulence and random amplified polymorphic DNA (RAPD) analyses. Isolates of barley stripe rust were virulent on some wheat cultivars and isolates of wheat stripe rust were virulent on some barley cultivars; barley stripe rust was not virulent on most wheat cultivars and wheat stripe rust was not virulent on most barley cultivars. Barley stripe rust and wheat stripe rust did not infect bluegrass and bluegrass stripe rust did not infect barley or wheat. Fourteen races of the barley stripe rust pathogen were detected using 11 barley differential cultivars. RAPD analyses separated the isolates of barley stripe rust, wheat stripe rust, and bluegrass stripe rust from one another. Barley stripe rust and wheat stripe rust were more closely related to each other than they were to bluegrass stripe rust. The three forms of stripe rust were not closely related to wheat leaf rust, barley leaf rust, or stem rust.

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

Roland F. Line
USDA-ARS

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

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

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

CONTROL OF SMUTS AND BUNTS WITH SEED TREATMENTS, 1995

Roland F. Line
USDA-ARS

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

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

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

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

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

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

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

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

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

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

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

General Comments Regarding Seed Treatments. The use of seed treatments for the control of smuts and bunts is the best example of the effectiveness, value, usefulness, and importance of chemicals for control of cereal diseases. Seed treatments have provided outstanding control of common bunt, flag smut, and loose smut with essentially no adverse environmental impact and a minimum cost to the grower. There is strong evidence that difenoconazole will provide similar control of dwarf bunt. Use of chemical seed treatments has prevented world-wide crop losses and saved the economy of the Pacific Northwest while preventing pollution of the environment with bunt and smut spores. The newest systemic fungicides control the diseases at rates lower than 0.5 ounces per acre, rates that have essentially no affect on the environment. If the seed treatments were not available, those diseases would return to their former importance, and the economy of the Pacific Northwest would be drastically affected. Another concern is that strains of the pathogens may evolve that are resistant to current fungicides. Therefore, there is a continual need for ongoing research on control of those diseases.

PROFITABILITY COMPARISON OF TWO-YEAR VS. THREE-YEAR WINTER WHEAT ROTATIONS

Kathleen Painter

Which is more profitable, a three-year rotation of winter wheat, spring barley and a pulse crop or a two-year rotation of winter wheat and a pulse? Since the high value winter wheat crop is raised every other year in the two-year rotation, it can sustain lower yields than wheat in the three-year rotation and still be as profitable. A newly developed set of crop rotation budgets for Eastern Whitman County provides the cost of production estimates used to compare relative profitability for these two rotations under varying yield assumptions.

Higher wheat yields can be expected in a three-year rotation compared to a two-year rotation due to decreased incidence of wheat diseases. In addition, annual weeds are easier to control in the three-year system, which will improve yields. As shown in Table 1, the two-year systems become approximately equal in profitability to the three-year rotations with a 65 bu/acre yield for the two-year systems and an 80 bu/acre yield for the three-year systems. These results are highly sensitive to assumptions concerning crop prices, barley and pea yields, and input cost assumptions. More information on costs of production are available in EB1437, *1995 Crop Rotation Budgets for Eastern Whitman County, Washington.*

Most farmers are concerned with the variability of crop yields for different systems as well as expected yields. A three-year rotation with winter wheat should reduce yield variability from wheat disease and weed infestations. Even if average yields for the three-year system are lower than the break-even yield for the two systems, the decrease in variability may be an important factor in planting decisions for some farmers.

Unfortunately, base acreage provisions in the Farm Bill prevent complete flexibility with respect to planting decisions. The flex provision in the 1990 Farm Bill currently in effect allows growers to plant up to 15% of their bases to alternative crops without losing base or yield history or decreasing deficiency payments. Some proposals for the 1995 Farm Bill would increase flexibility but it is difficult to predict what Congress will do. Nearly all farmers in this area participate in the farm program, so these provisions have a strong impact on planting decisions.

Table 1: Average Annual Net Returns Above Variable and Total Costs per Rotation Acre by Wheat Yield for Two- and Three-year Winter Wheat Rotations

Wheat Yield	Average Net Returns Over Variable Costs ($/acre/year)			
	WP	WL	WBP	WBL
55	64	66	53	54
60	74	76	59	61
65	**84**	**86**	66	67
70	93	95	72	73
75	103	105	79	80
80	113	115	**85**	**86**
85	122	124	91	93
90	132	134	98	99

LEGEND: WP = Winter Wheat/Dry Pea Rotation
WL = Winter Wheat/Lentil Rotation
WBP = Winter Wheat/Spring Barley/Dry Peas Rotation
WBL = Winter Wheat/Spring Barley/Lentil Rotation

NOTE: Yield assumptions are 1.75 tons/acre for spring barley, 20 cwt/acre for dry peas, and 12 cwt/acre for spring lentils. Price assumptions (inclusive of government payments) are $3.85/bu for winter and spring wheat, $88.68/ton for spring barley, $8.94/cwt for dry peas and $18.40/cwt for lentils. Breakeven net returns for two-year and three-year rotations are in bold print.

AN ECONOMIC COMPARISON OF SPRING BARLEY, SOFT WHITE SPRING WHEAT, AND HARD RED SPRING WHEAT PRODUCTION IN THE 15"-18" RAINFALL REGION OF WHITMAN COUNTY

Kathleen Painter

Spring wheat production can be a viable alternative to spring barley or winter wheat production in the 15"-18" rainfall region of Whitman County, as shown by a recent WSU Extension Bulletin (EB1799). Although spring wheat has lower yields than winter wheat, new varieties show increased yield potential. These could lead to higher expected yields and profits for this crop over time. In the drier regions of Whitman County and in similar regions elsewhere in eastern Washington, hard red spring wheat may be able to meet the protein requirements necessary for premium prices.

This report examines the relative profitability of three rotations:

Rotation 1: summer fallow/winter wheat/spring barley (SF-WW-SB)
Rotation 2: summer fallow/winter wheat/soft white spring wheat (SF-WW-SWSW)
Rotation 3: summer fallow/winter wheat/hard red spring wheat (SF-WW-HRSW)

The first rotation is probably most typical of this central Whitman County region. Some farmers will need increased wheat base in order to use Rotation 2 or 3. However, a farmer with insufficient barley base to use Rotation 1 may be able to switch some ground from a two-year to a three-year winter wheat rotation by planting spring wheat. A three-year rotation decreases the incidence of yield-reducing wheat diseases and helps control weeds. However, returns from increased winter wheat yields may not result in higher average profits as the high value winter wheat crop is raised just once every three years.

Given the assumptions in Table 1, average returns are maximized with Rotation 2, SF-WW-SWSW. In this study, soft white spring wheat was more profitable than either spring barley or hard red spring wheat. It earned $59/acre/year returns over variable costs and -$10/acre/year returns over total costs.

Although the price for hard red spring wheat averages $0.50/bu higher than for soft white spring wheat, this crop has higher fertilizer needs and lower expected yields. The rotations with spring barley and hard red spring wheat had nearly identical average returns at $53/acre/year and $52/acre/year returns over variable costs. All three rotations are quite close in average profits, probably within the range of error for this type of study. Further information on production costs, crop yields, and crop prices used in this report are available in EB1799, *1995 Crop Rotation Budgets for Central Whitman County, Washington.*

Table 1: Price and Yield Assumptions by Crop and Net Returns over Variable and Total Costs by Rotation

Rotation/Crop	Price (units/ acre)	Yield (units/ acre)	Net Returns over Total Costs ($/acre)	Net Returns over Total Costs ($/acre)
Rotation 1:				
Summer Fallow	NA	NA		
Winter Wheat (bu)	3.85	70		
Spring Barley (ton)	88.68	1.75		
AVERAGE			53	-13
Rotation 2:				
Summer Fallow	NA	NA		
Winter Wheat (bu)	3.85	70		
Soft White Spring Wheat (bu)	3.85	45		
AVERAGE			59	-10
Rotation 3:				
Summer Fallow	NA	NA		
Winter Wheat (bu)[1]	3.85	70		
Hard Red Spring Wheat (bu)	4.35	38		
AVERAGE			52	-12

NOTE: Crop prices include deficiency payments and are net of average transportation charges. Wheat and barley prices include government payments.

PACIFIC NORTHWEST ON-FARM TESTING
Expanding Opportunities in 1995

Stewart Wuest, STEEP II On-Farm Testing Coordinator
Baird Miller, WSU Extension Agronomist
Roger Veseth, WSU/UI Extension Conservation Tillage Specialist
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The early efforts of the STEEP II On-farm Testing Project are starting to show big returns. Beginning in 1991, our research focused on how to conduct effective, efficient on-farm tests that can provide needed information on a variety of topics that might be of concern to Pacific Northwest farmers. Extensive investigation of the optimum plot sizes and layout during the first couple years has proven that farmers can produce reliable data on their own farms, using their own equipment. At the same time, we encouraged and assisted a few growers in trying on-farm tests, and all we all learned about on-farm testing together.

The first on-farm tests, conducted in 1991-92, gave encouraging results, but many of the tests were limited by too few replications to accurately identify treatment differences. Since that time, many farmers and the people assisting them have learned that replicating side-by-side comparisons four or more times in a field is a very accurate way to test farming practices. The quality of the data being produced and the number of tests being conducted have increased greatly since 1992. Twenty-two field tests were reported in the 1992 edition of the *Pacific Northwest On-Farm Test Results* publication. That has grown to 37 in the 1993 publication and 52 in 1994.

Why Are Farmers Investing the Time in On-Farm Testing?

There is no question that on-farm tests involves a time commitment, ranging from several hours to a day or more to establish and harvest a trial. What motivates farmers to take time from their busy schedule to conduct on-farm tests? The most common reasons are that farmers want to increase yields, protect the environment, and improve profitability. Farmers are becoming more aware that to accomplish these objectives they have to accurately evaluate available management options. On-farm testing of some sort is the only way farmers can discover and verify which practices perform the best on their farm. Using properly designed, replicated and conducted on-farm tests provides the best information in the shortest time. On-farm tests are an excellent way to evaluate new ideas and learn how to make them perform properly before risking them on entire fields.

Some Examples

Topics for on-farm tests are only limited by farmer's innovativeness and creativity, which seem unbounded. Farmers have successfully tested subsoiling, less intensive tillage systems, summer fallow management alternatives, seed treatments and innoculants, herbicide rates, fertilizer rates and placement, crop rotations, new crops, and soil amendments, just to name a few. On-farm testing is also being used to address regional concerns such as methods for reducing wind erosion, the credit given for green cover in wheat/fallow conservation plans, differences in residue production by barley varieties, and the effects of stubble burning on soil erosion potential.

A Few Pointers

Designing a test that will produce accurate, conclusive information requires replicated, side-by-side comparisons. This is the only way to distinguish yield differences that occur naturally between two strips from differences actually caused by the treatments. Extensive research in the Inland Pacific Northwest has shown that long, narrow, side-by-side strips replicated at least four or more times can produce very accurate comparisons. The longer the strips are, the better the data is likely to be, but that depends on the field landscape and soil variability. There have been many successful tests with four replications of 300 ft strips, but the research has shown that 750 ft or longer strips are more likely to produce accurate results.

Briefly, the steps to laying out a valid test comparing two treatments commonly include: 1) choose an area in a field where a pair of long, side-by-side strips can be placed with the expectation that the yield (or weed pressure, or other factors to be measured) should be nearly equal; 2) assign the treatments to the plots randomly, such as with a coin toss; and 3) repeat the above process so there are at least four replications. The four replications could be next to each other, or in different areas of the field, or even in different fields. The best results occur when each replication is positioned so that variations in the field (high and low areas, soil variations, field borders, fertilizer overlaps, etc.) will be encountered equally by each strip in the replication.

The time it takes to mark out a field for a test can vary considerably. It can be as simple as splitting a drill or drill series: half receiving a new variety, seed treatment, or fertilizer mix and the other half receiving the check or standard treatment. Then the plots are created by driving the proper direction, back and forth over the test area, so that the treatments end up in the replicated, randomized arrangement that was planned beforehand. If yields are to be compared, as in most trials, make sure all the strips are wide enough to cut a full combine header width at harvest (plots wider than the header).

In field tests of some topics, the strips may need to be marked at specific widths using flags or stakes so that different treatments can be established in the proper places. If surface runoff or erosion comparisons are needed, landscape-specific trials need to be designed and it is recommended that help be sought from someone with experience in designing such tests.

Make sure to mark the plots so you can locate them later in season! Measuring from reference points or stakes on field borders can also help to locate trials for harvest or other data collection.

When measurements are made, such as stand counts or yield, record them separately for each strip. The data can be analyzed statistically using a hand calculator and step-by-step formulas, using a free, easy-to-use computer program from OSU called AGSTATS, or with help from your County Extension Agent. If you are a beginner at doing replicated experiments, ask for some help from your Extension Specialist or Agent, or others with on-farm testing experience. Most likely a little discussion with an experienced experimenter will save a mistake or two and make your on-farm test more successful.

Resources:

Pacific Northwest On-farm Test Results -- annual publications. Data and conclusions from tests are complied at the end of each year. Copies are available for 1992, 1993 and 1994. Contact your local County Extension Office or call the WSU Crop and Soil Sciences Extension Office (509-335-2915).

On-Farm Testing: A Grower's Guide, Washington State University Cooperative Extension bulletin EB1706. 1992. $1.00. A guide to designing and carrying out OFT. Includes forms for record keeping. Order from WSU Cooperative Extension Bulletin Office (509-335-2999).

On-Farm Test Record Form, Pacific Northwest Extension bulletin PNW487. 1995. $1.00. A convenient form to simplify planning and record keeping for on-farm tests. Contact your local County Extension Office or order directly from WSU Cooperative Extension Bulletin Office (509-335-2999).

Using an On-Farm Test for Variety Selection, Pacific Northwest Extension bulletin PNW486. 1995. $1.50. Specific instructions and considerations for performing on-farm variety comparisons. Contact your local County Extension Office or order directly from WSU Cooperative Extension Bulletin Office (509-335-2999).

WSU EXTENSION BULLETIN HIGHLIGHTS PNW WIND EROSION CONTROL EFFORT

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist

Cropland wind erosion has long been a concern of growers in the low precipitation areas of the Pacific Northwest. A regional project is underway to define the problem and help growers develop practical, effective solutions to this production and environmental problem. The project is described in WSU Extension bulletin MISC0177 Controlling Cropland Wind Erosion and Off-site Impacts in the Pacific Northwest...A Proactive Approach.

The bulletin provides an overview of the wind erosion problem, which can be particularly severe on cropland under the winter wheat-fallow system in the 8- to 12-inch precipitation zones. It is also a problem on irrigated cropland in the fall after low residue crops and in the spring before growing crops provide adequate cover. Approximately 6.8 million acres in Washington, Oregon and Idaho are susceptible to wind erosion.

In addition to the loss of soil productivity, growers have also sustained severe crop damage and replanting expenses along with associated reduced yield potentials. Dust storms from agricultural areas have raised public concern about air quality, traffic hazards and other environmental and economic impacts. Most of the air quality concern is focused on the very fine particulate material less than 10 microns in size, called PM-10 -- about 1/7 the diameter of a human hair.

Regional Project Initiated
The Northwest Columbia Plateau Wind Erosion/PM-10 Project is a comprehensive effort by USDA, EPA, WA State Dept. Of Ecology and several universities in the Northwest. Technical research for this project is being conducted by scientists from the USDA-Agricultural Research Service, Washington State University, the University of Idaho, and the University of Washington. Cooperators include researchers from other universities and states in the West, growers and grower organizations, the USDA-Natural Resources Conservation Service, Conservation Districts and the Ag service industry.

The Project began in 1993 with a series of grants from the EPA and the Washington State Dept. of Ecology. Grants from the USDA-Cooperative States Research, Extension and Education Service expanded research efforts beginning in 1994. Several research projects on production management technologies for erosion control also receive funding from the STEEP II (Solutions To Environmental and Economic Problems) research program in the Northwest. Project plans are underway for a 3-5 year research effort.

Eight major research objectives have been identified, each being addressed by 2 to 5 scientist. The entire Project is a team effort with success of most objectives depending on the close cooperation of all researchers and cooperators involved. The following is a brief listing of the Project research areas.

- Identify wind erosion characteristics of the PNW Columbia Plateau
- Measure cropland wind erosion and PM-10 emissions, and develop more accurate predictive tools
- Identify and verify downwind dispersion patterns of wind-blown dust and PM-10
- Determine the importance of natural wind erosion as a source of wind-blown dust and PM-10
- Develop and evaluate production management options
- Economic assessment of wind erosion impacts and control strategies
- Determine health effects of PM-10 from cropland compared to other sources
- Increase awareness and education of the problem and control options

There are four areas of research on production management practices. The focus in each is to identify and evaluate the effectiveness of alternative methods to minimize cropland wind erosion and PM-10 emissions while maintaining or increasing crop yield potential and profitability. These areas include:

1. Management practices for the current crop-fallow rotation that increase retention of surface residue, roughness and seed zone water.
2. Alternative crops, crop rotations and associated production practices.
3. Management practices for returning CRP land to crop production if contracts are not extended.
4. Management practices for irrigated cropland following low-residue crops and during crop establishment.

For more information on the Northwest Columbia Plateau Wind Erosion/PM-10 Research Project, contact Keith Saxton, Project Research Coordinator, USDA-ARS, WSU, Pullman, WA 99164-6120 (509) 335-2724.

Proactive Approach

Growers are encouraged to learn more about the Project and actively participate in developing practical, economical solutions to the problem. Most growers have always strived to be good stewards of the land, minimizing erosion and maintaining soil productivity. This research and education program offers them additional assistance in their efforts. They have much to gain from the major research thrust on developing more efficient and profitably management technologies.

Growers currently have a number of management practices available to help minimize cropland wind erosion. Although little is known about the effectiveness of these practices for controlling PM-10 emissions, preliminary research results indicate that practices providing good control of wind erosion will also significantly reduce PM-10 emissions. Growers in the Northwest commonly rely on managing surface residue and roughness to control wind erosion. Other practices include field strip systems, windbreaks, barrier strips of grass or a variety of other plants, and cover crops following low-residue crops or preceding crop establishment.

Contact your local Conservation District, NRCS and Cooperative Extension offices for more information on current wind erosion control practices for your production area.

Copies of the Extension Brochure

Copies of WSU Extension bulletin MISC0177 Controlling Cropland Wind Erosion and Off-site Impacts in the Pacific Northwest...A Proactive Approach are available without charge from local Cooperative Extension, NRCS and Conservation Districts in wind erosion areas of the Northwest. You can also call the WSU Extension Bulletins Office directly (509-335-2999) to order copies.

ENHANCEMENT OF GERMINATION OF WESTERN WHEATGRASS VIA SEED SCARIFICATION

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Western wheatgrass is a long-lived, rhizomatous perennial which exhibits excellent ground stabilizing characteristics. It is very widespread throughout western North America and is an important range species in much of the Great Plains. It occurs primarily on fine textured soils in the 14-20" annual precipitation zones and tolerates alkaline soils well. Western wheatgrass tolerates drought well if established during periods when moisture conditions are favorable.

Western wheatgrass is reportedly native to eastern and central Washington and SCS seed collections have been made as early as 1934. It is a minor range species in much of Washington but it has exhibited outstanding soil stabilizing ability on droughty sites in central Washington

The use of western wheatgrass in the inland Pacific Northwest has been limited because it is difficult to establish from seed. The seed typically does not begin germinating until soil temperatures are fairly warm, and the seed must be kept fully hydrated during this period. Moisture in the upper 1 inch of the soil is available only sporadically in much of the inland Pacific Northwest during the late spring when soils temperatures are warmer.

Increasing the rate of germination might improve successful establishment western wheatgrass. Scarifying seed of western wheatgrass was evaluated to determine if the rate of germination could be improved.

Scarification is a seed processing technique which removes a portion of the seed coat. This process essentially hurls the seed against a sandpaper lined drum which chips and grinds the seedcoat. Seed of western wheatgrass was processed for 30, 60, and 120 seconds in a small scarifier and then germinated. An unscarified sample was used to compare germination results.

Unscarified seed began germinating on day 6, most of the germination occurred on day 8, and germination continued to occur over a period of 28 days. Seeds began germinating one day sooner for the 30 second scarified seed and maximum germination occurred 1 day sooner. Very little germination occurred after 10 days. Seeds scarified for 60 seconds began germinating on day 4, maximum germination occurred on day 5.5, and no germination occurred after day 11. Scarification for 120 seconds increased the rate of germination as well but this level of scarification caused extensive damage to the seeds and the total germination was much less than the unscarified seed.

Germination of Western Wheatgrass Seed

Scarification Treatment	First Germination	Maximum Rate of Germination	Total Germination
unscarified	6 days	8 days	59%
30 seconds	5 days	7 days	78%
60 seconds	4 days	5.5 days	71%
120 seconds	4 days	7 days	32%

RIPPING STANDING WHEAT TO REDUCE SOIL LOSS AND INCREASE WATER INFILTRATION

William Schillinger and Dale Wilkins*

Water runoff and soil erosion frequently occur on frozen soils between December and March in fields seeded to winter wheat. Low infiltration rates in frozen soil are a major contributor to water runoff, soil erosion, and sedimentation in the Pacific Northwest (PNW). Soil losses can be especially high during heavy rainfall or rapid snow melt when a thawed soil overlies a subsurface frozen layer. We experienced this scenario in January and February 1995 throughout much of eastern Washington.

In areas of the PNW where soil freezing is common, growers routinely chisel or subsoil their wheat stubble after harvest to reduce the risk of soil erosion and increase water infiltration. Does it make sense to create similar tillage channels in planted wheat fields? This question has been studied for several years by the USDA-ARS in north-eastern Oregon. Early work showed that forming tillage slots at the time of seeding did not improve infiltration. This is because the loose dry surface soil sloughed back into the tillage channel, thus sealing the channel and eliminating the possibility of improved infiltration.

Current Research

The concept of ripping when the soil is frozen to a depth of about 4 inches is being tested in Oregon. Although it creates large clods which may be objectionable to some growers, this method is effective for keeping tillage slots open over-winter. Wheat yields have not been depressed by frozen soil tillage. Since initiating the study, no real water runoff or soil loss have occurred at the Oregon test sites.

We are conducting a related research project in collaboration with wheat grower Harold Clinesmith. The study is located on Clinesmith's farm near Benge, Washington. The cropping pattern is winter wheat - fallow and annual rainfall averages 12 inches. In this case, tillage is conducted in late fall, prior to soil freezing and when surface soils are wet. This reduces soil fracturing and plant disturbance compared to tilling frozen soils.

Results

We are now in the second year of our study at Benge. The first year we ripped the soil with a single-shank, with attached rotary subsoil spider, to a depth of 11 inches. The rips, spaced at 20 foot intervals, followed the contours of a hill (23 degree slope). The 1993-94 winter was dry and open, and essentially no water runoff occurred. The area immediately around the rip was significantly drier in March compared to our control plots. Although grain yield in the row closest to the rip was reduced, the overall grain yield for the plots was not affected.

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For the 1994-95 winter, we used a R&R subsoiler with all but the end shanks removed to create 24-inch deep tillage channels along the contours of the hill. We spaced the rips 12 feet apart. The hillside was especially prone to water erosion because late planted winter wheat had not yet emerged at the time of the ripping operation in mid-November. Between 19 November and 4 April, 7.1 inches of precipitation occurred. About half of this precipitation fell during January and February when surface soils were frequently frozen or when thawed soil overlaid frozen soil.

We measured rill erosion using the "Alutin" method on several dates during the 1994-95 winter. Soil loss was significantly reduced with ripping compared to control plots (Table 1). Tillage channels generally stopped rills, whereas many rills extended the entire length of the hillside in control plots. Rate of soil loss in ripped plots increased somewhat in March (Table 1), perhaps because tillage channels had filled with sediment by this time and the surface soil was saturated with water.

Water infiltration into the soil during the 1994-95 winter was significantly increased with ripping. Increased water infiltration to a depth of 6 feet was measured with a neutron probe as far as 3 feet down-slope from the tillage channel (Fig. 1, Fig. 2, and Fig 3.). There were no differences in water infiltration between ripped and control plots 5 feet down-slope from tillage channels.

Summary

The objective of this project is to explore methods to increase water infiltration and reduce water erosion during the crop winter. Ripping standing wheat did not reduce grain yield following the dry, open winter in 1993-94. During the 1994-95 winter, when water runoff and soil loss were a problem throughout much of eastern Washington, creating tillage channels after seeding significantly reduced soil loss and increased water infiltration into the soil. Grain yield components and crop characteristics will be measured from the experiment in the summer.

Acknowledgements

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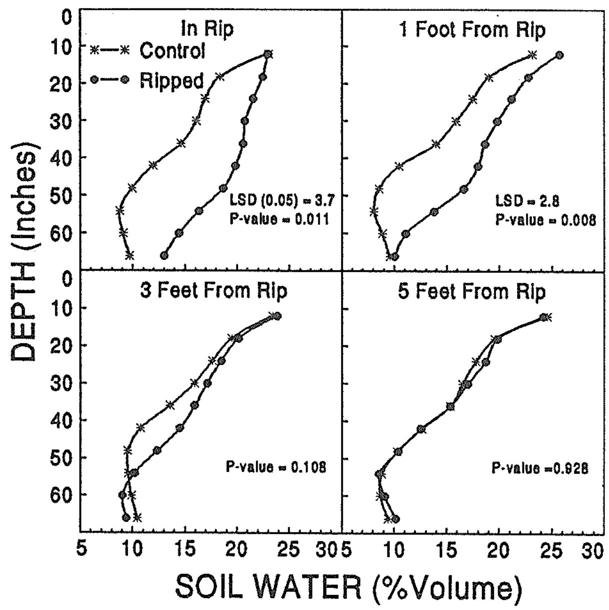

Figure 1. Water Infiltration as affected by ripping on January 27, 1995.

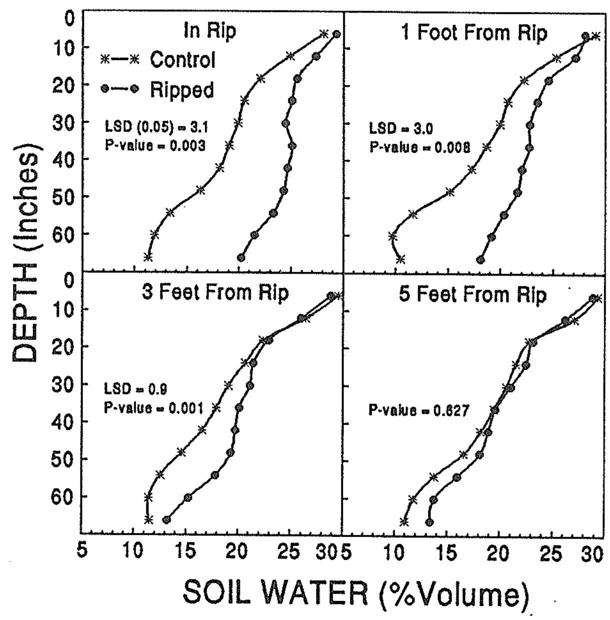

Figure 2. Water infiltration as affected by ripping on February 28, 1995.

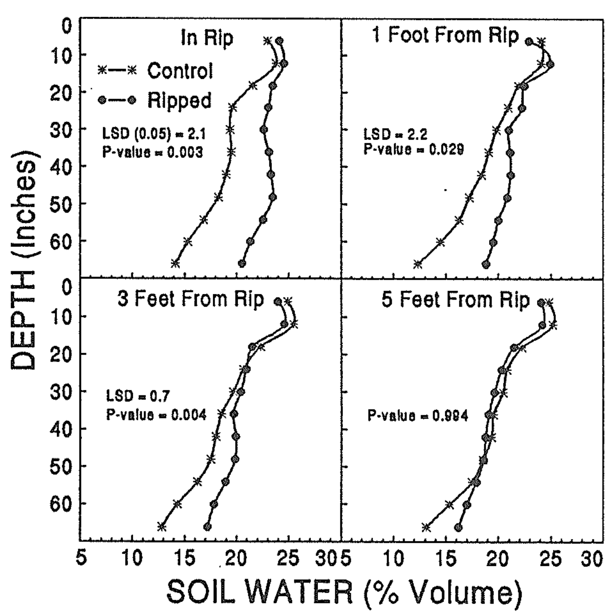

Figure 3. Water infiltration as affected by ripping on March 30, 1995.

Table 1. Soil loss (tons/acre) as affected by ripping on several sampling dates during the 1994-95 winter.

Date	Control	Ripped	*P*-Value
January 12	4.2	0.1	0.018
January 26	5.2	0.3	0.001
February 28	9.4	1.2	0.003
April 4	9.0	2.8	0.041

COMPARING DEEP FURROW DRILLS FOR WINTER WHEAT ESTABLISHMENT UNDER DRY SEEDING CONDITIONS

William Schillinger, Edwin Donaldson and Don Wysocki*

Most growers in low-rainfall summer fallow areas of the Pacific Northwest plant winter wheat with deep furrow split-packer drills. Deep furrow drills push dry soil into the ridges between furrows, allowing for deeper seed placement into wetter soil with minimum soil cover. Two types of deep furrow split-packer drills are available: 1) the John Deere HZ with in-line openers on either 14-inch or 16-inch centers, and 2) the International 150 with staggered openers on 18-inch centers.

A new deep furrow drill is being developed by Bob and Don Zimmerman of Almira, Washington, for planting in summer fallow conditions. The drill features three staggered gangs of shanks on 15-inch centers for placing fertilizer and opening the furrow. The depth of the shanks can be adjusted to move dry soil from the seedbed to the furrow ridge. The shanks are followed by angled packer wheels to form the furrow and firm the seedbed. The packer wheels have a 2-inch coulter in the center with seed opener directly behind the coulter. A small press wheel follows the packer wheel/coulter/opener assembly.

We initiated an experiment in 1994 to compare, under very dry seeding conditions, the planting effectiveness of three drill types: the John Deere HZ (16-inch centers), International 150, and the Zimmerman.

Study Description

The replicated experiment was conducted at Washington State University's Dryland Research Unit at Lind. Precipitation at Lind during the 1993-94 13-month fallow cycle was only 7.4 inches. Wheat stubble was chiseled 11 inches deep in the fall of 1993 on 24-inch centers. Primary spring tillage was conducted in late March 1994 at two depths: shallow - 4 inches; and deep - 7 inches, in adjacent plots with an undercutter sweep plow (32-inch sweeps). A rolling harrow was attached behind the undercutter to break up large clods and fill air voids. Plots were rodweeded three times during the late spring and summer to control weeds and maintain the dry surface mulch. Rodweeders were set to operate deep to establish a loose, thick, low bulk density soil mulch.

Seedzone water content of the plots was measured with an incremental soil sampler in late August. Moro club wheat was seeded at a rate of 30 lb./acre with the three drill types in both shallow and deep tillage plots on August 31, 1994. Seeding rate in one opener of each drill was carefully calibrated. The calibrated row was consistently used for measuring seedling emergence to avoid any difference due to openers. Wheat seedling

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emergence was measured by counting individual plants at 24-hour intervals beginning 9 days after planting.

Results

Seeding conditions on summer fallow at Lind, and throughout much of eastern Washington, were extremely marginal in 1994. In most years, soil water content adequate for germination and emergence is maintained just below the firm layer created by rodweeders. At the end of the dry 1993-94 fallow cycle, despite the efforts of even the most progressive growers, soil drying extended below the rodweeder depth, necessitating placement of seed 7 to 8 inches below the summer fallow surface to reach the minimum soil water content needed for wheat seedling emergence (Figure 1).

Seedling emergence counts on seven dates are shown in Table 1. The number of seeds planted which emerged ranged from 10% to 29% (1.3 to 3.5 seedlings per foot of row). Dry soil and a light (0.12 inch) crusting rain 13 days after planting hampered emergence in all treatments. Seedling emergence and stand establishment was best with the Zimmerman drill in both shallow and deep tilled fallow plots. There were no significant differences in seedling emergence between the John Deere HZ and International 150.

Clods and residue were still present on the soil surface of the John Deere HZ and International 150 treatments after seeding. Conversely, soil clods were absent and practically no surface residue remained in the Zimmerman plots.

Summary

Seedling emergence under very dry planting conditions at Lind was significantly improved with the Zimmerman drill compared to conventional split-packer drills. Stand establishment is the most important factor affecting wheat yields under dryland conditions in the Pacific Northwest. Although plant density was low in all plots, the Zimmerman drill demonstrated that the drills now available can be improved on for obtaining stands under difficult conditions. However, the Zimmerman drill pulverized surface clods and buried practically all surface residue. In low-rainfall wheat-fallow areas, clods and residue are needed after fall seeding to defend against wind erosion. Bob and Don Zimmerman are aware of the problem and have made many improvements on their drill since this trial was conducted. They are hoping to build a prototype drill with 20-inch spacing between seed rows which will leave the crest of the furrow undisturbed for wind erosion protection.

Acknowledgements

The authors gratefully acknowledge the contributions of Bob and Don Zimmerman. We thank Rodney Melcher for the use of his International 150 drill.

Table 1. Percentage of seeds planted which emerged at Lind as affected by drill type and depth of primary spring tillage.

	Days After Planting						
Drill Type - Tillage Depth	9	10	11	12	13	14	21
Zimmerman - 4" tillage	1	4	6	10	14	17	29
John Deere HZ - 4" tillage	0	1	1	3	6	9	11
International 150 - 4" tillage	0	1	3	5	7	9	12
Zimmerman - 7" tillage	0	1	3	6	11	15	21
John Deere HZ - 7" tillage	1	2	4	7	8	10	10
International 150 - 7" tillage	0	2	7	10	12	12	14
LSD 0.05	NS	NS	3.3	4.1	5.0	5.7	9.2

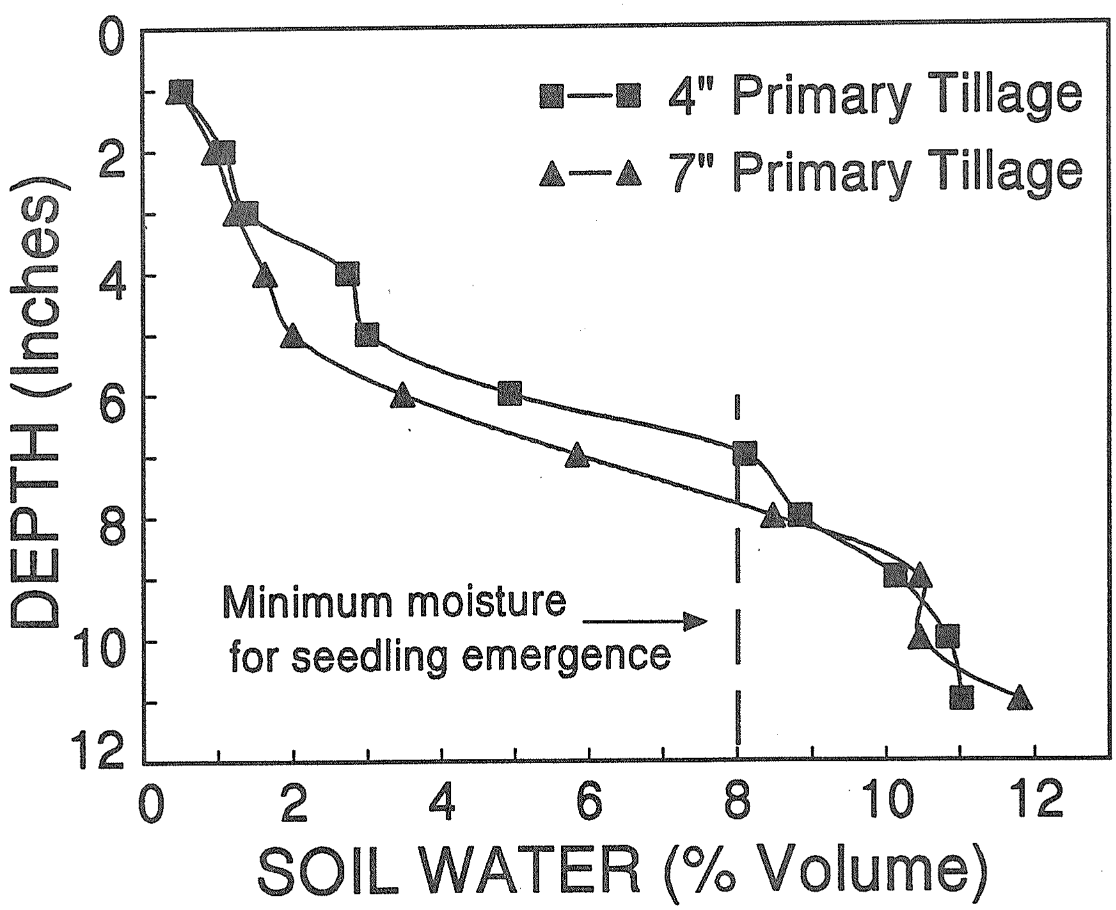

Figure 1. Seedzone water content at Lind on August 31, 1994, as affected by two primary spring tillage depths.

EXPLORING CROP RESIDUE OPTIONS FOR EROSION CONTROL FOLLOWING PEA AND LENTIL

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist
John Hammel, UI Research Soil Physicist
Stephen Guy, UI Extension Crop Management Specialist
Baird Miller, WSU Extension Agronomist

Soil erosion control in winter wheat after peas or lentils can be very difficult in the annual cropping region of the Inland Northwest. An important factors that contributes to the high erosion potential is the small amount of crop residue available after these legume crops. Pea and lentil residue production varies year to year with environmental conditions and commonly ranges from 1,000 to 2,500 pounds per acre. The fragile residue shatters easily under dry harvest conditions and can decompose rapidly under moist soil conditions. Even when tillage is limited, it is often difficult to maintain sufficient surface residue to adequately reduce erosion potential. In this article, we will briefly present grower options to increase surface residue levels and highlight new research efforts underway to enhance the feasibility and effectiveness of some of those options.

Before we continue with the discussion on residue, it is important to point out that erosion potential can also be increased by other factors such as lack of surface roughness and reduced water infiltration caused by surface soil compaction during spring tillage operations for legume establishment, or caused by deeper compaction from tractor traffic. These problems should also be addressed along with good residue management systems. There is research currently underway by John Hammel, UI Soil Scientist and other researchers investigating subsoil tillage, surface pitting and other tillage options to increase water infiltration and reduce erosion. Further efforts are needed to develop these conservation farming practices after pea and lentil crops.

Looking specifically at residue management choices, growers basically have four potential options to increase the amount of surface residue to improve erosion control in winter wheat after these crops:

1) Retain more of the legume residue on the surface through winter wheat seeding using direct seeding or minimum tillage systems.
2) Grow legume varieties or species that produce more crop residue.
3) Use crop rotations, fertilizers, and other cultural practices that enhance both legume yield and residue production.
4) Use minimum tillage practices for legume establishment after the preceding cereal crop to retain more cereal residue through winter wheat seeding after the legume crop.

Retain More Legume Residue Through Winter Wheat Seeding

Growers in this region have widely adopted minimum tillage and direct seeding systems for winter wheat after pea and lentil. The use of shank-and-seed systems has largely become the conventional tillage system for winter wheat after these legume crops. This typically involves direct-shank application of fertilizer without prior tillage, followed by either a cultivation or nonselective herbicide application, then seeding using conventional drills. Fertilizer applicators are usually either a tillage implement, such as a chisel or cultivator that the grower has modified for fertilizer application, or a heavy-duty, direct-shank fertilizer applicator that most fertilizer suppliers can provide for grower use. These modified tillage implements and direct-shank applicators have largely replaced the traditional heavy disc used as primary tillage to loosen the ground for conventional fertilizer applicators. Intensive tillage with the disc typically buried most of the legume residue.

Direct seeding of winter wheat after pea and lentil is also becoming more common with increased availability of conservation tillage drills and one-pass planting systems that can provide good soil and residue penetration, and deep-band fertilizer application at planting. Direct seeding and shank-and-seed systems both leave most of the legume residue on the surface. To provide additional surface residue for winter wheat after pea and lentil, growers need to look at other options in the cropping systems.

Grow Varieties that Produce More Residue

One of the easiest solutions to increasing residue levels after pea and lentil would be to grow varieties that produced more residue while maintaining or improving yield potential. Although there is some variation of residue production between current varieties, no varieties produce as much residue as desired for controlling erosion. A research effort to develop new high residue varieties is now underway by Fred Muehlbauer, USDA-ARS plant geneticist. If the program is successful, it will still take a number of years before new higher-residue varieties are available. What other options are available to growers now for improved erosion control?

Management Practices That Increase Legume Residue Production

Extensive Northwest research has documented that a 3-year rotation, such as winter wheat - spring crop - pea/lentil can often increase wheat yield potential and reduce weed and soilborne disease problems associated with winter wheat in a 2-year rotation. It is believed that pea and lentil yield and residue production also increase with the longer rotations because of a reduction in soilborne diseases affecting those crops, but more research is needed to evaluate rotation benefits for production and conservation in these legume crops.

If nutrient availability is limiting growth of pea and lentil crops, adjustments in fertilizer amounts, types and/or placement for better root access should increase residue production. The increasing acidification of soils in the pea and lentil region has the potential to restrict yield and residue production in some areas. Other cultural considerations which may influence legume residue production could include seeding rate, seeding date, seed treatments and harvest timing and methods. Further research is needed to evaluate the importance of a range of fertility and cultural practices on residue production in pea and lentil.

Use Minimum Tillage to Retain More of the Previous Crop's Residue Through Pea and Lentil Crops

Many growers are trying to plant peas and lentils under reduced tillage systems in order to retain more of the previous crop's residue on the surface through the legume crop and winter wheat planting. An important point to keep in mind is that this approach would work better under a 3-

year rotation, such as winter wheat-spring barley-pea or lentil, than a 2-year wheat-pea or lentil rotation. The additional year of spring crop is important in reducing soilborne diseases and winter annual grass weeds that can be problems in winter wheat with a reduced tillage system in a wheat-pea or lentil rotation.

Less potential for spring tillage compaction of surface soils could be another potential benefit of reduced tillage methods for pea and lentil establishment. Surface soil compaction from spring tillage and seedbed preparation can result in reduced water infiltration in pea and lentil fields after seeding and during the following winter wheat crop. If surface compaction exists, minimum tillage practices to fracture the soil at or before winter wheat seeding can improve infiltration and reduce runoff and erosion potential associated with surface compaction.

An additional benefit of carrying more spring crop residue through pea and lentil crops (compared to the other three options discussed above) provides improved erosion control during two erosion periods in rotations with pea and lentil. The greatest amount of cropland erosion in this region occurs during the wet winter months on fields of winter wheat planted after pea and lentil. However, intensive rainstorms in the spring and early summer on pea and lentil fields can also cause extensive soil erosion. Retaining more previous crop residue through pea and lentil seeding using reduced tillage would provide increased erosion control in these legume crops as well as in the following winter wheat crop.

On-farm research trials to evaluate the tillage and residue management option for retaining more spring cereal residue through pea and lentil crops are planned to begin in the fall of 1995. At least two growers in Latah County Idaho will be conducting the field operations on the trials. A tentative list of fall tillage systems to be evaluated with field-scale equipment include: 1) moldboard plow; 2) flail/chisel plow; 3) flail/Paratill subsoil; and 4) disc. The plow treatments would be spring cultivated and seeded with a conventional drill. The other three tillage systems would receive a herbicide application and then direct-seeded. The research trials will evaluate crop production potential, economics and soil conservation protection in each systems. Additional research trials are being discussed at other locations.

VARIABLE TILLAGE AND RESIDUE MANAGEMENT BY SOIL LANDSCAPE CAN INCREASE PRODUCTION POTENTIAL AND SOIL CONSERVATION

Roger Veseth, WSU/UI Extension Conservation Tillage Specialist

A field trial was initiated in the 1993-94 crop season to test the concept that reducing tillage intensity on more erodible, water-short portions of field landscapes could improve soil erosion protection, precipitation storage efficiency and crop yield potential. The results of this study have demonstrated significant production and conservation benefits, and indicate the need for continued development and evaluation of variable tillage and residue management strategies across field landscapes in the Inland Northwest.

Background on Variable Landscape Management

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

Water is one of the most limiting crop production factors in much of the Northwest. Tillage and residue management practices that increase soil water storage potential offer the greatest benefit in field areas where residue production is low and yield is typically limited more by available water than by weeds and diseases. These areas, such as ridgetops and upper slopes, also are usually most vulnerable to runoff and erosion because of the lower residue production, soil organic matter contents, and water infiltration rates, steeper slopes, and other factors. Increased water storage in these areas means greater yield potential.

In contrast, more intensive tillage and residue removal would be more appropriate on lower slopes and bottom land areas where yield is more limited by weed and disease problems than by available water, and erosion potential is minimum. Excess water and/or residue production in these field areas may cause further production problems as well.

Varying the intensity of tillage and residue management practices across these contrasting field landscapes can potentially improve both yield and resource protection. The first step in developing variable tillage and residue management strategies for this region is documenting the benefits...that was the point of this study. Figuring out equipment logistics and economic implications are the next steps needed in order to take advantage of the potential benefits.

Field Trial Overview

A field trial was initiated in the 1993-94 crop season to compare fall tillage treatments after winter wheat in a winter wheat-spring barley-fallow rotation. It was conducted on a 25-30% slope with south-southeast exposure in a 17-inch precipitation area. The study was conducted with Kevin

Scholz, a grower near Colfax, WA, in cooperation with other personnel from WSU, NRCS and the Ag equipment industry.

The initial year of the trial focused on water conservation and spring barley production. The field research site will continue to be monitored for water storage, soil erosion protection, and agronomic effects during the following 1995-96 winter wheat crop on fallow following spring barley. Comparisons of actual erosion may also be possible during the winter, depending on weather conditions.

Fall treatments on undisturbed stubble were: 1. Standard moldboard plowing without trashboards to a depth of 7 inches and furrow turned uphill; and 2. Disk-subsoiling using a Sunflower Disk-Ripper with front tandem disk with 20-inch disks at a 3-inch depth and 7-shank straight-point rippers on 2-ft spacings at about 12-inch depth. The Disk-Ripper was provided by Lavaine Logan, St. John Hardware in Fairfield, WA. Yield of winter wheat in the trial area was approximately 75-85 bu/acre.

Each treatments was replicated 4 times with pairs of treatments (replications) arranged end-to-end along the contour in the top 80 feet of a divided-slope field division. Plot lengths ranged from 300 to 450 feet. Plow treatments were established first, with the plow being pulled out to cross disk-ripper plots. The disk-ripper plots were established later with a zigzag pattern, turning on the adjourning plowed plot. These turning margins were excluded from data collection.

The disk-ripper resulted in similar tillage impacts on residue and roughness as with disking after harvest and late-fall chiseling, a common sequence of operations in the 15- to 19-inch intermediate precipitation area. Spring field operations on all plots included: harrowing, field cultivation, shank fertilizer application, rod weeding, and seeding to Steptoe spring barley on March 15 with a conventional double-disk drill with 7-inch row spacings.

A single combine pass was made up-and-down the slope on the end of each plot prior to harvesting the trial. Two full-header combine passes were taken along the contour in each plot. Yield weights were measured with portable truck scales.

Trial Results

The pre-tillage surface residue level in the spring (Table 1) after the disk-ripper was 2.8 greater than after plowing (3326 vs 1187 lb/acre). Percent surface residue after seeding spring barley (Table 2) was also significantly higher (67 vs 44% cover). It should be noted that the post-seeding level of surface residue following uphill plowing is substantially higher than is typically present after plowing when the plow furrow is turned down slope (commonly about 5 to 20%), confirming the value of uphill plowing as a conservation tillage practice on steep slopes, in addition to moving soil up slope. The higher level of surface residue under the disk-ripper significantly increased overwinter soil water storage by 0.67 inches in the top 3 feet of soil. There was no evidence of water loss from surface runoff overwinter or during barley establishment, so the difference in soil water availability overwinter is due to evaporation. The 320 lb/acre higher yield after disk-subsoiler was attributed to this increased overwinter soil water storage, plus the probability of continued lower evaporative loss between the March 9 sampling time and closure of the barley canopy cover.

Table 1. Spring pre-tillage surface residue level (lb/acre) on March 4, 1994

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Average
Plow	1015	998	1487	1247	1186.7a
Disk-subsoiler	3278	4182	2706	3138	3326.0 b
LSD (5%)[1]					1304
CV[2]					26%

[1] LSD (Least Significant Difference) at 5% means the smallest difference between treatment averages required to be statistically significant at the 5% probability level (5% of variability due to natural field variability)
[2] CV is Coefficient of Variation. Lower percentages mean lower natural variability and greater accuracy of detecting treatment differences.

Table 2. Percent surface residue after spring barley seeding on April 19, 1994

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Average
Plow	35	46	50	46	44.3a
Disk-subsoiler	59	76	67	67	67.3 b
LSD (5%)					8.7
CV					7.0%

Table 3. Inches of plant-available soil water content in the top 3 feet on March 9, 1994

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Average
Plow	5.13	5.58	5.21	5.51	5.36a
Disk-subsoiler	6.30	6.16	5.73	5.94	6.03 b
LSD (5%)					0.53
CV					4.2%

Table 4. Spring barley yield (lb/acre)

Treatment	Rep 1	Rep 2	Rep 3 [1]	Rep 4	Average
Plow	2090	2609	2603	2448	2437.5a
Disk-subsoiler	2565	2887	(1902)[1]	2820	2757.3 b
LSD (5%)					245
CV					2.7%

[1] Data from Rep 3 of the disk-ripper is not included in the analysis because a heavy wild oat infestation in the plot is believed to be largely responsible for the reduced yield compared to the other replications.

STRATEGIES FOR RETURNING CRP LAND TO CROP PRODUCTION

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Tim Walters, WSU Graduate Student
Harry Schafer, WSU Research Technician

Washington State CRP Situation

There are more than one million acres of CRP land in Washington State, nearly 14 percent of the 7.6 million cropland acres in a 20-county area of the central and eastern regions. It is estimated that about 90% of the contracted CRP acreage will be returned to crop production if provisions for extending CRP are not acceptable to producers. More than 50% of the contracts on more than 500,000 acres are scheduled to expire in the fall of 1996.

A majority of the CRP land is in the winter wheat-summer fallow region. This area receives eight to 14 inches annual precipitation and is vulnerable to wind erosion. Serious soil erosion problems could result if intensive tillage and residue removal practices are used in returning CRP land to crop production. Most growers in this dry region have little or no experience with converting grassland cover to crop production, particularly under conservation systems.

The Washington CRP Take-out Research Project

A research and education project was initiated in Washington State in 1994 to identify and promote local Best Management Practices (BMPs) for returning CRP land to crop production. It is designed as an umbrella project for a comprehensive, "grass roots" effort to evaluate prospective, locally-identified management options for specific agronomic zones of the state.

Miller and Veseth serve as co-leaders of the statewide team project. A number of other researchers, extension specialists and agents, and personnel from agricultural support agencies and industries are involved. Key players on each field trial are the growers who help plan and conduct field operations.

The project goal is to identify BMPs that optimize control of wind erosion, preservation of soil improvements gained during CRP, and agronomic performance and profitability of the first crops following CRP take-out. There are two primary research thrusts in this coordinated statewide project:

1. Develop BMPs for returning CRP land to winter wheat production following a summer fallow period.
2. Develop BMPs for returning CRP land to spring cereal production.
3. Evaluate soil quality changes resulting from taking CRP land back into crop production under different management systems.

Research Protocol

The field research is primarily a series of large-scale, replicated experiments with farm-scale equipment operated by the growers. This research approach is statistically very powerful, increases grower confidence in the research results, and facilitates more rapid adoption of BMPs compared to research conducted with small-plot equipment.

Before field experiments were established, we held local "brainstorming" meetings with four to six growers and personnel from USDA-NRCS, conservation districts and the agricultural service industry in seven counties with high CRP acreage. The most promising CRP take-out approaches, primarily tillage and residue management options, were selected for field research trials in specific production areas. Research plans were agreed upon with commitments from all the stakeholders involved in each trial.

Field research on killing CRP vegetation includes evaluations of both chemical and mechanical methods and timings. Research on preparation of the land for crop production includes evaluation of a variety of tillage and residue management options. The field trials are designed to produce a wide range of surface residue levels and surface roughness. Most trials have three to five "treatments" designed to represent management systems that growers identified as potential options for CRP take-out in their production area.

Eleven replicated field experiments with farm-scale equipment have been established so far in seven counties. Additional trials are being considered. Widths of individual treatment plots depend on implements used, but generally range from 30 to 50 feet. Plot lengths generally range from 800 to 1,500 feet. Treatments are replicated four times in each trial. Most trials are around 15 to 20 acres. In each trial the treatments are design to compare a range of tillage intensities and resulting residue levels.

Trials to evaluate CRP take-out management practices and fall versus spring starting time for summer fallow and winter wheat planting have been established in Adams, Douglas, Franklin, Garfield, and Lincoln counties. Primary tillage and residue management options being evaluated include: fall disc, spring disc, fall tine harrow/spring disc, fall mow/spring sweep, spring burn/sweep, fall flail/spring sweep, fall harrow/chisel, spring flail/sweep, and no-till seeding on chemical fallow after flailing, burning and no residue treatments.

Trials for spring crop production have been established in Asotin, Columbia, Douglas and Garfield counties. The primary tillage and residue management treatments include: fall disc, spring sweep/disc, spring disc, spring moldboard plow, spring burn/sweep, and no-till seeding into undisturbed grass or after fall burning. Additional trials with spring crops using no-till and tillage systems are being considered for the spring of 1996.

In each of these trials, data collection includes: initial grass residue, soil moisture and soil fertility, surface cover following planting and other factors affecting soil erosion potential, pest incidence, grain yield, test weight and protein, plus repeating part of this data collection during the second crop cycle after CRP take-out. Comparative crop enterprise budgets will be developed to evaluate the profitability of the treatments evaluated. The growers perform all of the crop production operations. Yield measurements are made with the grower's combine and portable truck scales or weigh wagons.

The on-farm testing, field-scale approach used in this CRP take-out research program should help to identify practical and effective management options.

In cooperation with other university and industry researchers, a number of satellite experiments with small plot equipment are being established on or near the large scale trials. These include evaluating alternative spring crop choices, fertilizer application options, nonselective herbicide rates and timings, soil quality changes, and other management questions.