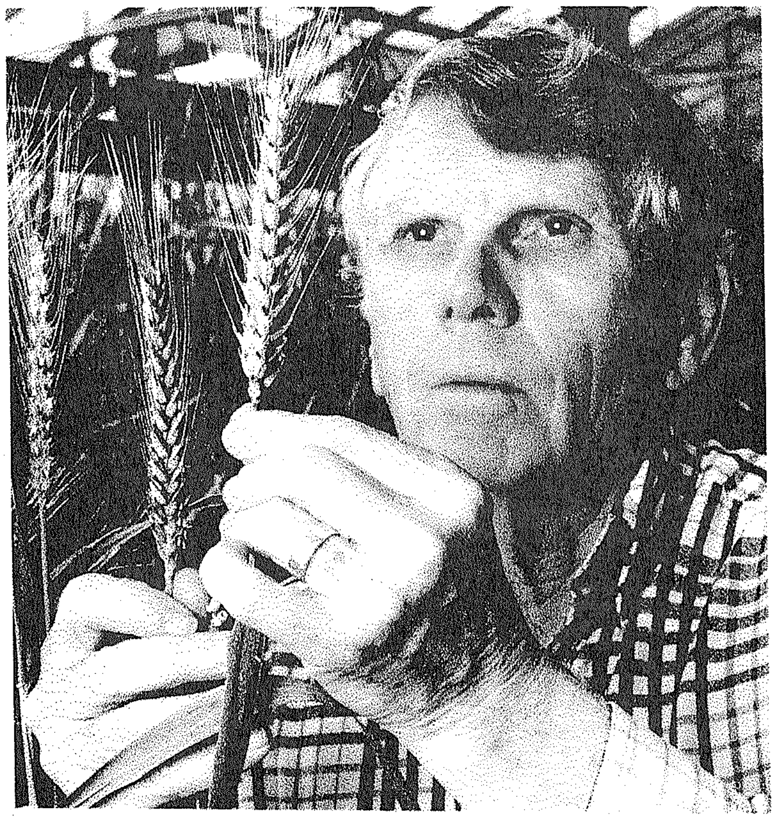
COOPERATIVE EXTENSION

Washington State University

Department of Crop and Soil Sciences

Technical Report 97-1



1997 Field Day Proceedings: Highlights of Research Progress

Dryland Research Unit, Lind June 9,1997	Spillman Farm, Pullman July 10,1997

Edwin Donaldson, Editor

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

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Dedication to ROBERT E. ALLAN

Dr. Robert E. Allan, USDA-ARS Research Geneticist with the Wheat Genetics, Quality, Physiology and Disease Research Unit, WSU, retired from ARS on Jan. 3, 1996. He continues his wheat genetics and breeding research as an ARS Collaborator and WSU Emeritus Professor in the Department of Crop and Soil Sciences.

Bob Allan received a B.S. degree from Iowa State University, and M.S. and Ph.D in Agronomy from Kansas State University. In 1957, he started his USDA-ARS career at Washington State University, when Dr. Orville Vogel hired him. He continued with the Unit, serving as Research Leader from 1972 to 1994. From 1981 to 1996, he served as Coordinator of the Western Regional Wheat Testing Program that includes 33 individual trials in the western U.S. and Canada. At WSU Dr. Allan served as advisor of 24 graduate students.

Early research on semidwarf genes: Dr. Allan conducted pioneering genetic research on wheat semidwarfism. He identified the Rht_1, Rht_2 semidwarf genes of Norin 10 and other parents used in the Green Revolution of wheat. This research facilitated use of these genes in varieties grown around the world. He discovered the insensitivity of specific semidwarf genes to gibberellic acid. This discovery stimulated a broad new research area on the regulation of plant growth processes and important agronomic traits of wheat.

Developed wheat varieties: Dr. Allan has developed eight wheat varieties and officially released 91 germplasm lines. His varieties have been widely grown in the Pacific Northwest. Since 1994 approximately 1 million acres have been planted each year with his varieties. He developed wheat varieties with resistance to strawbreaker foot rot, which is the main soilborne disease of wheat in the Pacific Northwest. Exploiting the unique foot rot resistance in a wild grass, he used translocation lines to breed the first U.S. wheat varieties, Madsen and Hyak, with high resistance to strawbreaker and combined rust resistance. To select for resistance Dr. Allan and coworkers developed one of the most successful examples of the use of marker-assisted selection in plant breeding, based on their discovery of a biochemical marker linked to resistance. Selection of the biochemical marker replaced a labor-intensive field selection test that required several months. The resistance to strawbreaker foot rot has greatly reduced the use of expensive fungicides otherwise needed to control the disease. Due to growth of the foot rot resistant varieties, an estimated 500,000 acres/year have not required fungicide thus saving growers several million dollars.

Dr. Allan has also led the way in developing club wheat varieties, which have superior quality, and are in high demand from Asian export markets. His varieties made up 70% of U.S. club wheat production in 1996. He developed two multiline club wheats, comprised of a mixture of component lines with different genes for disease resistance. His multilines are a unique way to achieve durable resistance to pathogens and reduce the need for chemical controls. In 1996 his multiline Rely was the most widely grown club wheat variety in Washington.

Release of new genetic material for future breeding programs: Through years of work Dr. Allan has developed unique genetic stocks including near isogenic lines in diverse genetic backgrounds that have facilitated studies on yield, adaptation, disease incidence, environmental stress, fertility restoration, nutrient use, and other physiological traits. These stocks have been used to elucidate: the influence of the compact spike gene on wheat adaptation, grain yield, the influence of semidwarf gene dosage on stand establishment, coldhardiness, lodging and a number of other traits. Results obtained from his special genetic stocks have significantly advanced basic knowledge of the genetic control of wheat growth and development, and have been applied directly to breeding. These genetic stocks are in high demand from plant breeders and molecular biologists. Because of the great number of potential uses, the release of this germplasm is likely to have an important impact on the future of wheat breeding programs for many years to come.

Awards and publications: Bob Allan is a Honorary Life Member of the Washington State Crop Improvement Association. He is a Fellow of both the American Society of Agronomy and Crop Science Societies. In 1995, he received a National USDA-ARS Technology Transfer Award and in 1996 the Award for Excellence in Technology Transfer from the Federal Laboratory Consortium. He has authored numerous publications.

Team: Dr. Allan has had excellent staff support in his research program. John Pritchett has supervised the field crew (joined ARS in 1961), Lynn Little has supervised crossing and data analysis (since 1975), and Patsy Sperry has served as Unit Secretary (since 1988).

COOPERATIVE PERSONNEL AND AREA OF ACTIVITY

Samuel Smith . . . . President, Washington State University
J. J. Zuiches . . . . Dean and Director of Research, College of Agriculture & Home Economics, and Director of Cooperative Extension
T. A. Lumpkin . . . . Chairman of Crop and Soil Sciences

Cereal Breeding, Genetics and Physiology

J. A. Anderson, R. E. Allan (Collaborator),
J. A. Pritchett, L. M. Little, USDA . . . . Wheat Genetics
K. K. Kidwell, G. B. Shelton,
V. L. DeMacon . . . . Spring Wheat Breeding & Genetics
S. E. Ullrich, D. von Wettstein, J. A. Clancy,
J. S. Cochran . . . . Barley Breeding & Genetics
A. Kleinhofs, D. Kudrna . . . . Barley Genetics
S. S. Jones, D. F. Moser, M. M. Cadle
S. R. Lyon, D. Steiner . . . . SWW, HWW Wheat Breeding
A. Kleinhofs . . . . Barley Evaluation Laboratory
B. C. Miller, P. E. Reisenauer . . . . Cereal Cropping Systems
M. K. Walker-Simmons, S. Verhey,
E. Storlie, USDA . . . . Wheat Physiology
P. Chevalier . . . . Cereal Physiology
R. L. Warner . . . . Seed Physiology

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B. Patterson, R. Ader . . . . Technicians
G. E. King, B. Davis . . . . Early Generation Testing

Cereal Diseases

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

Breeding and Culture of Dry Peas, Lentils and Chickpeas

F. J. Muehlbauer, J. L. Coker, R. Short, and C. J. Coyne, USDA

Weed Management

F. L. Young, USDA, and J. Yenish

Fertility Management and Conservation Systems

D. McCool, , A. Kennedy, K. Saxton, J. Smith, USDA,
T. E. Fiez, W. L. Pan

Soil Microbiology
D. F. Bezdicek, A. C. Kennedy

Soil Physics
G. S. Campbell

Agricultural Economics
D. Young

Animal Nutrition
J. Froseth

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

ACKNOWLEDGEMENT OF CONTRIBUTORS IN SUPPORT OF 1996-97 RESEARCH

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

Fertilizer, Seed and Amendments

AgrEvo USA Company
Gustafson
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WA Wheat Commission

Dry Land Unit and Spillman Farm Field Days Contributors

Adams County Wheat Growers
McGregor Company
American Malting Barley Assn
Whitman County Wheat Growers

Farmer Cooperators

John/Corrie Aeschliman	Colfax
Gene Aunne	Lacrosse
Dan Bauermeister	Connell
Mike Becker	Colton
Cecil Bramhall	Dayton
Dan/Doug Bruce	Farmington
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Cenex Supply & Marketing	Moses Lake
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Roger/Mary Dye	Pomeroy
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Chris Herron	Connell
Adelbert Jacobsen	Waterville
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Jerry Krause	Creston
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Mac Mills	St. John
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Roger Pennell	Whitman Co.
Bob Rea	Touchet
John Rea	Touchet
Ron Reinhardt	Fairfield
Rick Repp	St. John
Jim Richardson	Lamona
Jack Rodrigues	Wilbur
Dave Roseberry	Prosser

Farmer Cooperators

Doug Rowell	Prosser
Gerald/Ted/Mark Scheele	Fairfield
Art Schultheis	Colton
Gary Schwank	Lewiston ID
Tom Swaintz	Reardan
Larry Tanneberg	Coulee City
Lynn Tyacke	Prosser
Tony Viebrock	Waterville
Reggie Waldher	Pomeroy
Jim Walesby	Hartline
Bob Weigan	Colfax
Don Wellsandt	Ritzville
Doug Wellsandt	Ritzville
Western Plant Breeders	Bozeman MT
Brad Wetli	Mansfield
Curt/David/Gil White	Lamont
Russ Zenner	Genesee ID

HISTORY OF THE DRYLAND RESEARCH STATION

The Washington State University Dryland Research Station was created in 1915 to "promote the betterment of dryland farming" in the 8-to 12-inch rainfall area of eastern Washington. Adams County deeded 320 acres to WSU for this purpose. The Lind station has the lowest rainfall of any state or federal facility devoted to dryland research in the United States.

Research efforts at Lind throughout the years have largely centered on wheat. Wheat breeding, variety adaptation, weed and disease control, soil fertility, erosion control, and residue management are the main research priorities. Wanser and McCall were the first of several varieties of wheat developed at the Lind Dryland Research Station by plant breeding. Twenty acres of land can be irrigated for research trials. The primary purpose of irrigation on the Dryland Research Station is not to aid in the development of wheats for higher rainfall and irrigated agriculture, but to speed up and aid in the development of better varieties for the low-rainfall dryland region.

Dr. M. A. McCall was the first superintendent at Lind. 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 81 years, the Lind station has followed the policy of studying the problems associated with the 8-to 12-inch rainfall area.

The facilities at Lind include a small elevator which was constructed in 1937 for grain storage. An office and attached greenhouse were built in 1949 after the old office quarters burned down. In 1960, a 40' x 80' metal shop was constructed with WSU general building funds. An addition to the greenhouse was built with Washington Wheat Commission funding in 1964. In 1966, a deep well was drilled, testing over 430 gallons per minute. A pump and irrigation system were installed in 1967. A new seed processing and storage building was completed in 1983 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.

Growers raised funds in 1996 to establish an endowment to support the WSU Dryland Research Station. The endowment is managed by a committee of growers and WSU faculty. Grower representatives from Adams, Franklin, Benton, Douglas, Lincoln, and Grant counties are appointed by their respective county wheat growers associations. Endowment funds support facility improvement, research projects, equipment purchase, and other identified needs. Also in 1996, the State of Washington transferred ownership of 1000 acres of adjoining land to the WSU Dryland Research Station.

Since 1916 an annual field day has been held to show growers and other interested people the research on the station. This year marks the 81st field day. Visitors are welcome at any time, and your 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.

Table 1. Temperature and precipitation at Palouse Conservation Field Station, Pullman, 1996

Month	Monthly Avg. Temperature(F) Max.	Min.	Precipitation (in) 30-Yr Avg.*	Monthly	Total Accum.	Deviation from Avg. Monthly	Accum.
1996							
January	35.3	25.5	2.89	3.76	3.76	.87	.87
February	39.2	22.0	2.09	4.62	8.38	2.53	3.40
March	46.1	31.3	1.96	.64	9.02	-1.32	2.08
April	55.2	38.0	1.58	4.58	13.60	3.00	5.08
May	57.9	40.8	1.52	1.99	15.59	.47	5.55
June	71.8	46.6	1.49	.59	16.18	- .90	4.65
July	84.8	50.2	.53	.20	16.38	- .33	4.32
August	84.9	51.2	.95	.02	16.40	- .93	3.39
September	69.6	42.8	.99	1.05	17.45	.06	3.45
October	57.5	36.2	1.61	2.84	20.29	1.23	4.68
November	42.6	30.9	2.64	3.53	23.82	.89	5.57
December	34.6	23.0	3.07	5.51	29.33	2.44	8.01
TOTAL			21.32		29.33		8.01
1997							
January	35.7	24.5	2.89	2.66	2.66	- .23	- .23
February	39.1	28.1	2.09	1.79	4.45	- .30	- .53
March	46.3	32.5	1.96	1.85	6.30	- .11	- .64
April	51.9	33.8	1.58	2.61	8.91	1.03	.39
TOTAL			8.52		8.91		.39
1996 CROP YEAR Sept. 1995 thru June 30, 1996			19.84		25.82		5.98

*Thirty year average for precipitation, 1951-1980

1996 WINTER WHEAT

S.S. Jones

1996 was a record setting year for winter wheat in the state of Washington. Growers harvested 2.15 million acres, the fifth highest in the U.S. The average yield was 62 bu/ac with total production of 133.3 million bushels, the second highest total production in the nation. The average price per bushel was $4.75 bringing the value of production to $633.2 million, the highest valued winter wheat crop in state history. The goal of the winter wheat breeding program at WSU is for this success to continue by developing higher yielding, disease resistant varieties with excellent end-use characteristics for all market classes of winter wheat.

Accomplishments

Yield and disease trials are now being conducted at 16 sites statewide. Of these, 6 are in the low rainfall zone (< 12"), 6 in the intermediate zone (12-18"), and 4 in the high rainfall zone (>18").

A Cephalosporium nursery was established at Pullman last fall. The lines being tested are the only lines in the world with true Cephalosporium resistance.

Several lines with snowmold resistance equal to or better than Eltan have been identified. Some of these are club wheats. There are no snowmold resistant clubs currently available for northern Douglas county.

For the first time a yield trial for noodle wheats was planted at four locations. This demonstrates the progress being made in the hard white market class as we now have produced enough elite lines of this type for a separate trial.

Hard white wheat breeding nurseries are now being grown state wide not only for variety selection, but also to determine the areas where the hard whites may be grown and still produce a desirable end-use quality.

All plots grown at Spillman Farm are also duplicated at the Lind Field Station. There is substantial white wheat acreage in the drier areas that was previously being ignored.

Through incorporation of the lab and greenhouse with the field testing, our selection process for superior lines now occurs before harvest for everything except yield.

Results

Foundation seed of a new hard red wheat named Finley (WA7773) will be available this fall. It yields similarly to Hatton and Weston but has superior end-use quality. It also has stripe rust resistance and good emergence.

WA7834, a tall soft white club wheat, has been approved for preliminary breeder seed increase and is considered a Moro replacement. It emerges equal to or better than Moro, has stripe rust resistance and high levels of tolerance to Fusarium and snowmold, and has exhibited good winterhardiness. In the Moro production area it has a four year yield average that is 11.5 bu/ac greater than Moro with a test weight 2.0 lbs/bu greater. It is approximately 2 inches shorter than Moro and did not lodge under conditions where Moro was 100% lodged. Quality data shows it to be equal or superior to Moro in almost all traits.

Hard white wheat WA7835 was also approved for preliminary breeder seed increase. It appears to be better adapted to the high rainfall areas, but statewide it outyielded Eltan and Madsen by 4 and 5 bu/ac respectively with a 1.1 lbs/bu higher test weight. In the higher rainfall regions WA7835 outyielded Madsen by an average of over 10 bushels per acre. Samples submitted to the Wheat Marketing Center and the WWQL for evaluation showed that WA7835 has good noodle qualities.

WA7813, a soft white common, was the number one yielding variety in the Western Regional Soft Winter Wheat Nursery for 1996. At nine locations over 4 states its average yield was 99.3 bu/ac. In the irrigated nursery at Aberdeen, ID WA7813 was the top yielding variety at 179.6 bu/ac .

1996 STATE/EXTENSION WINTER WHEAT

E. Donaldson, S.S. Jones, P.E. Reisenauer, and B.C. Miller

The 1996 soft white winter wheat variety evaluation trials were established at 13 locations in 8 counties. A total of 26 soft white winter varieties were evaluated. In a cooperative effort, 5 additional soft white and 5 hard red winter nurseries were established by the breeders. Varieties in the trials included all significant publicly released varieties from the Pacific Northwest, public varieties from the tri-state nurseries being considered for release and private varieties entered on a 'fee for entry' basis.

Fall planting conditions were excellent at most locations. The nurseries at Farmington and Fairfield were planted later than usual due to cool wet weather. Starter fertilizer was used at all locations. Stand establishment was excellent. An unusually mild winter allowed the late planted nurseries to establish well. The winter conditions changed at the end of January with sub-zero temperatures and large amounts of snowfall. Snow cover protected the varieties and winter survival was excellent.

All nurseries were subjected to a warm and extremely dry summer. 'Timely rains' were nonexistent, yet the crops were extremely tolerant of the adverse conditions. Hot, dry winds did not occur throughout the season, this condition being a major factor in the resulting high yields and excellent grain quality. The Dusty nursery was severely infested with foot rot and yields were variety dependant. Cephalosporium stripe was present in the Anatone nursery.

The results from these trials and the WSU breeder's trials were summarized and reported in a winter Washington State Crop Improvement Seed Buying Guide. The variety performance results were also reported in the Washington Association of Wheat Growers Green Sheet, Wheat Life, each of the county agent's newsletters, and placed on Internet for electronic access.

1996 WSU HARD RED WINTER WHEAT SUMMARY

VARIETY NAME	YIELD (BU/A) LIND	HORSE HEAVEN	CONNELL	FINLEY	COULEE CITY	VARIETY AVERAGE	TEST WEIGHT (LBS/BU) LIND	HORSE HEAVEN	CONNELL	FINLEY	COULEE CITY	VARIETY AVERAGE	VARIETY NAME
ANDREWS	66.3	27.6	59.2	47.0	38.1	51.2	57.4	57.8	60.8	60.1	54.6	58.2	ANDREWS
BUCHANAN	56.3	47.2	66.7	60.4	46.3	55.2	58.1	59.1	60.5	60.7	58.1	59.5	BUCHANAN
HATTON	52.1	32.5	67.5	48.8	45.5	49.3	59.8	61.2	62.3	62.2	59.6	61.0	HATTON
KARL	25.4	14.4	26.2	31.2	37.2	28.5	58.8	58.9	60.6	60.2	59.2	59.7	KARL
QUANTUM HYBRID 542	74.7	36.6	71.7	57.4	54.4	56.1	60.0	59.5	62.3	61.2	58.7	60.2	QUANTUM HYBRID 542
SYMPHONY	76.1	*	69.3	28.1	47.1	*	57.2	*	59.9	60.1	53.5	*	SYMPHONY
WANSER	56.3	34.1	58.7	51.8	55.4	51.0	58.6	59.2	61.2	60.5	58.4	59.6	WANSER
WESTON	57.3	37.2	61.7	41.5	52.6	51.2	60.5	60.2	61.6	60.8	69.7	62.8	WESTON
NURSERY MEAN	60.5	38.8	65.7	55.4	47.4	53.8	58.2	58.9	60.8	60.4	57.9	59.2	NURSERY MEAN
CV (%)	14.4	14.3	12.2	12.0	14.5	13.5	2.0	1.6	1.2	7.5	6.7	4.7	CV (%)
LSD @ .10	10.9	7.3	9.4	8.1	8.0	3.9	1.4	1.3	0.9	5.5	4.6	1.5	LSD @ .10

Analysis method - General Linear Models Proceedure

1996 WSU WINTER WHEAT VARIETY TRIAL SUMMARY
YIELD (BU/A)

VARIETY NAME	PULLMAN	LAMONT	DUSTY	DAYTON	CRESTON	ASOTIN	MAYVIEW	REARDAN	ST. JOHN	FAIRFIELD	BICKLETON	FARMINGTON	MOSES LAKE	LIND	RITZVILLE	POMEROY	WALLA WALLA	COULEE CITY	VARIETY AVERAGE
Soft White Common																			
BASIN	117.4	91.3	77.6	129.4	88.8	71.1	110.5	113.2	115.0	74.1	58.2	123.6	119.0	64.7	91.7	86.2	130.1	50.0	95.1
CASHUP	122.7	94.3	83.5	129.8	100.7	74.7	118.2	131.1	111.8	91.4	62.5	135.4	121.1	84.6	101.2	99.9	141.5	60.4	103.6
DAWS	117.9	106.4	70.7	122.3	93.7	80.4	124.4	117.2	110.1	85.2	59.9	119.5	114.7	71.3	102.3	93.6	142.7	62.5	99.7
ELTAN	98.5	109.6	56.5	103.1	103.3	77.1	101.2	93.0	90.4	75.0	63.0	100.7	81.2	79.9	106.6	97.9	125.7	61.8	90.3
HILL 81	109.8	104.0	83.7	120.9	90.7	65.4	112.6	111.3	112.3	69.0	60.9	122.8	129.9	83.8	96.4	87.1	134.6	55.6	97.3
ID14502B	118.5	116.9	95.8	133.1	92.7	65.0	117.8	123.7	121.3	81.1	73.5	125.8	128.6	*	*	*	*	*	*
LAMBERT	130.6	114.9	93.1	116.2	99.9	76.2	130.2	110.2	120.1	91.9	70.6	134.7	128.5	82.1	100.2	90.1	151.9	49.9	105.1
LEWJAIN	90.8	102.9	81.5	107.1	88.5	66.6	106.2	94.2	78.3	56.1	65.5	96.1	88.4	69.6	96.9	84.8	128.6	56.0	86.6
MACVICAR	121.7	117.6	84.9	126.3	81.4	61.6	129.0	97.9	104.3	82.6	67.6	130.4	113.2	70.7	86.1	88.7	137.0	34.0	96.4
MADSEN	121.9	96.0	94.8	125.7	83.5	70.1	110.4	108.1	107.4	91.1	66.1	125.4	136.7	77.9	94.3	98.3	128.2	45.7	99.0
NUGAINES	102.2	90.3	70.1	118.2	79.0	68.0	104.0	97.6	89.3	64.0	63.5	115.1	103.6	70.6	87.8	81.9	126.2	55.8	88.2
ROD	123.4	115.1	65.2	127.1	101.5	86.4	134.7	115.3	102.9	85.1	72.4	132.0	121.5	80.1	104.6	98.2	138.0	63.0	103.7
STEPHENS	115.8	107.3	86.1	122.0	77.3	58.3	127.3	98.4	95.7	77.7	70.6	128.8	128.6	72.1	87.0	85.7	141.6	35.8	95.3
WA7686	113.7	106.5	102.6	127.5	96.1	77.6	121.8	113.2	116.4	82.3	67.8	137.8	123.2	69.4	96.5	103.2	145.6	62.7	103.6
WA7794	113.3	98.9	94.1	119.1	97.2	74.5	114.6	117.9	108.8	72.2	57.9	128.6	138.0	77.8	102.9	90.9	131.2	61.0	99.9
WPB 470	121.7	100.5	99.7	148.4	88.2	75.0	125.3	121.2	111.4	79.6	69.8	128.6	150.4	76.9	98.0	97.5	157.8	39.3	105.0
Soft White Club																			
HILLER	128.9	106.8	78.1	127.0	109.5	80.0	134.2	119.9	121.8	93.1	70.7	133.6	121.4	86.8	102.3	106.7	140.6	54.0	106.4
HYAK	128.2	108.7	87.5	106.2	97.6	66.3	118.3	116.9	104.3	75.7	66.7	122.7	93.6	77.7	93.2	101.0	102.2	56.5	95.7
OR92054	123.5	109.3	75.7	94.2	95.9	74.2	127.1	117.2	107.4	81.8	64.5	127.3	101.0	88.2	97.3	104.8	130.0	61.3	98.9
RELY	120.0	103.5	69.6	93.5	94.0	80.3	119.8	107.8	114.2	77.2	65.3	123.5	112.3	77.4	108.3	89.0	124.8	60.5	96.7
ROHDE	117.9	100.4	71.4	90.6	97.5	79.7	122.1	115.7	121.0	72.1	59.5	128.3	115.2	71.9	98.8	82.5	135.0	59.7	96.6
TRES	97.4	98.9	71.4	97.8	90.7	78.5	116.1	103.3	100.4	66.8	68.4	96.1	109.1	83.3	98.0	88.7	109.5	69.4	91.3
WA7697	96.5	108.2	96.4	123.4	96.6	81.9	126.3	123.5	121.8	81.5	62.4	129.0	118.2	72.5	93.3	105.9	139.1	51.6	101.6
WA7752	115.5	98.2	74.2	114.8	100.3	87.6	126.2	125.6	102.9	86.3	62.6	135.7	108.4	81.6	106.3	100.9	132.1	63.8	101.3
WA7793	109.6	106.0	93.7	114.9	96.8	75.7	126.8	111.4	112.1	83.2	65.9	125.2	115.7	79.8	102.5	105.0	142.3	58.9	101.4
Hard White Common																			
NUWEST	91.9	99.2	49.0	81.3	82.0	56.8	99.4	90.9	76.4	76.4	59.4	103.7	97.0	*	*	*	*	*	*
NURSERY MEAN	113.9	105.1	79.5	119.2	93.2	71.3	118.3	110.0	106.9	78.4	64.7	124.9	118.4	76.1	96.7	92.9	131.4	55.6	*
CV (%)	14.6	8.1	11.3	9.6	7.8	12.0	5.9	5.5	10.8	9.4	7.4	9.1	10.9	12.4	5.1	9.5	7.0	18.4	*
LSD @ .10	19.5	10.0	10.5	13.6	8.5	10.0	8.1	7.1	13.5	8.6	5.6	14.0	15.1	11.3	5.8	10.5	10.8	12.2	*

Analysis method - General Linear Models Proceedure

1996 WSU WINTER WHEAT VARIETY TRIAL SUMMARY
TEST WEIGHT (LBS/BU)

VARIETY NAME	PULLMAN	LAMONT	DUSTY	DAYTON	CRESTON	ASOTIN	MAYVIEW	REARDAN	ST. JOHN	FAIRFIELD	BICKLETON	FARMINGTON	MOSES LAKE	LIND	RITZVILLE	POMEROY	WALLA WALLA	COULEE CITY	VARIETY AVERAGE
Soft White Common																			
BASIN	60.0	60.0	57.9	61.9	57.8	59.4	60.2	59.2	59.2	59.3	59.4	60.5	54.0	60.7	61.8	60.5	60.9	58.1	59.5
CASHUP	59.6	60.7	59.1	62.6	59.4	58.8	60.2	59.6	60.4	58.6	59.0	60.0	56.0	60.3	62.0	60.0	60.6	57.2	59.7
DAWS	60.0	59.8	56.3	60.9	58.5	58.7	61.1	58.9	59.7	60.4	59.1	60.2	55.6	60.1	61.4	61.6	59.7	56.6	59.4
ELTAN	59.8	58.3	53.4	60.2	57.2	59.1	60.0	54.7	58.5	58.5	56.7	59.9	53.1	59.9	60.4	59.6	60.3	56.7	58.1
HILL 81	59.7	59.0	57.3	61.8	57.5	58.6	61.0	59.7	59.9	58.1	57.0	60.3	59.4	60.4	61.8	60.8	61.5	58.0	59.5
ID14502B	60.5	61.4	60.4	62.6	59.0	58.6	61.9	59.1	61.1	59.3	60.1	60.4	57.3	*	*	*	*	*	*
LAMBERT	59.5	58.0	56.8	60.6	55.1	57.0	59.0	56.8	58.9	58.8	57.4	58.8	55.5	60.1	61.0	60.7	60.5	56.1	58.4
LEWJAIN	59.2	58.8	56.7	60.6	56.9	59.6	60.7	55.5	57.8	57.7	58.3	59.6	53.6	60.2	61.3	59.8	59.8	55.2	58.4
MACVICAR	59.7	59.6	57.1	59.7	56.0	55.1	60.0	57.0	57.5	57.0	58.4	59.1	53.0	59.7	60.7	60.0	59.7	52.8	57.9
MADSEN	59.8	58.6	58.1	61.8	56.8	58.2	60.6	58.7	59.3	59.3	57.5	59.8	59.0	59.9	61.4	61.3	60.1	56.8	59.3
NUGAINES	60.9	61.5	59.0	62.7	59.5	60.5	61.9	59.5	60.2	61.1	60.0	61.1	56.3	61.6	63.5	61.8	60.9	59.8	60.7
ROD	57.7	59.1	53.1	59.7	55.6	56.2	58.8	56.0	57.0	56.6	57.6	58.4	54.1	59.2	60.3	59.2	59.5	54.2	57.4
STEPHENS	58.7	59.7	57.9	61.1	56.0	54.3	59.7	56.9	57.6	56.4	58.2	58.8	56.5	59.9	60.0	60.0	60.6	53.0	58.1
WA7686	58.0	58.9	57.7	61.2	56.5	56.8	59.3	57.5	58.0	57.0	56.6	58.4	56.3	59.8	61.2	60.1	60.0	56.1	58.3
WA7794	59.5	59.7	60.4	61.3	58.6	58.9	60.7	59.4	58.9	58.0	58.6	60.4	57.5	59.9	61.3	61.7	60.6	56.8	59.6
WPB 470	62.3	63.3	60.2	63.8	61.4	61.1	62.8	61.5	61.7	61.6	63.0	63.2	62.6	62.5	63.8	63.2	63.4	57.3	62.2
Soft White Club																			
HILLER	56.7	57.1	54.2	58.9	54.6	54.6	58.0	56.2	57.2	56.0	55.2	56.7	53.4	57.5	59.1	58.1	57.9	52.1	56.3
HYAK	59.0	58.4	56.4	58.9	55.5	56.0	59.3	58.1	58.0	57.7	56.5	59.2	53.1	59.1	60.0	60.4	59.2	54.1	57.7
OR92054	59.4	60.1	59.2	60.2	57.6	57.0	60.4	58.6	59.9	57.8	57.6	59.6	55.6	60.1	60.9	61.9	61.2	55.0	59.0
RELY	58.9	59.2	56.0	60.3	56.4	57.4	59.5	58.3	59.0	58.5	57.1	59.6	55.3	59.2	60.7	59.4	59.6	56.1	58.4
ROHDE	60.9	59.7	56.4	61.9	58.1	59.7	61.5	59.5	60.4	60.9	58.6	60.9	55.6	61.0	61.8	61.3	62.3	58.1	59.9
TRES	59.0	59.6	58.3	60.9	57.7	58.6	60.6	58.6	59.2	58.5	57.8	59.4	57.5	59.5	61.2	60.9	59.8	56.8	59.1
WA7697	60.0	60.6	59.6	62.3	57.5	58.8	61.3	60.0	60.2	59.5	58.6	61.0	56.1	60.8	62.1	61.8	61.6	56.1	59.9
WA7752	60.6	60.1	58.6	62.5	58.0	58.9	61.0	61.4	60.8	61.0	57.7	61.6	57.5	60.5	62.9	62.2	61.6	58.4	60.3
WA7793	57.3	57.4	55.7	59.7	55.2	55.5	58.3	56.6	57.7	57.5	55.4	58.4	55.1	57.1	58.3	59.2	58.5	54.1	57.1
Hard White Common																			
NUWEST	60.9	60.7	55.6	60.8	58.6	59.3	61.1	59.9	59.8	60.3	58.6	60.5	57.9	*	*	*	*	*	*
NURSERY MEAN	59.4	59.4	56.9	61.1	57.2	57.7	60.2	58.2	59.0	58.1	57.9	59.7	56.3	60.0	61.2	60.6	60.4	56.1	*
CV (%)	1.5	0.9	2.0	1.4	1.4	1.5	0.5	1.7	1.8	2.7	0.7	1.0	3.4	1.3	0.6	1.3	1.0	2.8	*
LSD @ .10	1.0	0.6	1.3	1.0	1.0	1.0	0.3	1.2	1.3	1.9	0.5	0.7	2.2	1.0	0.4	0.9	0.7	1.9	*

Analysis method - General Linear Models Proceedure

1996 WSU WINTER WHEAT VARIETY TRIAL SUMMARY
PROTEIN (%)

VARIETY NAME	PULLMAN	LAMONT	DUSTY	DAYTON	CRESTON	ASOTIN	MAYVIEW	REARDAN	ST. JOHN	FAIRFIELD	BICKLETON	FARMINGTON	MOSES LAKE	LIND	RITZVILLE	POMEROY	WALLA WALLA	COULEE CITY	VARIETY AVERAGE
Soft White Common																			
BASIN	9.0	7.6	9.5	10.7	8.6	8.8	9.9	10.1	11.2	9.9	6.4	10.0	11.2	10.3	9.8	10.2	11.5	11.1	9.8
CASHUP	8.6	8.1	10.1	10.4	8.1	8.5	9.4	9.8	11.5	9.8	6.4	9.9	12.1	10.2	9.2	10.8	11.8	11.1	9.8
DAWS	7.8	7.9	9.9	10.8	8.4	8.5	9.6	9.8	11.7	9.9	6.7	10.4	11.7	10.6	9.1	9.9	12.1	12.4	9.8
ELTAN	8.7	7.1	10.6	10.5	8.2	8.9	10.0	11.1	11.7	10.7	6.1	9.8	11.7	11.0	8.6	10.1	12.0	11.9	9.9
HILL 81	9.2	7.4	9.9	10.9	8.8	9.9	10.2	10.2	12.3	11.3	6.4	10.1	11.1	11.7	9.8	10.0	12.2	11.7	10.2
ID14502B	7.9	7.6	10.1	10.9	8.3	8.7	9.8	9.8	11.4	10.3	6.2	9.8	11.3	*	*	*	*	*	*
LAMBERT	8.4	7.3	9.5	10.5	8.0	9.0	9.3	9.9	11.3	9.6	6.4	9.5	11.5	10.7	9.6	10.2	12.0	11.6	9.7
LEWJAIN	9.3	7.4	10.2	11.0	8.7	9.2	10.7	11.0	12.6	11.6	6.2	10.6	12.0	11.6	10.1	10.4	12.3	12.4	10.4
MACVICAR	8.5	7.4	9.4	10.6	8.1	9.4	9.4	9.9	11.3	11.6	6.6	10.1	11.1	11.2	9.5	10.2	11.7	11.8	9.9
MADSEN	9.0	7.3	10.2	10.8	9.4	9.5	10.6	11.5	12.2	10.2	6.5	10.3	11.5	11.9	9.8	10.2	12.3	11.3	10.3
NUGAINES	8.6	7.0	8.8	10.5	8.6	8.9	10.3	10.2	11.8	10.7	6.0	9.7	11.4	10.5	9.4	10.1	11.6	11.0	9.7
ROD	7.6	7.2	9.6	10.8	8.0	8.5	9.5	10.6	11.7	10.1	6.1	10.1	11.8	11.1	9.0	9.6	11.7	12.0	9.7
STEPHENS	8.9	8.0	10.1	11.2	8.8	10.1	10.1	10.3	11.9	11.1	6.9	10.0	11.4	11.5	10.1	11.0	12.0	12.2	10.3
WA7686	8.7	8.1	9.8	10.8	8.4	9.0	10.1	11.2	12.8	10.6	6.6	10.4	11.5	11.3	10.0	10.9	12.3	11.8	10.2
WA7794	8.7	6.9	9.7	10.7	7.9	8.6	9.9	10.5	11.8	10.9	6.1	10.3	11.4	11.9	9.3	9.7	12.1	11.6	9.9
WPB 470	9.3	8.1	9.9	11.1	8.6	9.1	10.3	10.7	12.9	10.7	6.8	11.0	12.1	13.2	10.4	10.5	12.6	13.0	10.6
Soft White Club																			
HILLER	8.5	7.4	9.9	10.1	7.8	8.5	9.4	10.4	11.4	10.1	6.3	10.5	12.1	11.6	9.2	9.5	11.8	12.4	9.8
HYAK	9.0	6.9	9.6	10.3	8.3	9.2	9.9	11.6	11.7	10.9	5.7	10.0	11.8	11.6	8.6	9.0	12.1	10.7	9.8
OR92054	8.3	7.9	10.0	11.0	8.2	9.0	9.3	9.3	11.4	10.5	5.7	9.5	11.5	11.9	8.5	9.4	11.1	11.6	9.7
RELY	8.1	7.5	9.9	10.2	7.9	8.3	9.4	9.7	11.1	10.1	5.9	10.0	12.1	11.3	8.4	9.1	11.9	11.3	9.6
ROHDE	8.0	7.7	10.3	11.2	8.4	8.6	10.1	10.4	12.1	10.8	6.1	10.0	11.9	11.0	8.5	9.3	11.9	11.3	9.9
TRES	7.4	7.6	9.9	10.7	8.8	8.7	9.8	10.4	11.8	10.9	5.7	10.4	11.7	11.1	8.2	9.3	11.7	10.7	9.7
WA7697	7.8	7.8	9.6	10.5	8.5	8.8	10.0	10.0	12.2	10.3	6.3	9.9	11.8	11.2	9.0	9.2	11.8	12.1	9.8
WA7752	8.0	7.8	10.5	11.1	8.6	8.1	10.1	10.5	13.0	9.5	6.2	10.6	12.7	12.1	9.4	10.2	13.0	11.1	10.1
WA7793	7.9	7.2	9.4	10.9	8.4	8.1	9.9	9.6	12.5	9.6	5.8	9.7	11.9	11.0	8.7	9.8	12.3	11.3	9.7
Hard White Common																			
NUWEST	8.5	6.9	9.6	11.2	8.2	10.0	11.1	9.9	12.7	11.5	5.5	10.4	12.3	*	*	*	*	*	*
NURSERY MEAN	8.6	7.5	9.9	10.8	8.4	9.1	10.0	10.3	12.0	10.8	6.3	10.2	11.7	11.3	9.3	10.0	12.1	11.7	*
CV (%)	10.3	4.7	5.4	9.1	5.7	4.9	3.6	11.0	6.2	12.1	3.4	6.2	3.0	7.5	6.0	9.5	2.9	11.4	*
LSD @ .10	1.0	0.4	0.6	1.7	0.6	0.5	0.4	1.3	0.9	1.5	0.3	0.8	0.4	1.0	0.7	1.1	0.4	1.6	*

Analysis method - General Linear Models Proceedure

SEEDLING EMERGENCE OF PACIFIC NORTHWEST SOFT WHITE WINTER WHEATS FROM DEEP PLANTING

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The Problem

Sixty percent of Washington's winter wheat production area receives from 6-to 12-inches of annual precipitation. Growers in this 3 million acre low-rainfall dryland region are unable to take full advantage of the extensive progress in soft white winter wheat (SWW) improvement over that past 30 years because all SWW varieties in the Pacific Northwest, except Moro, possess dwarfing genes. Moro was released 31 years ago by Oregon State University and, by today's standards, has poor disease resistance, modest yield potential and grain quality, is difficult to thresh, and has weak straw. Despite these problems, Moro is the number one club wheat grown in Washington because seedlings are capable of emerging from deep planting through thick soil cover.

Stand establishment problems in low-precipitation dryland areas of the Pacific Northwest became particularly acute when 'Gaines' and other semidwarf "green revolution" winter wheats, with coleoptiles 30-to-40% shorter than non-semidwarf wheats, came into production. Semidwarfs have higher yield potential than non-semidwarfs. Coleoptile length and rate of first leaf growth are significantly correlated with emergence capability. Rate of coleoptile elongation is also important.

The objective of our research was to compare seedling emergence and stand establishment of Moro: (*I*) to other SWW wheat varieties available to growers in low-rainfall dryland areas of eastern Washington, and; (*ii*) to lines with long coleoptiles in advanced testing as possible candidates for release as Moro replacements.

Study Description and Results

From 10 plantings at 2 locations over 3 years, we measured the emergence capability of: (*I*) nine SWW varieties and; (*ii*) twelve SWW advanced lines possessing long coleoptiles. In both wet and dry years, seedlings emerged through 4.5-to 6.3-inches of soil cover with volumetric water content in the seed zone ranging from 11-to-18 percent.

Moro, the only non-semidwarf SWW variety available to Pacific Northwest growers, always emerged significantly faster and achieved the best final stand compared to semidwarf varieties, which carry either the Rht_1 or Rht_2 reduced-height genes. Moro has a coleoptile length of 3.5 inches. The advanced lines tested had equal or superior straw strength, disease resistance, or grain quality compared to Moro. The best emerging advanced lines had coleoptiles longer than 4 inches and emergence ranged from 26-to-42% of total seeds planted compared to 15-to-22% for Moro. Coleoptile length and shoot length were highly correlated with emergence capability among both varieties and advanced lines.

Results highlight progress in breeding SWW wheats for emergence under dry Pacific Northwest conditions. Our goal is to develop winter wheat varieties with emergence equal to, or better, than Moro and surpass it for other traits.

SPRING WHEAT BREEDING AND GENETICS: 1996 PROGRESS REPORT

K. Kidwell, B. Barrett, V. DeMacon and G. Shelton

Spring Wheat Breeding

1. Program Overview: Over 650 crosses were made 1996, and novel genes conferring resistance to the Hessian fly and Russian wheat aphid were incorporated into adapted soft white, hard red, hard white and spring club germplasm. F_1 seed was increased to generate segregating progenies for use: 1) in backcross breeding strategies; 2) in protein marker-assisted selection for end-use quality improvement; 3) as genetic mapping populations for identifying DNA markers linked to insect resistance and spring growth habit (SGH) genes; and 4) in the conventional cultivar development program. Approximately six hundred F_2, 688 F_3 and 303 F_4 families were advanced to the next generation, and 15,000 F_5 lines were evaluated in the field for agronomic characteristics. Over 650 F_6 lines were evaluated in multiple field trials, and grain samples from 272 lines with superior agronomic performance were sent to the WWQL for quality assessment. Seventh generation lines (105) were evaluated in replicated field trials, and more than 100 advanced lines (F_8+) were evaluated at 3 to 11 locations under annual crop, crop/fallow and irrigated conditions (See 1996 Spring Wheat Variety Performance Data).

2. Advanced Lines with Potential for Release: WA007831 is a common, semi-dwarf soft white spring wheat with mid-season maturity. Based on 1996 variety performance data, WA007831 was among the highest yielding soft white entries at most locations. Test weights of grain from this line typically were within 0.5 lb/bu of the nursery mean, and grain protein content were typically equivalent to or slightly higher than the nursery average for soft white entries. This is the first year that WA007831 was evaluated in the commercial variety and tri-state nurseries. Further field testing and multiple location baking and milling tests are required before the release potential of this variety can be determined.

WA007802 is a common, semi-dwarf hard red spring wheat with mid-season maturity that is typically 2-4 inches taller than Westbred 926. Results from the 1996 variety trials indicated that WA007802 has excellent grain yield potential, and this line was often the highest yielding hard red entry in the nursery. Test weights of grain from WA007802 often were slightly lower than the average for hard red entries; however, grain protein contents were equivalent to the nursery mean at most locations. This is the second year that WA007802 has been evaluated in the commercial variety and tri-state nurseries, and grain from this line was evaluated by PNW Wheat Quality Council members in 1995. Despite the low grain protein content of the sample evaluated by council members, end-use quality results were encouraging. WA007802 was approved for pre-release in 1997. If approved for final release, this line will be targeted to the semi-arid, hard red spring wheat production region in eastern WA as a replacement for Butte 86.

3. Additional Breeding Efforts

A. Early Generation Screening for End-Use Quality Potential: The high molecular weight (HMW) glutenin patterns of 742 lines were determined, and this information was used to select parents and to identify early generation progeny with superior end-use quality potential for advancement or for use in backcross breeding strategies.

B. Developing Noodle Wheats for the PNW: Significant progress has been made towards establishing a hard white (HW) spring wheat breeding program at WSU. Forty seven crosses were made among HW lines with superior noodle color and adapted soft white (SW) spring varieties to convert elite SW lines carrying bread genes to hard white wheats. Currently, the noodle color potential of individual lines within families is being assessed through a tyrosinase procedure. The HMW glutenin patterns of individuals with superior color potential is determined after color assessment through half-seed analyses, and lines with acceptable color potential and glutenin patterns are selected for advancement. In addition, 70 crosses between elite spring wheat germplasm from the PNW and superior Australian noodle wheats have been made, and F_1 seed was increased in the greenhouse.

C. Winter/Spring Conversions: Advanced generation seed from winter X spring crosses segregates for growth habit, therefore, F_2 seed from 112 winter club X spring crosses was used to establish winter (ARS club wheat program) and spring (WSU spring wheat program) selection nurseries. These families also segregated for head type, therefore, common and compact heads were snapped separately from each entry, and F_3 plots from selected lines were planted in the field in 1997. In addition, remnant seed was planted in the greenhouse for crossing purposes, and 162 crosses to elite winter or spring lines were made.

Similar procedures are being used to incorporate elite winter common germplasm into the spring wheat breeding program, and 71 involving adapted winter common germplasm were advanced in the greenhouse. Seed generated by crossing elite winter germplasm to HF resistant gene donors was divided between the WSU spring and winter wheat breeding programs for advancement in 1997 field trials.

D. Incorporating Insect Resistance Genes into Adapted Germplasm: Novel genes conferring resistance to the Hessian fly (HF; 6 genes) and Russian wheat aphid (RWA; 5 genes) have been incorporated into adapted soft white, hard red, hard white and spring club germplasm. F_2, F_3, BC_1F_1 or BC_2 seed has been generated for 117 families carrying Hessian fly resistance genes. Based on results from glutenin analyses, selected lines will be sent to Dr. J. Hatchett (ARS, KSU) for insect screenings. Seedlings that demonstrate an acceptable level of resistance to the WA biotype(s) of HF will be sent back to WSU for advancement.

Ninety-five crosses were made among elite, adapted germplasm and PI lines carry five, unique RWA resistance genes. F_1 seed from these crosses was harvested from the greenhouse in October. Resulting seed was increased in the greenhouse during the spring of 1997, and BC_1 and topcross seed will be harvested by mid-summer. F_2 and BC_1F_1 seed will be sent to Dr. C. Baker (ARS, Oklahoma State) for insect screening and selection.

E. Results From Other Research Efforts:

1. Characterizing Spring Growth Habit Genes In Adapted Varieties: Several spring growth habit (SGH) genes have been identified in wheat and at least three are known to be controlled by single, dominant genes (*Vrn*1, *Vrn*2 and *Vrn*3). Results from other studies indicated that genotypes carrying two, dominant SGH genes mature earlier and have higher grain yield potential than lines with only one SGH gene; therefore, it may be possible to improve spring wheat yields by manipulating alleles at *Vrn* loci. The objective of this study was to determine which *Vrn* gene(s) is(are) carried by elite, spring wheat germplasm from the Pacific Northwest. Individual plants from 59 spring wheat lines were crossed to near-isogenic testers carrying *Vrn*1, *Vrn*2 or *Vrn*3. Progeny from 1 to 4 F_2 families for each variety by tester combination were evaluated for growth habit in the field at Pullman, WA, in 1996. To determine which *Vrn* gene(s) was(were) present in each line, segregation data were tested for goodness of fit to a 15:1 and a 63:1 ratio using the Chi-square statistic. The identity of *Vrn* genes carried by 39 of the 59 lines tested was conclusively determined ($p>0.05$). Results indicated that a majority of these lines carry *Vrn*1 alone (16/39) or in combination with other SGH genes (18/39). *Vrn*2 and *Vrn*3 were each detected in ten of 39 lines; however, these genes were typically found in combination with other SGH genes. An unidentified *Vrn* gene(s) also was(were) detected in seven adapted lines. Studies are currently underway to confirm the identify of *Vrn* genes present in the other 20 adapted spring wheat lines. This information will be used to select the appropriate parents to cross to recover offspring carrying superior *Vrn* gene combinations to improve grain yield potential of spring wheat.

2. Environmental Influences on the Relationship among SDS Microsedimentation Volume, HMW Glutenins, and Protein Content of Spring Wheat Grain: Efficient assessment and prediction of end-use quality is a key component for developing wheat varieties that produce highly marketable wheat grain. Protein quantity and quality determines end-use quality, and flour protein contents are correlated with HMW glutenin bands and SDS sedimentation (sed) volumes. A simple, inexpensive technique (microsed) has been developed to measure sed volumes of early generation lines. The objectives of this study were to *I*) assess environmental influence on relationships among microsed values and protein contents of spring wheat flour; and *ii*) determine if glutenin banding patterns can be predicted from microsed data. Grain samples from 18 elite spring wheats grown in 2 locations were evaluated. At each location, correlation between sed volume and flour % protein was significant ($p < 0.0001$); however regression coefficients at each location were different ($p = 0.0009$). At both locations, high sed volumes were associated with glutenin bands 1, 17+18 and 5+10; while low sed volumes correlated with null, 7+9, and 2+12 alleles. These data suggest microsed analysis provides environmentally independent, cost-effective prediction of HMW glutenin bands; and accurate prediction of grain protein content within environments.

3. Assessing Genetic Diversity Among Regionally Adapted Wheat Germplasm: Assessment of regionally adapted germplasm provides an estimate of the genetic breadth of the local germplasm base, identifies potential heterotic groups for crossing purposes , and can expedite breeding efforts to supply cultivars that meet a broad spectrum of environmental and market demands. Many molecular marker systems have been employed to quantify diversity levels among genomes; however, low polymorphism levels have been detected in self-pollinating crops such as wheat and soybean. A recently developed technique, Amplified Fragment Length Polymorphism (AFLP) may be a valuable DNA marker system for detecting allelic diversity in self-pollinating species since it amplifies 50 to 100 loci per reaction. AFLPs are currently being used to quantify DNA relatedness among 54 elite spring and winter wheat accessions from the Pacific Northwest. Preliminary results indicate that AFLPs are useful for distinguishing among wheat genotypes and this technique may be useful for creating DNA fingerprints of cultivars.

1996 SPRING WHEAT VARIETY PERFORMANCE DATA

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Thirty-nine spring wheat entries were evaluated for agronomic performance at twelve sites in eastern Washington during the 1996 growing season, and results from 23 named varieties or advanced lines are reported here. Planting conditions, fertilizer rates, precipitation levels and harvest dates for each location are listed in Table 1. Grain yields, test weights and protein contents for entries grown at locations with less than 16 inches of average annual rainfall (low), between 16 and 20 inches (intermediate), greater than 20 inches (high) and under irrigation are listed in tables 2, 3, 4 and 5, respectively. Soil moisture levels were well above average at planting. Cool, wet conditions delayed seeding until late April or early May at locations with more than 16 inches of average annual rainfall. Spring grain yields in the low rainfall areas were excellent (Table 2); however, lack of precipitation during the growing season limited grain yield potential at locations with high average annual rainfall levels (Tables 3 and 4). Additional performance information for certified spring wheat varieties can be found in the "1997 Certified Seed Buying Guide for Barley and Wheat, Spring Varieties," published by WSU and the Washington State Crop Improvement Association. This information also can be found on the **WSU Variety Performance Information** web page at http://variety.wsu.edu.

Acknowledgments: The authors are extremely grateful for the cooperation of the growers that donate their land and time to successfully establish and maintain these trials. This effort could not be completed without their assistance. We especially thank Bruce Sauer (Lind), Dale Bauermeister (Connell), Ron Juris (Bickleton), Don, Steve and Dan Moore (Dusty), Don Wellsandt (Ritzville), Mary and Roger Dye (Pomeroy), Randy James (Dayton), Hal Johnson (Reardan), Mac Mills (St. John), Gerald Scheele (Fairfield), Dick Hoffman and Steve Kuehner (Pullman), and Earl Stuckel, John Stienbock and Mark Weber (Royal Slope) for their contributions to the spring variety evaluation program. Funding for work was provided by the Washington Wheat Commission and Washington State University.

Table 1. Cultural data for the 1996 WSU and Extension spring wheat variety evaluation trials.

Annual Rainfall (in)	Nursery Location	Previous Crop	lb Base Fertilizer N	lb Base Fertilizer P	lb Base Fertilizer S	Planting Date	Seeding Rate (lb/A)	lb Starter Fertilizer N	lb Starter Fertilizer P	lb Starter Fertilizer S	Planter Type*	Row Space (in)	Soil Moisture** (in)	Precip. after planting (in)	Harvest Date	Soil Type
< 16	Lind Annual	Spring Wheat	26	0	12	19-Mar	60	7	21	0	H	9	6.2	2.77	1-Aug	Ritzville Silt Loam
	Lind Fallow	Fallow	26	0	12	15-Mar	60	7	21	0	DD	6	7.5	2.77	30-Jul	Ritzville Silt Loam
	Bickleton	Spring Barley	40	0	0	3-May	60	7	21	0	DD	6	5.8	0.78	22-Aug	Broadax Silt Loam
	Dusty	Spring Barley	82	0	12	27-Mar	70	7	21	0	DD	6	7.6	4.25	31-Jul	Onyx Silt Loam
	Ritzville	Winter Wheat	60	0	0	28-Mar	60	5	16	0	H	9	4.7	6.13	13-Aug	Walla Walla Silt Loam
16-20	Pomeroy	Spring Wheat	75	0	12	9-Apr	80	7	21	0	H	9	8.6	5.66	15-Aug	Athena Silt Loam
	Dayton	Winter Wheat	80	0	12	11-Apr	80	7	21	0	DD	6	7.7	2.12	20-Aug	Athena Silt Loam
	Reardan	Winter Wheat	75	0	5	30-Apr	80	18	5	7	H	9	8.9	5.02	3-Sep	Hanning Silt Loam
	St. John	Winter Wheat	70	0	12	15-Apr	80	7	21	0	DD	6	8.5	3.52	26-Aug	Athena Silt Loam
> 20	Fairfield	Winter Wheat	65	10	7	22-Apr	80	7	21	0	DD	6	7.9	5.17	30-Aug	Naff Silt Loam
	Pullman	Peas	87	17	10	3-May	80	8	4	0	DD	6	8.2	3.23	22-Aug	Palouse Silt Loam
Irrigated	Royal Slope**	Alfalfa	180	30	20	20-Mar	90	0	0	0	DD	4	Pre-irrigated	1.49	8-Aug	Neppel Sandy Loam

* DD = double disc drill; H= Hoe openers

** Inches of moistue in the top 4 ft for all locations except Bickleton where a 3 ft profile was evaluated.

*** 90 lb K2O, 5 lb Zinc and 1 lb Boron also was applied with the base fertilizer.

Table 2. Grain yields, test weights and protein levels of selected 1996 spring wheat variety trial entries from locations with less then 16 inches of average annual rainfall. Data from experimental lines and historical checks were not reported.

Variety	Seed Status*	Lind Annual Crop	Lind Fallow	Bickleton	Dusty	Ritzville	Average Across Locations	Lind Annual Crop	Lind Fallow	Bickleton	Dusty	Ritzville	Average Across Locations	Lind Annual Crop	Lind Fallow	Bickleton	Dusty	Ritzville	Average Across Locations
		Yield (bu/A)						Test Weight (lb/bu)						Protein (%)					
Soft White																			
Alpowa	A	38	53	46	74	53	53	60.3	61.2	59.0	61.1	61.4	60.6	12.7	10.8	9.2	11.4	10.7	11.0
Centennial	A	37	51	37	63	54	48	59.7	60.1	54.9	60.7	61.3	59.3	12.4	11.1	10.7	12.1	10.5	11.4
Edwall	A	35	55	36	72	55	51	56.2	57.6	51.9	57.3	58.6	56.3	12.2	10.6	10.7	11.8	10.2	11.1
ID488	E	33	50	43	67	54	50	59.1	60.0	57.3	61.2	61.4	59.8	12.3	10.9	9.8	11.1	10.3	10.9
Penawawa	A	38	53	40	65	53	50	58.8	60.4	56.1	60.2	61.2	59.3	12.2	10.2	10.2	12.1	10.3	11.0
Pomerelle	A	36	47	37	61	48	46	60.3	59.3	56.2	58.6	59.8	58.8	12.6	11.2	10.4	12.1	9.7	11.2
Westbred Sprite	A	33	50	44	67	51	49	58.3	59.4	55.9	58.5	60.4	58.5	13.6	11.2	10.3	12.6	10.4	11.6
Vanna	A	38	55	43	70	52	52	58.2	59.1	54.9	59.6	60.3	58.4	12.6	10.7	9.8	11.3	9.6	10.8
Wadual 94	F	35	52	40	67	47	48	58.0	59.5	57.6	59.7	60.9	59.1	14.5	11.7	10.8	12.7	10.6	12.1
Wakanz	A	36	50	35	64	51	47	57.6	59.2	54.6	59.0	59.6	58.0	13.0	11.0	10.2	11.9	10.4	11.3
Wawawai	R	37	54	50	73	54	53	59.0	60.8	59.5	60.2	61.6	60.2	13.0	11.5	9.5	11.7	10.3	11.2
Whitebird	A	37	48	38	66	50	48	60.1	59.6	56.2	60.2	60.8	59.4	12.2	11.2	10.2	11.6	9.9	11.0
WA7805	E	37	51	40	74	51	51	58.5	59.1	57.2	60.2	60.7	59.1	12.6	11.0	10.3	11.9	10.4	11.2
WA7831	E	40	52	46	70	53	52	58.3	59.5	56.8	59.1	60.3	58.8	12.8	10.9	10.3	12.2	10.8	11.4
Average		36	51	41	68	52	50	58.7	59.6	56.3	59.7	60.6	59.0	12.8	11.0	10.2	11.9	10.3	11.2
White Club																			
Calorwa	F	32	47	40	62	47	46	59.0	59.8	57.4	59.8	59.8	59.2	12.5	10.9	10.1	12.6	11.3	11.5
Hard Red																			
Butte 86	A	34	46	35	59	43	44	60.0	60.7	57.0	59.8	60.5	59.6	13.9	11.9	11.3	13.9	13.2	12.8
Express	A	31	52	37	65	44	46	58.6	60.6	56.1	58.8	60.1	58.8	14.2	12.3	11.1	14.0	12.4	12.8
Spillman	A	35	51	34	57	45	44	57.6	59.7	54.2	56.8	59.7	57.6	14.3	12.7	11.2	14.2	11.8	12.8
Westbred 926	A	32	43	37	62	42	43	58.6	60.6	56.4	58.6	60.6	59.0	14.4	12.6	11.7	14.0	11.9	12.9
Westbred 936	A	31	50	35	68	45	46	59.3	60.7	55.9	58.3	61.1	59.1	14.2	12.5	11.3	13.6	11.1	12.5
WA7802	E	36	49	38	67	49	48	58.4	59.7	57.3	58.4	60.2	58.8	14.4	12.6	10.7	13.9	11.8	12.7
Average		33	49	36	63	45	45	58.8	60.3	56.2	58.5	60.4	58.8	14.2	12.4	11.2	13.9	12.0	12.8
Hard White																			
ID377S	F	37	49	37	68	52	48	59.4	60.6	58.0	60.4	62.1	60.1	13.9	12.2	10.4	12.9	10.5	12.0
Klasic	A	31	23	36	59	47	39	59.2	62.1	58.0	61.4	62.3	60.6	13.7	13.8	10.5	12.6	10.5	12.2
Average		34	36	37	63	49	44	59.3	61.4	58.0	60.9	62.2	60.4	13.8	13.0	10.5	12.8	10.5	12.1
Average per location		35	49	39	66	49	48	58.8	60.0	56.5	59.5	60.6	58.8	13.2	11.5	10.5	12.5	10.8	11.7
LSD (10%)		4	5	9	8	3	6												

*A = Available; B = Breeder Seed; F = Foundation Seed; R = Registered Seed; E = Experimental Seed

Table 3. Grain yields, test weights and protein levels of selected 1996 spring wheat variety trial entries from locations with 16 to 20 inches of average annual rainfall.

Variety	Seed Status*	Pomeroy	Dayton	Reardan	St. John	Average Across Locations	Pomeroy	Dayton	Reardan	St. John	Average Across Locations	Pomeroy	Dayton	Reardan	St. John	Average Across Locations
		Yield (bu/A)					Test Weight (lb/bu)					Protein (%)				
Soft White																
Alpowa	A	45	30	77	48	50	61.9	61.2	61.9	59.6	61.2	12.0	9.0	8.6	12.4	10.5
Centennial	A	48	29	71	46	48	61.9	61.1	60.3	59.9	60.8	11.3	9.9	9.1	12.5	10.7
Edwall	A	53	26	74	50	51	57.5	58.3	59.3	56.0	57.8	11.3	9.6	9.1	11.7	10.4
ID488	E	52	29	75	50	52	61.6	61.7	60.7	60.5	61.1	11.4	9.5	8.5	12.0	10.4
Penawawa	A	52	27	74	50	50	60.6	60.3	61.5	59.5	60.5	11.5	10.1	9.0	11.7	10.6
Pomerelle	A	51	25	70	41	47	59.2	60.3	59.4	59.6	59.6	12.0	10.0	9.4	13.0	11.1
Westbred Sprite	A	51	22	71	45	47	60.0	59.8	59.8	57.1	59.2	12.3	10.6	9.7	13.3	11.5
Vanna	A	53	26	67	46	48	59.7	59.6	60.2	57.7	59.3	11.5	9.9	8.6	12.0	10.5
Wadual 94	F	51	22	70	46	47	59.7	60.3	60.6	59.4	60.0	13.1	11.1	10.3	13.8	12.1
Wakanz	A	46	35	75	48	51	58.7	60.5	60.2	58.3	59.4	12.2	11.0	9.5	13.2	11.5
Wawawai	R	50	35	78	48	53	60.8	61.9	61.3	60.2	61.1	12.0	10.6	9.9	12.4	11.2
Whitebird	A	49	24	68	47	47	59.8	59.8	60.2	59.6	59.9	12.4	9.9	8.8	12.3	10.9
WA7805	E	51	32	74	45	51	60.8	61.0	61.2	58.7	60.4	11.4	9.5	9.3	12.7	10.7
WA7831	E	55	29	77	46	52	60.8	59.9	61.4	58.1	60.1	12.3	9.8	9.4	12.3	11.0
Average		50	28	73	47	50	60.2	60.4	60.6	58.9	60.0	11.9	10.0	9.2	12.5	10.9
White Club																
Calorwa	F	49	28	75	39	48	59.9	61.3	60.6	58.2	60.0	12.3	10.1	9.5	12.8	11.2
Hard Red																
Butte 86	A	35	25	66	50	44	59.9	61.4	61.8	59.8	60.7	13.5	10.0	10.9	13.0	11.9
Express	A	38	17	59	39	38	59.8	60.4	61.4	58.0	59.9	13.2	10.9	10.6	13.8	12.1
Spillman	A	45	25	68	42	45	58.8	59.9	59.6	57.7	59.0	12.4	10.4	10.5	14.3	11.9
Westbred 926	A	40	25	62	41	42	58.8	60.6	60.8	58.0	59.6	13.3	11.6	11.3	14.6	12.7
Westbred 936	A	44	27	64	47	46	59.0	61.2	61.5	58.0	59.9	13.3	10.8	10.0	14.2	12.1
WA7802	E	50	28	71	39	47	59.0	61.7	60.9	57.8	59.9	13.3	10.1	10.6	13.6	11.9
Average		42	25	65	43	44	59.2	60.9	61.0	58.2	59.8	13.2	10.6	10.7	13.9	12.1
Hard White																
ID377S	F	55	24	82	45	51	60.6	61.7	62.3	59.6	61.1	12.9	10.1	9.9	12.8	11.4
Klasic	A	46	21	66	46	45	60.3	60.9	62.2	61.2	61.2	12.5	11.5	10.1	13.2	11.8
Average		51	23	74	45	48	60.5	61.3	62.3	60.4	61.1	12.7	10.8	10.0	13.0	11.6
Average per location		48	27	71	45	48	60.0	60.6	60.8	58.8	60.1	12.3	10.3	9.7	12.9	11.3
LSD(10%)		6	5	6	9	6										

*A = Available; B = Breeder Seed; F = Foundation Seed; R = Registered Seed; E = Experimental Seed.

Table 4. Grain yields, test weights and protein levels of selected 1996 spring wheat variety trial entries from locations with more than 20 inches of average annual rainfall.

Variety	Seed Status*	Yield (bu/A) Fairfield	Yield (bu/A) Pullman	Yield (bu/A) Average Across Locations	Test Weight (lb/bu) Fairfield	Test Weight (lb/bu) Pullman	Test Weight (lb/bu) Average Across Locations	Protein (%) Fairfield	Protein (%) Pullman	Protein (%) Average Across Locations
Soft White										
Alpowa	A	81	72	77	62.1	61.3	61.7	9.0	11.6	10.3
Centennial	A	80	65	73	61.2	60.7	61.0	9.1	11.7	10.4
Edwall	A	84	64	74	58.9	56.3	57.6	9.5	12.0	10.8
ID488	E	75	70	72	61.3	61.2	61.3	9.0	11.2	10.1
Penawawa	A	78	64	71	61.2	59.7	60.5	9.0	12.2	10.6
Pomerelle	A	82	72	77	59.6	60.1	59.9	9.0	11.0	10.0
Westbred Sprite	A	78	67	72	60.7	58.5	59.6	9.3	12.2	10.8
Vanna	A	79	69	74	59.8	59.2	59.5	8.5	11.1	9.8
Wadual 94	F	70	67	68	61.5	60.5	61.0	10.6	12.6	11.6
Wakanz	A	72	61	67	60.4	58.5	59.5	9.7	12.2	11.0
Wawawai	R	81	67	74	62.2	59.5	60.9	9.5	12.1	10.8
Whitebird	A	75	68	72	60.5	59.9	60.2	9.3	11.4	10.4
WA7805	E	79	71	75	61.2	61.5	61.4	9.3	11.7	10.5
WA7831	E	78	68	73	61.0	59.4	60.2	9.1	11.8	10.5
Average		78	67	73	60.8	59.7	60.3	9.3	11.8	10.5
White Club										
Calorwa	F	73	66	70	61.1	60.8	61.0	9.6	11.9	10.8
Hard Red										
Butte 86	A	60	56	58	61.8	59.0	60.4	11.1	14.0	12.6
Express	A	70	61	66	62.0	59.6	60.8	10.1	13.5	11.8
Spillman	A	69	63	66	59.7	57.3	58.5	10.3	13.1	11.7
Westbred 926	A	64	56	60	60.7	57.8	59.3	11.4	14.1	12.8
Westbred 936	A	65	65	65	60.9	59.6	60.3	10.8	13.3	12.1
WA7802	E	73	66	70	60.8	59.5	60.2	10.6	12.8	11.7
Average		67	61	64	61.0	58.8	59.9	10.7	13.5	12.1
Hard White										
ID377S	F	80	79	79	62.2	61.4	61.8	9.1	11.6	10.4
Klasic	A	57	56	57	61.8	60.4	61.1	10.8	12.5	11.7
Average		69	67	68	62.0	60.9	61.5	10.0	12.1	11.0
Average per location		74	66	70	61.0	59.6	60.3	9.7	12.2	11.0
LSD (10%)		8	5	6						

*A = Available; B = Breeder Seed; F = Foundation Seed; R = Registered Seed;
E = Experimental Seed

Table 5. Grain yields, test weights and protein levels of selected 1996 spring wheat variety trial entries in the irrigated nursery at Royal Slope.

Variety	Seed Status*	Yield (bu/A)	Test Weight (lb/bu)	Protein (%)
Soft White				
Alpowa	A	144	65.2	11.3
Centennial	A	123	63.7	10.9
Edwall	A	135	62.1	11.3
ID488	E	143	63.8	10.6
Penawawa	A	146	64.4	11.2
Pomerelle	A	147	61.9	10.5
Westbred Sprite	A	138	64.6	11.3
Vanna	A	142	63.4	10.8
Wadual 94	F	128	63.6	12.7
Wakanz	A	127	63.1	11.7
Wawawai	R	130	64.3	11.6
Whitebird	A	131	63.1	11.2
WA7805	E	139	64.0	11.2
WA7831	E	138	63.7	11.7
	Average	137	63.6	11.3
White Club				
Calorwa	F	129	63.2	11.4
Hard Red				
Butte 86	A	107	63.8	14.4
Express	A	122	64.1	13.6
Spillman	A	126	63.3	13.0
Westbred 926	A	112	63.4	14.0
Westbred 936	A	118	64.2	13.3
WA7802	E	126	63.4	13.2
	Average	119	63.7	13.6
Hard White				
ID377S	F	143	65.1	12.3
Klasic	A	116	65.6	12.6
	Average	130	65.4	12.5
Average per location		131	63.8	12.0
LSD (10%)		7		

*A = Available; B = Breeder Seed; F = Foundation Seed; R = Registered Seed; E = Experimental Seed

USDA–ARS WHEAT BREEDING & GENETICS

J.A. Anderson, J.A. Pritchett, L.M. Little, R.E. Allan (Collaborator)

Personnel changes.
Dr. James Anderson arrived in July, 1996 to replace Dr. Robert Allan as Research Geneticist with the USDA-ARS in Pullman, Washington.

Soft White Winter Wheat Variety Development.
One thousand two hundred fifty crosses were made during the 1996 field season. Parents included elite breeding materials and germplasm for genetic studies. More than 11,000 early generation lines were evaluated based on plant type and disease reaction. One hundred twelve of 1266 F_4 lines were selected based on plant type, the micro-sedimentation test to predict dough strength, and presence of a footrot resistance gene via an isozyme marker. An unreplicated preliminary yield trial harvested from six environments and a replicated advanced yield trial at five environments were used to evaluate 152 and 106 lines, respectively. One soft white winter wheat line (WA7794) and two club lines (WA7752 and WA7793) were included in state-wide yield trials.

High quality advanced club selections were identified that express outstanding resistance to strawbreaker foot rot. These lines definitely have the gene for resistance that occurs in Hyak. It is likely they have a second gene from the French variety 'Cappelle'. They exceeded the yield of Hyak by as much as 20% in our footrot inoculated tests. These lines also have resistance to all USA stripe rust races. They possess high yield potential and out-yielded Hiller and Rohde by 5 to 12% across all 1996 ARS trials.

There has been increasing concern with the release of Hiller regarding the Federal Inspection Service grading of club varieties. Grain samples of five club wheats grown at 17 Extension trial locations (2 reps each) in 1996 were submitted to the Federal Grain Inspection Service. All of the WA7752 and Rely samples and 33 of the 34 Tres samples graded as club. Another advanced line, WA7793, graded as club in 21 of 32 samples. Hiller graded club in only 8 of 32 samples. Due to these results, WA7793 will not be considered for release.

Six breeding locations were added in the Fall of 1996. In addition to former sites at Central Ferry, Pullman, and Walla Walla, USDA-ARS breeding lines were planted at Harrington, Lind, and Pomeroy. Dr. Stephen Jones planted the ARS elite nursery at Connell, Hartline, and Ritzville.

Our project continues to coordinate the Western Regional Nurseries. The 1996 Regional Hard Winter, Soft White Winter, and Spring Nurseries were grown by collaborators at 9 to 12 locations each in the Pacific Northwest.

Oregon Club Wheat Lines Added.
A total of 430 lines in yield trials and more than 10,000 early generation lines have been added to our project from the former Oregon club breeding program based in Pendleton. We are coordinating the evaluation of this germplasm in Oregon and Washington locations. Due to the

large quantity of these materials, only the early generation lines and the most advanced Oregon lines (Elite Trial) were grown at Pullman for performance evaluations. It is anticipated that entries which perform well in the 1997 Oregon preliminary yield trials will be tested in Washington locations in the 1998 crop year.

Tall Clubs.
The goal of this project is to breed club wheat varieties that will out-perform Moro in the low rainfall areas. The approach emphasizes selecting lines that equal Moro for emergence characteristics while exceeding it for disease resistance, yield potential and club wheat quality. Two yield trials are used to evaluate tall clubs. One is the ARS preliminary tall nursery that is planted at Pullman (for disease evaluation) and Lind. Experimental lines that perform well in this trial are advanced to a combined ARS/WSU tall wheat trial that is planted at 5 dryland locations by Dr. Jones.

New semidwarfing genes are being investigated that do not negatively affect emergence. Two of the three new semidwarfing genes studied appear promising for emergence and yield potential. Five club lines with the semidwarfing gene *Rht8* are up to 10% shorter than Moro, and have stand establishment characteristics, coleoptile lengths, and seedling growth rates identical to Moro. These lines out-yielded Moro by up to 4% in our tests in higher rainfall environments. Twelve of the 13 ARS lines included in the combined ARS/WSU tall trial exceeded the yield of Moro. Two of the *Rht8* lines had grain yields similar to Rely and emergence similar to Moro in low rainfall environments. Pending satisfactory performance in 1997, one of these lines may be candidates for pre-release.

The dwarfing gene *Rht12* reduces plant height by 40 to 50% in non-semidwarf varieties and 30 to 40 % in semidwarfs. This gene can enhance or reduce yields by as much as 20%, depending on the genetic background. Yield response of the gene in a Moro background needs additional study. The *Rht12* gene does not adversely effect emergence, but delays heading 5 to 8 days.

Removing semidwarfing genes from varieties also has potential for developing wheats for the low rainfall zones where emergence is a problem. The best one of these lines yielded 8% more than Moro in 1996 tests in the dryland region.

Use of Markers in Breeding.
DNA markers are being used to tag genes of interest, specifically for preharvest sprouting resistance, cold hardiness, and grain quality traits. We continue to use the isozyme marker for the footrot resistance gene. The markers will be used to build core germplasm that can be directly used in crosses to produce new varieties. Such markers will be relied upon in screening of germplasm prior to entry in preliminary yield trials.

Within the past few years, increased emphasis has been placed on screening early generation lines (F_4 grain) for end-use quality. The microsedimentation test has been particularly valuable in eliminating poor quality lines in early generations. More than 1,000 F_4 lines were evaluated for test weight, protein content, hardness, and microsedimentation during the winter of 1996/97.

IMPROVEMENT OF WINTERHARDINESS IN WHEAT

Kay Walker-Simmons, Eric Storlie, James Anderson and Robert E. Allan
USDA-ARS, Washington State University

Goal: The goal of this project is to reduce winterkill damage by developing winter wheat varieties with improved winterhardiness. Emphasis is on developing new, rapid and efficient methods to incorporate genes for increased coldhardiness into Pacific Northwest varieties.

Problem: Cold injury is the major weather-related problem of winter wheat in Washington. An estimated 70% of present acreage is planted in varieties that are vulnerable to cold injury. Club wheat varieties are particularly vulnerable to winterkill. Because of this vulnerability improving winterhardiness is one of the highest research priorities of Washington wheat producers.

Development of a new freezing simulation test: A freezing simulation test that can be used to evaluate winterhardiness levels in breeding lines year around has been developed. Development was made possible by the purchase of an environmentally controlled growth chamber with a Washington Wheat Commission equipment grant in Jan. 1996. The freeze simulation test consists of subjecting wheat crown tissue to freezing temperatures down to -15°C(5°F). After freezing, the crown tissue is returned to normal growing conditions and tested for regrowth. Test results are reported in LT_{50} values (temperature where 50% of plants are killed).

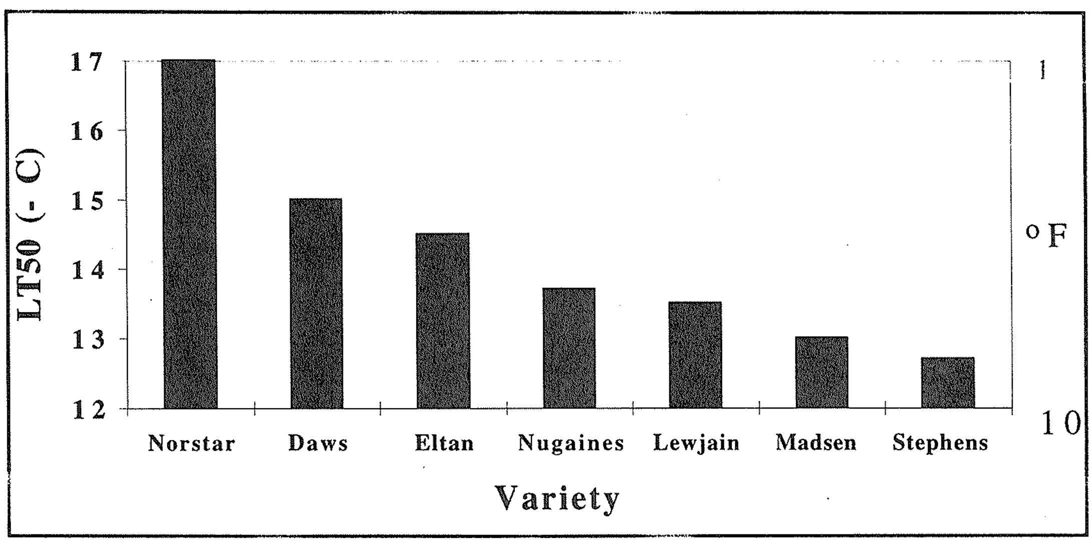

Figure 1. LT_{50} means of Pacific Northwest and Norstar winter wheat cultivars (E.W. Storlie et al., 1996, and unpublished data). Norstar LT_{50} is lower than -15°C in our freezing test chamber and is -17°C according to Briger et al., 1995.

Screening of Pacific Northwest varieties: Screening of Pacific Northwest winter wheats (common and clubs) has been completed. LT_{50} results for some varieties are shown in Figure 1 along with results for the very cold hardy Canadian variety Norstar. LT_{50} results show that the most cold hardy cultivar, Daws, with an LT_{50} value of -14.5°C, can survive freezing temperatures 2°C lower than the least cold hardy cultivar, Stephens, which has an LT_{50} of -12.5°C ($P = .05$).

Our LT_{50} results for Pacific Northwest (common white winter) wheat cultivars correlate well with field survivability ratings (r=.81). Field survival ratings for these cultivars (Certified Seed Buying Guide, Washington, 1995) show that the most cold hardy cultivar is Daws (ranked cold hardy) and the least hardy cultivar is Stephens (ranked nonhardy). The 2°C difference in LT_{50} values is evidently sufficient to confer field survival of Daws through most Pacific Northwest winters. Daws, but not Stephens, survived the 1991 winter when 70% of the winter wheat crop in the Pacific Northwest was lost to winterkill.

Development of DNA markers linked to coldhardiness in PNW varieties: DNA probes linked to coldhardiness have the potential to speed up genetic selection. We are identifying DNA probes for winterhardiness in PNW varieties. A potential method to incorporate genes for higher coldhardiness levels may be by manipulating the *Vrn1-Fr1* interval linked to freezing tolerance on wheat chromosome 5AL. Chromosome mapping by other scientists indicate that the *Vrn1-Fr1* interval can affect coldhardiness levels and potential DNA markers linked to coldhardiness in some model wheat varieties have been identified. We have examined the potential use of these DNA markers in near-isogenic wheat lines (NILs) with very similar genetic backgrounds but that differ in *Vrn1-Fr1* alleles. These NILs were developed by selecting for spring vs. winter growth habits by R.E. Allan. We probed DNA samples from the winter/spring NILs with a DNA probe linked to the *Vrn1-Fr1* interval, and have shown that winter and spring alleles exhibit a different pattern. Our results show that the DNA probe can distinguish between the winter and spring *Vrn1-Fr1* alleles of this NIL population.

Using the DNA probe, we have recently identified different marker patterns among some winter wheat cultivars (Norstar, Daws and Stephens - data not shown). This encouraging preliminary result suggests that it will be possible for us to identify DNA markers linked to allelic variants for coldhardiness among Pacific Northwest varieties.

New crosses with more winterhardy parents: Crosses with coldhardy white winter wheat parents (Daws, Eltan, and Jacmar) have been made. New crosses with the very cold hardy Canadian variety, Norstar, with Madsen are in progress.

New facilities for winterhardiness in WSU Wheat Greenhouse and Growth Chamber Facility: The new WSU wheat research facility schedule for completion in Fall 1997 will include several new growth chambers for expanded testing of winterhardiness in Washington-grown varieties. Growth rooms will freezing capability to -13°F(-25°C) will be installed. These new facilities will enable us, for the first time, to assess multiple breeding lines for coldhardiness levels.

BARLEY IMPROVEMENT RESEARCH

S.E.Ullrich, V.A. Jitkov, J.A. Clancy, J.S. Cochran, A. Kleinhofs, D. von Wettstein,
F. Han, B.C. Miller, E. Donaldson, P.E. Reisenauer, J.A. Froseth,
R.F. Line, *and* R.J. Cook

Cultivar Development/Variety Testing

The overall goal of the WSU Barley Improvement Program is to make barley a more profitable or valuable crop. Specific objectives are to improve agronomic and grain quality factors and pest (disease and insect) resistance for dryland and irrigated production. The emphasis is on two-row spring barley with additional efforts on six-row spring, spring hulless and/or waxy, and winter types.

The Barley Improvement Program officially released two new spring barley cultivars in 1997; 'Bear', a two-row hulless type and 'Washford,' a six-row hooded (beardless) hay type.

Bear -- A New Two-Row Spring Hulless Barley. Bear has produced significantly and consistently higher yields than 'Condor' and 'Scout.' The yield of Bear was 113% of Condor and 117% of Scout over 5 years of trials at Pullman (1991-95) and 105% of Condor over 13 locations in eastern Washington in 1995. Bear outyielded Condor in each of the four production zones in 1995 trials. Bear yielded 136% of Condor and 100% of Scout and 'Phoenix' over four location years (1994-95) in northern Idaho. Bear yielded 117% of 'Merlin' and 129% of 'Shonkin' over six locations in 1995 in southern Idaho. The test weight of Bear has ranged from 57 to 60 lb/bu and is typically a little lower than that of Condor and a little higher than that of Scout. Heading date is similar among these three cultivars. Plant height of Bear is similar to that of Condor and shorter than that of Scout. It has about the same medium to high lodging resistance as that of Condor and a little greater than that of Scout. Few disease symptoms have been noted for Bear and the other hulless cultivars in tests in eastern Washington.

Nutritional quality of Bear appears to be good based on a starter pig trial. It had a higher average daily gain and gain/feed ratio than Condor. Based on mobile nylon bag dry matter digestibility and digestible energy, Bear was rated excellent compared to hulled 2- and 6-row types. It is expected to be used for livestock feed and potentially for human food.

Washford – A New Six-Row Spring Forage (hooded) Barley. Harvested at the grain soft-dough stage, Washford produced 13% (7% in Oregon) more wet weight than Belford and 15% more dry weight. It also produced 24% more wet weight and 15% more dry weight than 'Stepford.' Washford produced 22% more seed than Belford and 12% more than Stepford. All yield results have been consistent across tests. Washford is shorter than Belford by 8% (10% in Oregon) and similar to Stepford. It has greater lodging resistance than both other varieties (4, 8, 16% lodging for Washford, Stepford, Belford in Washington). Under irrigated conditions in Oregon, Washford was 12% lodged vs. 57% for Belford. All agronomic data are averages over 6 years of tests at Pullman. Washford had the highest hay yield at four of the eight 1996 Montana/Wyoming locations and was equal to the highest yielder at two additional locations. Few disease symptoms have been noted on the forage barleys. However, Washford has shown some susceptibility to loose smut caused by *Ustilago nuda*. There is limited quality data, but in one trial at Pullman, acid detergent fiber of hay (at soft dough stage) was 28.3 and 27.0% for Washford and Belford, respectively. Protein was 9.5 and 10.4% for Washford and Belford, respectively. In vitro, dry matter disappearance was 62.9 and 63.5% for Washford and Belford, respectively. Washford is expected to be used primarily for hay, but also other forage uses for ruminant livestock. It should supplant Belford.

For spring barley in 1996, 83 crosses were made. In 1997, plants will be selected from 103 segregating F_3 populations (50-100/population) from the previous year's crosses. In addition, there are 83 F_2 populations in the field and 50 F_3 single seed descent populations in the greenhouse. Lines will be selected from approximately 8,000 head and plant rows including homozygous doubled haploid (from anther culture) plant rows. There are 700 single replication evaluation plots planted at Spillman Farm and Ritzville this year; the entries of which mostly came from 1995 head/plant rows. The more advanced lines are tested in 18 30- to 60-entry major yield trials at Spillman Farm and throughout eastern Washington including a 36 entry preliminary state yield trial at three locations – Pullman, Fairfield, and Ritzville – and the state uniform trial of 46 entries planted at 12 locations (6 extension/Miller, Donaldson, and Reisenauer). There are approximately 10 grower-conducted on-farm tests in 7 counties in 1997 coordinated by Kevin Anderson of Great Western Malting Company.

Barley performance in 1996 was presented in the November 22, 1996 *Green Sheet* and in the January 1997 *Wheat Life*.

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 have been conducted in the Department of Animal Sciences primarily by John Froseth.

Pest Resistance. 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 Russian 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. RWA resistant lines are in field tests in 1997.Barley stripe rust (BSR) 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 stripe rust reaction the past several years in Bolivia, Texas, and now at WSU. The first good field ratings for BSR in eastern Washington were compiled from the 1996 state uniform nursery at Dusty. Several breeding lines showed good resistance. Expanded field testing of BSR resistant lines is occurring in 1997. Soil borne pathogens probably affect barley production more than we realize. A new effort was initiated 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. Barley cultivars and breeding lines have been identified with resistance to

Rhizoctonia solani for the first time. Relatively simple inheritance of resistance is indicated which should facilitate breeding for resistance to this soil borne pathogen.

Application of Biotechnology

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 relevant to cultivar development. We are verifying QTL identified and developing molecular marker assisted selection strategies for use in the breeding program. Initially, we are concentrating on the dormancy trait from Steptoe, several malting quality traits from Morex, and *Rhizoctonia* resistance from identified germplasm sources. Mapping populations from the Harrington/TR306 and Harrington/Morex crosses are also being evaluated. 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.

Collaboration in breeding proanthocyanidin-free barley and transformation of barley with a heat-stable beta-glucanase (brewing and feed quality traits) is underway with Diter von Wettstein and Judy Cochran. The proanthocyanidin-free barley project has been a long-time collaboration. The transformation project will see transformed plants in the field for the second year in 1997.

1996 STATE/EXTENSION SPRING BARLEY

E. Donaldson, S.E. Ullrich, P.E. Reisenauer, J.S. Cochran, V. Jitkov, and B.C. Miller

The 1995-96 barley variety evaluation trials were conducted at 6 spring locations in 4 eastern Washington counties. Complimentary nurseries in six additional locations were grown by the breeding program. Fifty-four spring varieties, thirty 6-row and twenty-four 2-row, were included in the evaluation trials. For management purposes the irrigated site was moved from Moses Lake to Lind. A flex crop production zone nursery site was established at Ritzville. These two sites were assumed by the breeders. In return, the variety testing program assumed the Fairfield site and the responsibility of grain processing and data analysis of the complimentary breeder nurseries. Varieties in the testing program included all significant released public varieties from the Pacific Northwest, public varieties from the tri-state being considered for release and private varieties entered on a 'fee for entry' basis.

The results from these trials and the WSU plant breeder's trials were summarized and reported in a spring Washington State Crop Improvement Seed Buying Guide. The variety performance results were also reported in the Washington Association of Wheat Grower's Green Sheet, Wheat Life, each of the county agent's newsletters, and on Internet.

Early spring planting conditions were excellent, but an extended period of cool wet weather hampered timely planting of the last nurseries. Starter fertilizer was applied at all locations. The nurseries established well but were subjected to and extremely dry summer, with the plants having to rely on soil moisture reserves. Despite the adverse conditions the spring barley yielded well at most locations. Lamont, Dayton and Bickleton suffered reduced yields with markedly low test weights at Lamont and Bickleton. Several of the nurseries showed a high CV, indicating less confidence can be placed in the data. To interpret results with more reliability, data should be considered over years and locations.

Barley stripe rust was present in the Dusty nursery. The extremely dry summer brought a halt to the infestation, and the disease did not impact the nursery. Excellent variety resistance readings were gathered. Although the most popular grown varieties are susceptible, it is not known what economic implications may result in the future. A rust resistant line, Bancroft, has been released by the University of Idaho.

1996 SPRING BARLEY SUMMARY
TEST WEIGHT (LBS/BU)

VARIETY NAME	LAMONT	DAYTON	BICKLETON	MAYVIEW	LIND DRY	RITZVILLE	PULLMAN	REARDAN	DUSTY	ST. JOHN	FAIRFIELD	LIND IRR.	VARIETY AVERAGE
2-ROW													
ALEXIS	48.4	51.9	44.5	52.1	51.5	51.5	53.0	50.6	53.4	53.0	51.5	52.5	51.2
BANCROFT	48.0	51.1	44.6	51.4	51.3	52.1	52.4	50.6	52.2	52.0	50.4	51.3	50.6
BARONESSE	47.6	51.8	44.0	52.0	49.3	53.1	53.7	51.3	51.9	52.0	51.5	52.8	50.9
CAMINANT	47.6	51.2	43.6	51.0	50.9	51.2	51.2	49.2	51.4	50.8	50.0	53.8	50.2
CHINOOK	48.9	51.2	45.4	52.0	51.6	52.6	53.9	51.9	53.0	52.6	51.8	53.7	51.5
CREST	47.5	53.1	41.8	53.9	50.3	52.0	53.9	51.3	52.4	53.2	52.5	53.7	51.3
GALLATIN	48.8	52.0	44.2	53.2	51.3	52.9	54.6	51.5	53.6	53.1	52.9	53.6	51.8
GARNET	47.3	50.6	42.5	51.9	49.5	50.4	51.4	50.0	51.7	51.2	50.4	52.6	50.0
HARRINGTON	46.6	50.3	43.6	52.8	49.3	51.4	51.2	48.8	51.7	51.2	51.9	53.8	50.2
MELTAN	50.0	52.0	49.1	52.8	52.5	53.6	54.4	51.5	53.9	53.4	52.3	52.4	52.3
TARGHEE	47.4	51.6	43.3	52.5	50.7	52.1	52.8	49.5	52.7	52.1	50.9	51.7	50.6
6-ROW													
COLTER	46.0	49.3	44.3	48.0	49.1	48.9	49.4	48.3	51.1	49.2	47.5	52.3	48.6
MARANNA	45.9	49.0	41.0	49.9	48.7	49.7	49.5	47.8	46.5	47.1	48.5	51.8	47.9
MOREX	47.8	50.0	46.3	50.8	50.3	49.9	51.1	49.3	51.9	51.6	50.3	50.3	50.0
PAYETTE	46.3	49.1	46.6	49.2	49.1	49.3	49.2	48.6	49.5	50.1	47.6	51.6	48.8
STANDER	47.1	50.8	47.6	51.5	49.1	50.5	50.9	48.5	52.6	51.7	49.4	52.6	50.2
STEPTOE	45.1	47.3	44.5	48.3	45.5	49.1	48.4	46.0	48.9	48.7	47.0	51.5	47.5
NURSERY MEAN	46.7	49.6	43.9	49.8	49.5	50.2	50.8	48.8	51.2	50.6	49.5	52.1	49.4
CV %	1.9	1.3	6.3	1.7	2.5	1.0	1.4	2.1	2.6	2.0	0.9	3.3	2.5
LSD @ .10	1.2	0.9	3.7	1.2	1.6	0.7	1.0	1.4	1.8	1.3	0.6	2.3	0.6

Malting varieties

Analysis method - General Linear Models Proceedure

1996 SPRING BARLEY SUMMARY
TEST WEIGHT (LBS/BU)

VARIETY NAME	LAMONT	DAYTON	BICKLETON	MAYVIEW	LIND DRY	RITZVILLE	PULLMAN	REARDAN	DUSTY	ST. JOHN	FAIRFIELD	LIND IRR.	VARIETY AVERAGE
2-ROW													
ALEXIS	48.4	51.9	44.5	52.1	51.5	51.5	53.0	50.6	53.4	53.0	51.5	52.5	51.2
BANCROFT	48.0	51.1	44.6	51.4	51.3	52.1	52.4	50.6	52.2	52.0	50.4	51.3	50.6
BARONESSE	47.6	51.8	44.0	52.0	49.3	53.1	53.7	51.3	51.9	52.0	51.5	52.8	50.9
CAMINANT	47.6	51.2	43.6	51.0	50.9	51.2	51.2	49.2	51.4	50.8	50.0	53.8	50.2
CHINOOK	48.9	51.2	45.4	52.0	51.6	52.6	53.9	51.9	53.0	52.6	51.8	53.7	51.5
CREST	47.5	53.1	41.8	53.9	50.3	52.0	53.9	51.3	52.4	53.2	52.5	53.7	51.3
GALLATIN	48.8	52.0	44.2	53.2	51.3	52.9	54.6	51.5	53.6	53.1	52.9	53.6	51.8
GARNET	47.3	50.6	42.5	51.9	49.5	50.4	51.4	50.0	51.7	51.2	50.4	52.6	50.0
HARRINGTON	46.6	50.3	43.6	52.8	49.3	51.4	51.2	48.8	51.7	51.2	51.9	53.8	50.2
MELTAN	50.0	52.0	49.1	52.8	52.5	53.6	54.4	51.5	53.9	53.4	52.3	52.4	52.3
TARGHEE	47.4	51.6	43.3	52.5	50.7	52.1	52.8	49.5	52.7	52.1	50.9	51.7	50.6
6-ROW													
COLTER	46.0	49.3	44.3	48.0	49.1	48.9	49.4	48.3	51.1	49.2	47.5	52.3	48.6
MARANNA	45.9	49.0	41.0	49.9	48.7	49.7	49.5	47.8	46.5	47.1	48.5	51.8	47.9
MOREX	47.8	50.0	46.3	50.8	50.3	49.9	51.1	49.3	51.9	51.6	50.3	50.3	50.0
PAYETTE	46.3	49.1	46.6	49.2	49.1	49.3	49.2	48.6	49.5	50.1	47.6	51.6	48.8
STANDER	47.1	50.8	47.6	51.5	49.1	50.5	50.9	48.5	52.6	51.7	49.4	52.6	50.2
STEPTOE	45.1	47.3	44.5	48.3	45.5	49.1	48.4	46.0	48.9	48.7	47.0	51.5	47.5
NURSERY MEAN	46.7	49.6	43.9	49.8	49.5	50.2	50.8	48.8	51.2	50.6	49.5	52.1	49.4
CV %	1.9	1.3	6.3	1.7	2.5	1.0	1.4	2.1	2.6	2.0	0.9	3.3	2.5
LSD @ .10	1.2	0.9	3.7	1.2	1.6	0.7	1.0	1.4	1.8	1.3	0.6	2.3	0.6

** Malting varieties*

Analysis method - General Linear Models Proceedure

BREEDING DIMENSIONS OF PALOUSE GRAIN LEGUME CROPS - 1997

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

The grain legume industry needs a wide range of dry pea. lentil, chickpea and Austrian winter pea varieties to meet market demands and to remain competitive. These types must be environmentally adapted, have disease resistance and be high yielding. Meeting these demands has necessitated accelerating the breeding process. Increased greenhouse use for screening early generation breeding material coupled with intense field evaluations of selected material has resulted in dramatically reducing the overall time from crossing to variety release. The breeding efforts directed at each of these crops are described below.

Dry Peas:

Dry pea is 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 for breaking disease cycles and for improving weed control and fertility status of the soils. The pea 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 seedcoats. The method currently in use in the greenhouse and laboratory to identify good color qualities of the seedcoats 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. Large yellow pea varieties are needed that are resistant to these diseases and have bright color and resist mechanical damage during combining and cleaning. In addition, the industry needs a Marrowfat type pea with disease resistance and high yields that will also have quality traits such as bleach resistance and large seed size.

Recent releases of dry pea varieties

Shawnee (PS010603) is a large yellow cotyledon variety that has the normal tall plant habit and normal leaf type released in 1997. The variety is resistant to fusarium wilt race 1 and powdery mildew. It is high yielding and is expected to replace Umatilla and Latah. Seed of Shawnee should be available on a limited basis to growers in 1998.

Fallon (PS210387) is a semi-dwarf semi-leafless large yellow pea variety that was released in 1997. The variety is resistant to fusarium wilt, powdery mildew and is high yielding. Seed size is larger than Umatilla, Latah, and Shawnee. The semi-leafless trait is expected to improve standing ability and reduce foliar disease. Very limited amounts of seed will be available to growers in 1998.

Joel (PS110028) is a normal leafed tall green cotyledon type pea that has resistance to fusarium wilt race 1, powdery mildew and has tolerance to some of the viruses. The variety was released in 1997. Seed size is larger than Columbian and color is good. Limited amounts of seed will be available to growers in 1998.

Development of a marrowfat type variety is progressing and we anticipate a pre-release in 1998. Lines are being selected for adaptation to Palouse conditions, disease resistance, typical marrowfat seed size and good color.

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 worldwide. Indications are that an exceptionally large yellow seeded lentil with uniformly green seedcoats 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. Improved seed sources of the other lentil types would also benefit the industry.

<u>Recent releases of lentil varieties</u>.

Mason (LC960254) is a large yellow cotyledon variety that has seedcoats that are green and free of mottling. Seed size is comparable to the Laird variety produced in Canada. Yields for Mason over the past six years have surpassed that of Brewer. Limited amounts of seed of Mason will be available to growers in 1998.

Work is underway toward developing a Turkish red types, Spanish Brown types with resistance to ascochyta blight and toward developing an improved seed source for the Eston type.

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.

Recent releases of chickpea varieties

Evans (CA188163) is a large seeded kabuli type that has seed size that is intermediate between Sanford and Dwelley. The variety is 5-7 days earlier to flower when compared to Sanford and Dwelley and it also matures about 5 days earlier. Evans is also resistant to Ascochyta blight and has comparable yields. Foundation seed will be produced in 1997 and be available for planting in 1998. The variety is expected to alleviate the problem of late maturity of both Sanford and Dwelley.

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 cereals and it fits well into the rotation. Fall planting is important because wet soil conditions often make planting difficult in the spring. In the past, Austrian winter peas have been exported to the Orient where they are used as filler in the production of An-paste; a confection made mostly from usually very expensive Adzuki beans. Austrians are also used for green manure 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 and thereby reducing the humidity in the lower canopy. The root disease problem is somewhat more difficult. However, we have established root disease screening nurseries to identify genetic material with tolerance. Multiple disease resistant varieties are needed if this crop is to continue as an integral part of the cropping system used on the Camas prairie. The most urgent need is to develop varieties with resistance to these diseases and with sufficient winter hardiness to be grown over a wide area.

Granger, the recently released Austrian Winter pea variety, was significantly higher yielding when compared to Melrose, Fenn, and Common and had a nearly 900kg/ha (800lbs/acre) yield advantage in 1995. Granger is a semi-leafless type that is taller than Melrose, Fenn or Glacier. Even though Granger 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.

Crosses have been made to add powdery mildew resistance, Aphanomyces resistance and virus resistance to Austrian winter pea types. These crosses have been increased in the greenhouse and are currently being evaluated in the field. To improve the vine strength and standing ability of Austrian winter peas, we have used 'Bohatyr' in the crossing program. Bohatyr, for Czechoslovakia, has exceptionally strong and woody stems that improve standing ability. The woody stem trait if combined with the semi-leafless trait should greatly improve standing ability and help avoid foliar diseases such as Sclerotinia white mold and Ascochyta blight while improving 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.

Winter hardy lentils. We are currently working on the development of winter hardy lentils that could be planted in the fall and overwinter. The germplasm is available and sufficient hardiness is present that will ensure survival over most winters. Winter hardy lentils would need to be planted in a no-till or very minimum till situation to avoid soil erosion. Yield gains of 25 to 50% over spring-sown types are expected.

PUTTING CROP MODELS TO WORK: ASSESSING THE POTENTIAL OF GRAIN CORN IN THE DRYLAND CROPPING AREAS OF EASTERN WASHINGTON AND NORTHERN IDAHO

Tim Fiez
Extension Soil Fertility Specialist

WHY DRYLAND CORN?

The success of multi-crop notil rotational systems developed by Dr. Dwayne Beck and others in the upper Great Plains region has spurred interest in growing nontraditional crops in the dryland areas of the Pacific Northwest. One crop of particular interest is grain or field corn. Grain corn has been a profitable addition to traditional wheat-based systems in South Dakota.

WILL IT GROW?

While the Columbia Basin is a great corn-growing region, there are a lot of unknowns in regard to growing dryland corn. Although we obviously have enough warm growing days to grow corn to maturity in the Columbia Basin, the accumulation of growing degree days, or thermal time, decreases as you move to higher elevation locations of the dryland area. Can corn grow to maturity in Pullman or further north? Secondly, areas with adequate degree-days could possibly be too dry. What depth can corn extract water from, and will this stored soil moisture last through August? Finally, can corn yields be competitive on a net return basis with traditional dryland crops?

FINDING ANSWERS

Seeing is Believing. To assess the potential for dryland corn within our region, a group of organizations[1] and growers came together last year to conduct a series of variety demonstrations throughout the dryland area. The location of these trials ranged from Walla Walla to Harrington and represented a broad range of climatic conditions. These trials demonstrated that short season hybrids could be grown successfully in our dryland region.

Use of Crop Models. While field trials are the traditional tool for assessing crop production practices and varieties, field trials are limited in two important ways. First, to assess the effects of weather conditions, a field trial should be conducted over multiple years so practices or variety performance can be tested under wet, dry, cold or hot conditions. Secondly, care must be taken in extrapolating results from the testing location to other untested locations. For example, if you conduct a trial in Pullman, can you expect similar results in Tekoa or Dusty? To overcome the site-specific nature of field trials, trials are usually repeated in multiple locations such as the variety testing program. Thus, using field trials to assess the potential for dryland corn in our area

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[1] The dryland corn effort in 1996 was a group effort which included The McGregor Company, Monsanto, Pioneer Hi-Bred International, Tumac Machinery, Walla Walla County NRCS, the Walla Walla County Conservation District, Roland Schirman and Columbia County Extension, and Washington State University Pullman.

will take time to assess year to year variability and a lot of resources to conduct the trials at multiple locations.

To help find the answers to how dryland corn will perform in the dryland areas, a group of us[2] came together last year to use a *crop model* to predict corn performance. A crop model is a system of mathematical equations that describe how plants and soils respond to the environment. Given a description of certain soil physical properties and plant physiological parameters, a crop model will use daily weather data to calculate soil and plant parameters such as soil moisture, crop dry matter, crop leaf area index, and crop yield.

Crop models are powerful tools to augment field trials. First, crop models can predict crop performance for different weather "years". A model can be run with historical weather data or with computer generated weather data. Thus, it would be possible to predict corn yield for the year 1992, a dry year. Second, crop models can be used to test performance at sites where no field trials are conducted. If you can describe a few soil properties such as bulk density and rooting depth and there are historical weather data for the area, you can use the crop model to predict what would happen.

PUTTING MODELS TO WORK

Corroboration. To put the crop models to work, we needed to 1) measure corn growth parameters such as degree-days to flowering, and 2) corroborate the modeled results with actual field results. This second step is needed to confirm the performance of the model before we predict what might happen with different weather or at other locations.

To develop the crop parameters and to collect the corroboration data, we collected detailed weather, soil and crop data at two corn field trials, located in Genesee and Dayton[3], in 1996. Collected data included air temperature, rain, solar radiation, soil water content, total above ground corn dry matter, corn leaf area, corn yield, and the date of specific corn growth stages. All corn growth data were taken from the variety Pioneer 3963.

An example of model performance is shown in Figure 1. Note how the modeled soil water content tracks the observed data. Similar graphs (not shown) to Figure 1 were constructed for soil water at deeper soil depths, corn dry matter production, and corn leaf area to corroborate that the model adequately predicted observed field data.

Looking into the Future. One of our primary goals is to use the crop model to predict the chance of growing corn successfully in different areas of the dryland region. As mentioned initially, there appears to be a balance between having adequate temperatures or thermal time to grow corn to maturity and having adequate soil water and precipitation to meet evapotranspiration. With the crop model, we can simulate how corn will perform at different

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[2] Dr. Claudio Stockle, Dept. of Biosystems Engineering, WSU; Drs. Gaylon Campbell and Tim Fiez, Dept. of Crop and Soil Sciences, WSU; Javier Marcos, Graduate Research Assistant, Dept. of Crop and Soil Sciences, WSU.

[3] We thank Russ Zenner and Pat Barker for letting us collect data on their farms.

locations in the dryland region over long periods of time. We choose to model corn performance at four locations: Dayton, Lacrosse, Pullman, and Harrington. As shown in Figure 2, Dayton and Lacrosse are relatively warm sites while Pullman and Harrington are relatively cool sites. In terms of precipitation, Lacrosse is the driest followed by Harrington, Dayton, and Pullman in order of increasing average yearly precipitation.

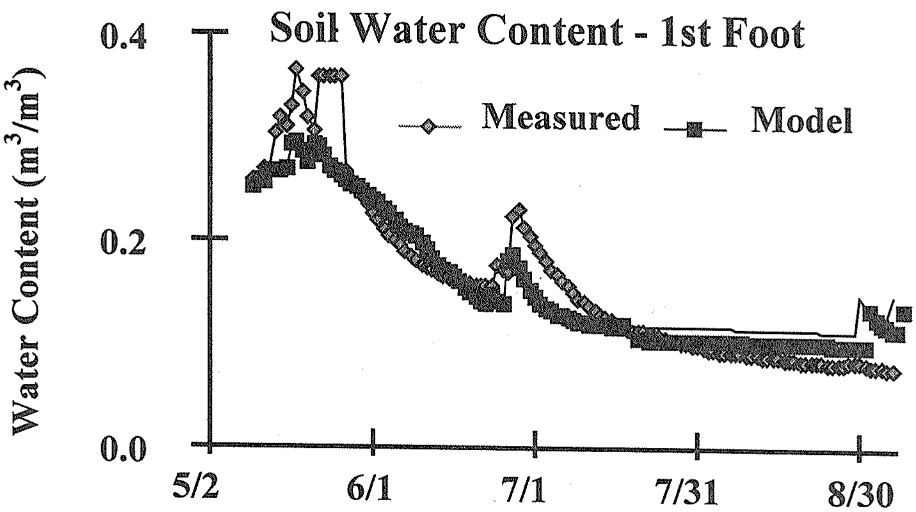


Figure 1. Modeled versus observed soil water content at Dayton, WA.

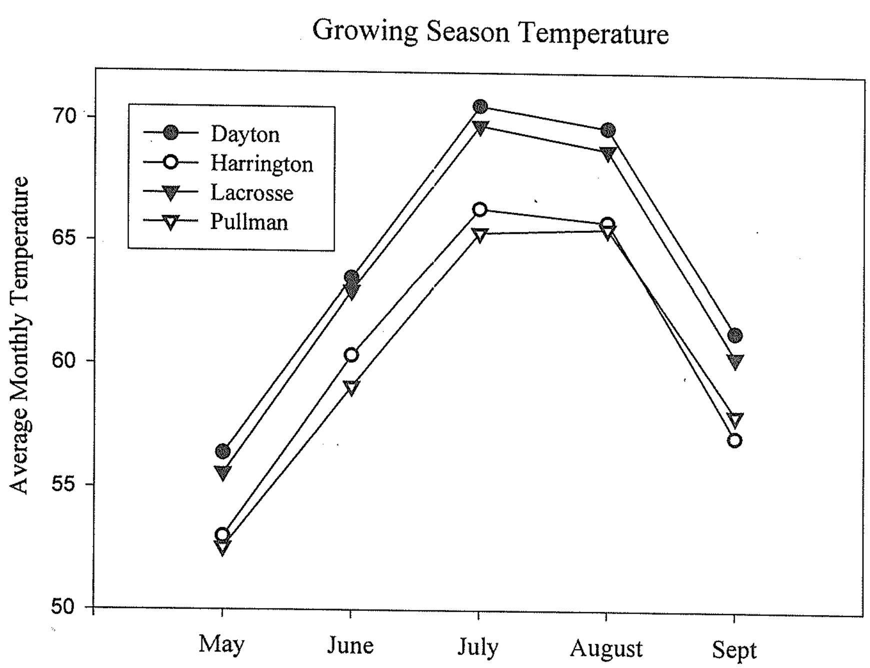


Figure 2. Long term average growing season temperatures at modeled locations. Each point represents the monthly mean (average of maximum and minimum temperatures).

For each of the four sites, we generated 50 years of weather data. Since no year of weather will repeat exactly, we generate weather mathematically that reflects the long-term weather distribution of a site instead of using historical weather records. Yield results from these simulations are shown in Figure 3.

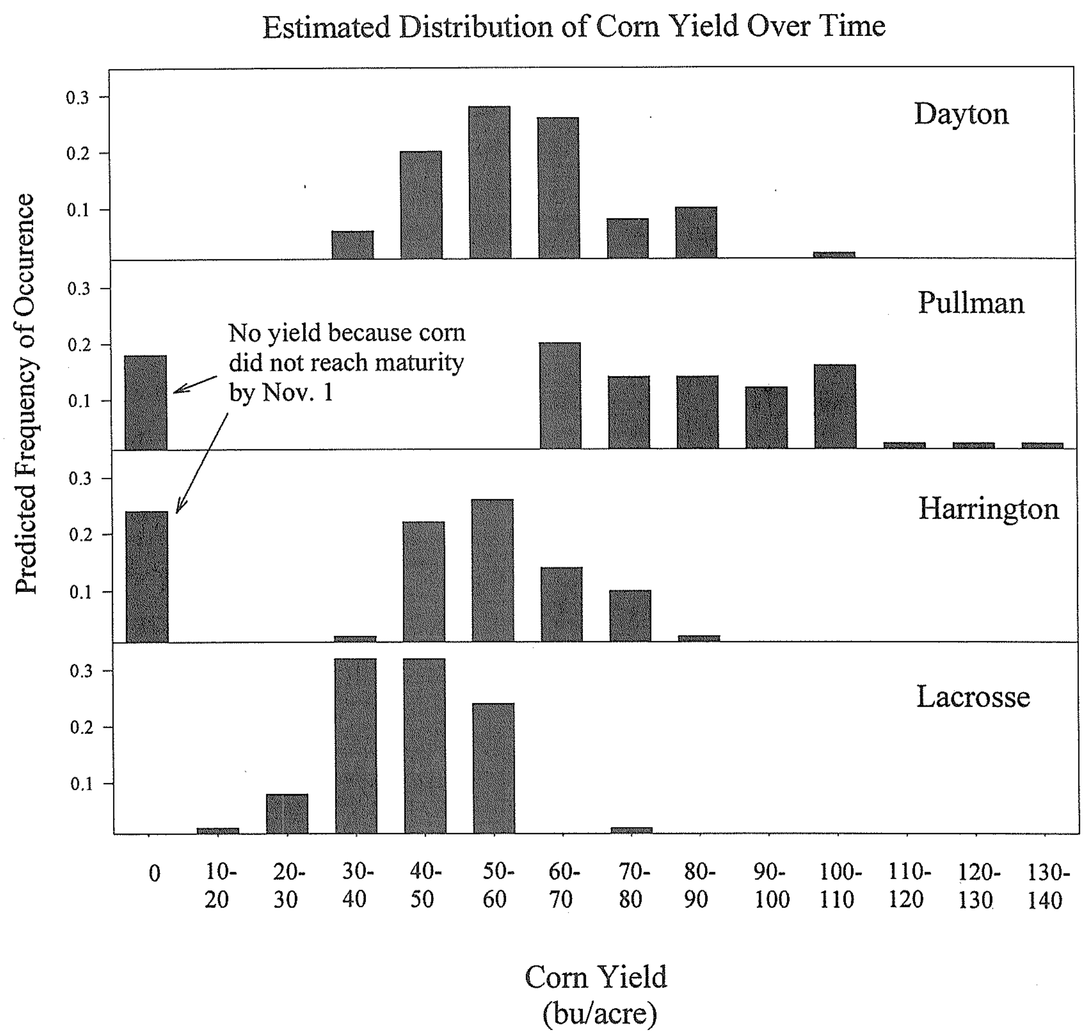


Figure 3. **Preliminary** results of long term simulations of Pioneer 3963 at selected locations in Eastern Washington.

Examining the long-term simulation results, two issues are apparent. First, growing corn to maturity appears to be a problem in one out of five years for the cooler locations, Pullman and Harrington. Second, water stress will limit corn yields as evidenced by lower yields in Lacrosse, the driest site. The results in Figure 3 are preliminary as we are continuing to refine our knowledge of corn growth parameters. We are collecting data on additional corn varieties in 1997. However, it appears from our modeling in 1996, care must be taken to choose varieties that will mature in the cooler areas of the dryland region and that any step to save soil moisture such as notil planting will be important to achieve maximum yields.

For more information about this project, contact Tim Fiez (509-335-2997, tfiez@wsu.edu) or visit our new corn website, http://drycrops.wsu.edu/corn.

ALTERNATIVE ANNUAL CROP ROTATIONS FOR LOW-RAINFALL DRYLAND USING NO-TILL

Bill Schillinger, Jim Cook, Bob Papendick, Roger Veseth, Keith Saxton, Bob Gillespie, Joe Yenish, Ann Kennedy, Harry Schafer, and John Driessen
Washington State University and USDA-ARS

Washington State University and USDA-ARS researchers have teamed up with growers Ron Jirava and Brad Wetli to launch a six-year research project on alternative crop rotations using no-till. The project, which began this spring, will evaluate diverse, annual, no-till cropping systems as a substitute for winter wheat-summer fallow at sites in Adams and Douglas counties. We will grow broadleaf crops to determine their potential to reduce soil-borne diseases and increase grain yield in subsequent plantings of spring wheat. Annual precipitation at the Jirava farm near Ritzville averages 11.5 inches and soil depth is greater than six feet. There is only 2.5 feet of soil over bedrock in our plots at the Wetli farm near Mansfield and precipitation (much of it as snow) is about 10 inches per year.

At both on-farm sites, we will study a four year crop rotation of: spring wheat - spring wheat - safflower - yellow mustard. For comparison, we also have continuous annual spring wheat and continuous spring wheat-spring barley treatments. Soil biological and physical properties from soil samples collected at the beginning of the project and after six years of continuous no-till annual spring cropping will be compared.

Why do we need this project?

Growers in low-rainfall dryland areas want more research-based information on: 1) annual spring cropping, especially no-till annual cropping; 2) broadleaf alternative crops and; 3) how best to fit alternative crops into cereal-based annual cropping systems. Broadleaf alternative crops are needed in the low-rainfall areas to reduce soil-borne diseases of cereals and to enhance crop marketing opportunities. We need to evaluate the agronomic and economic potential for alternative crops in low-rainfall areas and learn how to best fit them into cereal-based cropping systems. Recent technological advancements in the design of no-till drills provide improved fertilizer and seed placement and the capability to pass through heavy residue.

Expected outcomes of this research are improved knowledge on: 1) the long-term feasibility of annual no-till spring cropping; 2) the agronomic potential of several broadleaf alternative crops; 3) the extent to which broadleaf alternative crops reduce soil-born disease pressure in wheat; and; 4) soil quality changes as affected by long-term minimum disturbance no-till planting practices.

CHICKPEA INOCULATION TRIALS

David Bezdicek, Mary Fauci, and Roland Schirman

The lack of research on chickpea inoculation in Washington and Idaho is partly due to the recent introduction of chickpea as a viable alternative crop. Another reason is inconsistent yields in inoculation trials. Chickpea is not inoculated by pea and lentil rhizobia strains found in the pulse growing soils of the Palouse, as it requires a special type of rhizobia available from the major inoculum companies. Because most of our soils do not contain native strains of chickpea rhizobia, we have an excellent opportunity to introduce highly effective strains into the region.

When mixing rhizobia with seed in the planter box, the peat tends to settle towards bottom of the planter box resulting in inconsistent nodulation. Liquid and granular sources of rhizobia now available commercially make it more convenient for application of rhizobia using large scale planting equipment. Liquid inoculants can be added to the seed as it is augered into the grain drill. However, chickpea is highly susceptible to damping off organisms which requires that fungicides be applied usually as a seed treatment. Previous studies in our laboratory have shown that captan is highly toxic to chickpea rhizobia resulting in reduced seed yield in the field. If seed is coated with chemicals toxic to rhizobia, then the effectiveness of liquid inoculation may be in question. Another solution is to add rhizobia as a granular form of peat, which can be applied in the planting row away from the seed. This method is effective, but costly and many drills are not equipped with grass seed or fertilizer attachments used for granular delivery of rhizobia.

In 1996, we initiated several studies in cooperation with several inoculant companies to evaluate methods of inoculation and chickpea rhizobial strains. These studies were conducted in small plots at Pullman in cooperation with Fred Muehlbauer and in replicated field sized plots in Columbia County in cooperation with Roland Schirman.

<u>Replicated Small Plots Trials-</u> WSU Spillman Farm:
Eleven inoculation treatments were evaluated in a randomized block design with 4 replications (Table 1). Plots size was 8 x 20 ft. The area contained some indigenous chickpea rhizobia (not by design). Planting date was 21 May 1996. Sanford variety was planted at the rate of 120 lbs/ac. Seed was treated with apron, molybdenum, and benlate prior to inoculation. Inoculum was applied according to the manufacture's recommendation. Harvest was on 10 October 1996. Data were taken on surface available N (ammonium and nitrate), MPN chickpea rhizobia, nodulation, and seed yield.

At Pullman, the full yield potential was not realized due to the late planting date and the short growing season. However, the best nodulation in terms of nodule weight was obtained for the granular treatment at the highest rate and one of the liquid treatments (Table 1). Yield differences were not significant which may be a reflection of the short growing season and the fact that the site did contain rhizobia capable of nodulating chickpea.

<u>On-farm trials:</u>
Three on-farm sites were evaluated in 1996 in Columbia County designed by and carried out by

Roland Schirman in cooperation with Jack DeWitt, Touchet Valley Seeds, Dayton, WA and three growers as shown in Table 2. The purpose of the study was to compare the traditional planter box treatment with a commercially available liquid inoculum. The field size trial was managed by the growers. We attempted to select sites not previously grown to chickpea so as to evaluate the full potential of the different methods of inoculation. Plot size was 5 acres with 3 replications. Chickpeas (Sanford or Dwelley) were treated with molybdenum, captan, benlate, apron, lindane and inoculated with either a peat carrier in the planter box or mixed with a liquid inoculum as described by the manufacturer. The same strain 27A2 effective on chickpea was provided in both carriers by Lipha Tech. Land preparation, planting, and weed control were conducted by the grower. The DeWitt site was irrigated. Nodulation was assessed and yield data were taken from the plot area using weighing devices.

Chickpeas at the McKinley site were very well nodulated apparently because chickpea was grown previously at that site in 1989. Nodule weight was 10 to 50 times greater at the McKinley site than at the other two sites (Table 3). Nodulation by the planter box method (peat) was consistently higher than for the liquid treatment at the Thorn and Dewitt sites. Yields were not significantly different due to treatment (Table 4). These results, although not conclusive, may suggest some toxic effects from the seed treatment chemicals on the viability rhizobia for the liquid treatment, since there is more intimate contact between the chemical and rhizobia than in the planter box treatment.

We appreciate the cooperation and assistance of Fred Muehlbauer, Rick Short, and Jerry Coker in providing plot land and in the planting and harvesting of plots. We are appreciative of Jack DeWitt, Touchet Valley Seeds for providing and treating the seed. On-farm plot land was graciously provided by Jack DeWitt, Wilford and Eric Thorn, and David McKinley. We are grateful to the following individuals and companies who provided products and useful advice: Stewart Smith, Lipha Tech, Milwaukee, WI; Russell Hynes, Agrium, Inc, Saskatoon, SK; Steve Stephens, MicroBioRhizogen, Saskatoon, SK; and Tom Wacek, Urbana Laboratories, St. Joseph, MO.

Table 1. Treatments, nodule weight, and yield of chickpea at Pullman in 1996

Treatments	Nodule weight (mg/plant)		Yield (lbs/ac)	
Uninoculated control	15.7	cd*	1021	ab
Liquid, Agrium:5 oz/100 lbs seed	9.7	d	1069	ab
Liquid, Urbana Labs: 1 ml/lb seed	24.3	ab	1045	ab
Liquid, Micro BioRhizogen: 100 ml/27.2 kg seed	17.7	c	1289	a
Granular (strain 27A2), Lipha Tech: 5 lbs/acre	18.8	bc	1353	a
Commercial granular, Lipha Tech: 5 lbs/acre	17.4	c	1231	a
Commercial granular, Lipha Tech: 15 lbs/acre	26.9	a	784	b
Stick peat, Urbana Labs: 5 lbs/acre	13.9	cd	835	b
Stick peat, Micro BioRhizogen: 1 kg/818 kg seed	17.2	c	1232	a
Peat, Lipha Tech: 187g/45 kg seed	17.8	c	1069	ab
Peat (strain 27A2), Lipha Tech, 187g/45 kg seed	15.6	cd	1108	ab

* Similar letters are not significantly different at the p=0.05 level of significance

Table 2. Soil surface inorganic N and native chickpea rhizobia (based on most probable number) prior to seeding

Site	Nitrate-N mg/kg	Ammonium-N mg/kg	Native rhizobia, MPN
Spillman	9.1	1.7	10^2
DeWitt	30.3	1.1	0
McKinley	7.3	3.9	10^2
Thorn	7.3	1.9	10^1

Table 3. Nodulation weight (mg/plant) of chickpea from two inoculation sources at three on-farm sites in Columbia County

	Inoculation source		
Site	Control	Peat	Liquid
Dewitt	0.9	6.1	1.8
Thorn	4.4	6.1	1.4
McKinley	55.3	53.2	70.7

Table 4. Chickpea yield (lbs/ac) from two inoculation sources at three on-farm sites in Columbia County

	Inoculation source		
Site	Control	Peat	Liquid
Dewitt	2204	2292	2311
Thorn	1125	1137	1064
McKinley	804	694	778

IMPACT OF LONG-TERM NO-TILL ON SOIL PHYSICAL, CHEMICAL, AND MICROBIAL PROPERTIES

M.F. Fauci[1], D.F. Bezdicek[1], J.E. Hammel[2], R.D. Roe[3], and J. Mathison[2]
[1]Washington State University, [2]University of Idaho, [3]Natural Resources Conservation Service

Our goal is to document the changes in soil quality attributed to no-till (NT) agriculture in the agroclimatic zones in eastern Washington and northern Idaho. We evaluate soil physical, chemical, and biological properties of long-term NT fields in a study we initiated in 1996. Fields have been in NT from 10-25 years and have been under grower management using field-sized equipment and conditions. Two sites were sampled and analyzed in 1996. In spring of 1997, three additional sites were identified and sampled. All NT sites were compared to adjacent land managed conventionally.

Agroclimate zones, locations, and production systems in 1996 and 1997

Zone	Location	Production system/comparison
High rainfall	Palouse, WA	20+ y NT wheat-barley-pea vs. new NT
	Colfax, WA	10 y NT mostly wheat, some lentil vs. conventional
Intermediate rainfall	Lewiston, ID	NT winter wheat (1980-92), 3 y rotation since vs. conventional
	St. John, WA	15 y NT wheat-fallow vs. conventional
Low rainfall	Touchet, WA	14 y continuous NT spring wheat vs. wheat-fallow

The data presented in the following graphs come from samples taken in the spring of 1996 at the Palouse and Touchet sites. Important findings are discussed below. In the graphs, asterisks above comparisons denote significant difference between tillage treatments.

Soil impedance - The dense zone in both NT sites is presumably the result of heavy NT drill traffic. Roots may have difficulty penetrating soil when impedance exceeds 250-350 psi.
Organic matter - The surface of the Palouse NT site is very high in organic matter. This site has approximately 10 inches more top soil than its comparison. At Touchet organic matter content is low, less than 2%, and differences between treatments are small. The OM decreases with depth under NT and is more evenly distributed under conventional tillage.
Soil pH - Soil pH at the 2-4" zone under NT is very low, less than 5. This may influence germination, disease, and nodulation, etc. Seeds are planted within 2-4" zone in Palouse, but most likely lower at Touchet.
Phosphate - There is much more available P (phosphate) in the surface of the NT sites than in the conventional. Most P in soil is organic and unavailable to plant until converted by the microorganisms.
N release - Under ideal conditions the organic rich, active surface layers release more N in ten days. This reflects a higher reserve of N in the NT soil.
NO_3-N by depth - There is higher nitrate levels at lower depths in NT at Touchet. The trend is similar at Palouse, but nitrate concentrations are much lower.

Preliminary Conclusions

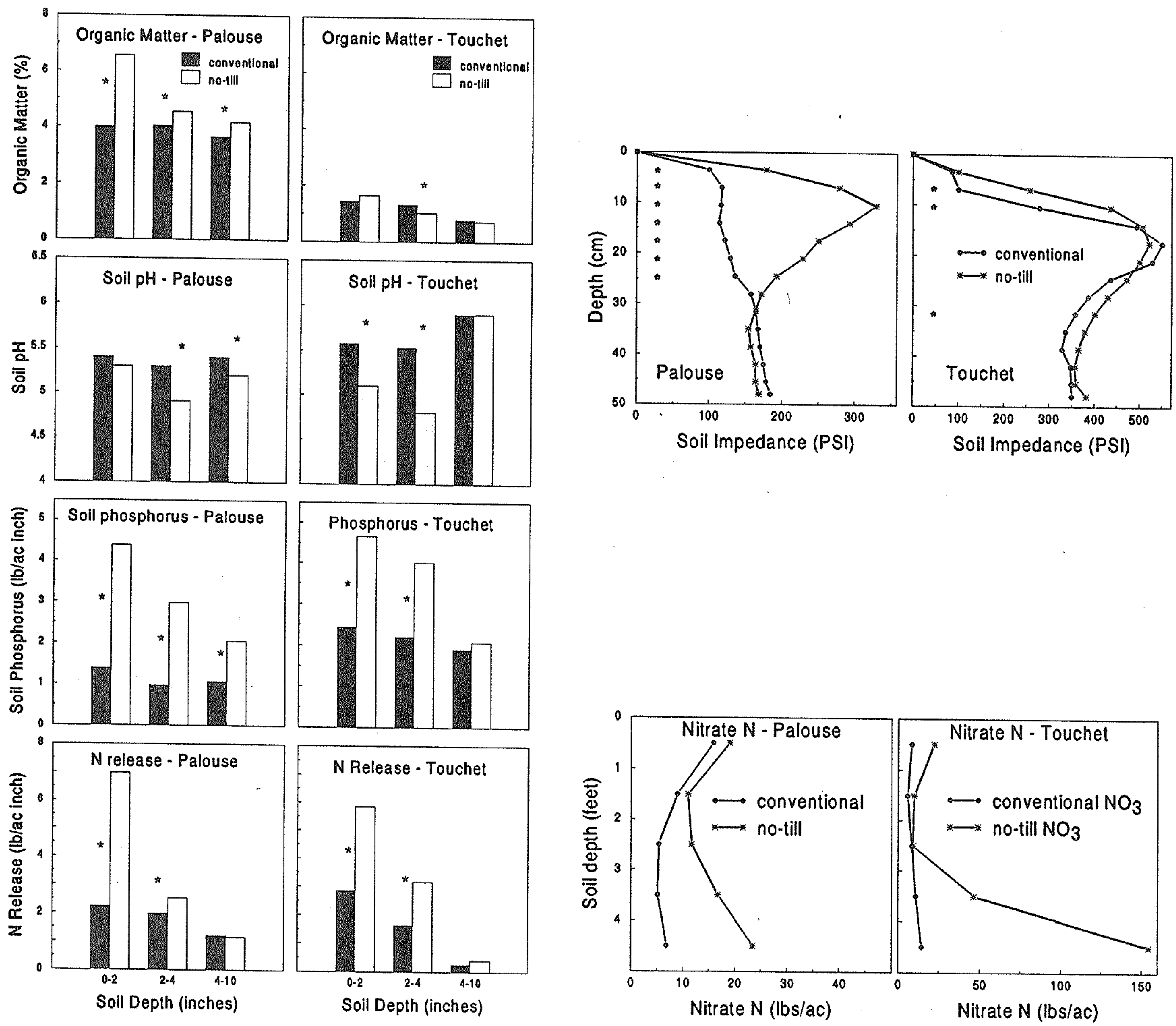
Soil penetrometer resistance is high under NT at Palouse. Plant roots may have difficulty penetrating the layer with greater than 250-350 psi. Soil pH at 2-4" in NT is very low. Both pH and nutrients are more evenly distributed under conventional tillage. Organic matter is concentrated at the soil surface in NT. An active microbial community cycles nutrients as they consume soil organic matter for energy releasing plant available nutrients and stabilized organic matter. The N release assay and phosphate concentration at the surface reflect this biological activity. There is a high nitrate concentration below 4 feet under NT at Touchet and a similar trend at Palouse. N supplying capacity of the NT surface may need to be accounted for to fine-tune fertilizer rates to avoid nitrates at depth.

Related work

Based on pH results from the 1996 sampling, we have started some lime trials on NT ground in spring 1997. Dave Bezdicek and Dennis Roe are documenting case studies with some of the participants. This includes video and interviewing of the participants about their reason for adopting NT management and the choices and decisions they encountered.

Acknowledgments

We appreciate the cooperation of Tom Cocking, Mike Cronk, Duane Kjack, Frank Lange, Dick Lloyd, Roger Pennell, Bob Rea, John Rea, Rick Repp, and Garry Schwank in providing plot land.



Organic Matter - Palouse
Organic Matter - Touchet
conventional
no-till
Organic Matter (%)
Soil pH - Palouse
Soil pH - Touchet
Soil pH
Soil phosphorus - Palouse
Phosphorus - Touchet
Soil Phosphorus (lb/ac inch)
N release - Palouse
N Release - Touchet
N Release (lb/ac inch)
0-2
2-4
4-10
Soil Depth (inches)
Depth (cm)
Palouse
Touchet
Soil Impedance (PSI)
Nitrate N - Palouse
Nitrate N - Touchet
conventional NO3
no-till NO3
Soil depth (feet)
Nitrate N (lbs/ac)

NEW MINIMUM TILLAGE SYSTEMS FOR LEGUME-WINTER WHEAT CROPPING SEQUENCE

Roger Veseth, WSU/UI Conservation Tillage Specialist; Stephen Guy, UI Crop Management Specialist; Donn Thill, UI Weed Scientist; John Hammel, UI Soil Scientist; Tim Fiez, WSU Soil Fertility Specialist; Joe Yenish, WSU Weed Scientist

Some revolutionary changes in tillage practices for spring dry pea, lentil and other spring grain legumes are underway in the Inland Northwest that offer exciting potential benefits in soil erosion control, soil quality, yield potential and profitability. Innovative growers and university scientists have combined efforts to develop integrated management systems for the use of minimum tillage in legume-winter wheat crop sequences. The following is a brief description of why a change is needed and the new management systems that are being developed.

The Problem

In the Palouse region, soil erosion can be a serious problem in crop rotations with grain legumes followed by winter wheat. Intensive tillage has traditionally been used to bury the previous cereal crop residue, incorporate herbicides and prepare a finely-tilled, low-residue seedbed for spring grain legumes. Spring field operations when soils are wet can result in significant soil compaction from tractor traffic and tillage implements. The combination of little or no cereal crop residue retained on the soil surface after legume planting and soil compaction from the spring tillage operations can leave legume fields vulnerable to soil erosion during intense rainstorms in the spring and early summer. Soil compaction also can directly reduce crop yield potential.

Grain legumes produce relatively little crop residue, which is fragile and shatters easily during dry harvest conditions, and decomposes rapidly under moist conditions. Even though Palouse growers have made a significant shift towards minimum tillage or direct seeding of winter wheat, surface residue cover from the legume crop alone is often inadequate for erosion control. Without carryover cereal residue preceding the legume crop and prevention of soil compaction often associated with the legume production, a winter wheat crop after grain legumes can be highly vulnerable to erosion during the critical November to April period when about 70% percent of the yearly precipitation occurs. Winter wheat is usually seeded in October to reduce the risk of a number of weed, insect and disease problems, and/or because of dry soil conditions earlier in the fall. Consequently, the wheat crop usually over-winters as small plants and provides little erosion protection.

Surface runoff and soil erosion can both cause yield losses in grain legume and winter wheat crops. Water running off the fields is water not stored for grain production. The greatest impact would occur on upper slopes and ridgetops where yields are most limited by available water. Erosion can reduce current crop yields by loss of plant stands and reduced plant vigor. Soil loss will also reduce the yields of future crops due to loss of soil fertility, water holding capacity, rooting depth and other soil quality and productivity factors.

Solutions To the Problem

Some innovative growers in the Palouse are beginning to grow spring legumes using minimum tillage systems. An important development in minimum tillage seeding of legumes is the recent availability of herbicides that offer weed control without soil incorporation or that are applied post emergence. A 3-year research project by scientists from University of Idaho and Washington State University was initiated in 1996 to assist growers in developing integrated management systems for these reduced tillage production practices. It is an interdisciplinary team project coordinated by Stephen Guy, UI Crop Management Specialist. The project is partially supported by grants to UI and WSU from the STEEP III (Solutions To Environmental and Economic Problems) conservation farming research program in Idaho, Oregon and Washington.

The goal for growers and scientists is to develop integrated management systems for planting grain legumes using minimum tillage. This would retain more of the previous cereal crop residue on the surface and minimize spring soil compaction, reducing the potential for runoff and soil erosion, and improving water infiltration. The grain legume crop and pest management systems need to optimize yield, quality and residue production. In addition, winter wheat planting systems must then continue to retain surface residue from the legume and previous cereal crops, and maintain soil physical conditions for effective water infiltration. The overall goal is to improve erosion control, yield potential and profitability in the legume-winter wheat rotational cycle.

The research effort focuses on the following management considerations:

1) Surface residue retention, surface roughness, and soil other physical properties affecting water infiltration and erosion potential in minimum and intensive tillage systems for establishing legumes and winter wheat
2) Crop yield, quality and profitability of the legume and winter wheat crops under the minimum and intensive tillage systems
3) Effectiveness of current and prospective herbicides for weed control in legumes under minimum and intensive tillage systems.
4) Incidence of weeds and diseases in the legume-winter wheat rotational sequence under minimum and intensive tillage systems
5) Surface retention of spring wheat versus spring barley residue through the following legume-winter wheat cropping sequence under minimum and intensive tillage systems
6) Residue production and decomposition rate differences between legume species and varieties
7) Effects of fertilizers, fertilizer placement and other crop management options on legume yield, quality and residue production under minimum and intensive tillage systems

Need for a 3-Year Rotation -- An important point to keep in mind is that minimum tillage establishment of spring legumes will be much more successful in a crop rotation of three years or longer, such as winter wheat-spring cereal-legume, than in a 2-year winter wheat-legume rotation. The additional year of spring crop in the rotation is very important in reducing the potential for soilborne diseases and winter annual grass weeds that can be problems under a minimum tillage system in a 2-year rotation. Residue levels are much lower after spring cereals than winter wheat, making minimum tillage systems more feasible for grain legume establishment.

Preliminary Results
Two growers are currently involved in large scale on-farm tests of minimum tillage establishment of pea and lentil with their field equipment. Preliminary results of a 1995-1997 on-farm test by Wayne Jensen, from Genesee, ID, show the success of minimum tillage for planting spring pea after spring wheat compared to conventional tillage (Table 1). This trial began in the fall of 1995 after a 90 bu/A spring wheat crop. Three tillage systems being evaluated include 1) conventional tillage system of fall moldboard plow - two spring cultivations for herbicide incorporation - seed with conventional double disc drills; 2) minimum tillage system of fall chisel - fall cultivate - spring herbicide application without soil incorporation - direct seed with a John Deere 455 minimum tillage drill with off-set double discs; and 3) fall flail before the system in number 2 above. The trial was seeded to Antigo pea in mid-March 1996. The entire trial was direct seeded to winter wheat with a Yielder no-till drill in October and data collection will continue through winter wheat harvest in 1997.

The two minimum tillage systems retained over 52% surface cover from the spring wheat residue through pea seeding compared to 10% with conventional tillage. Minimum tillage pea yields were slightly higher than yields with conventional tillage, but the difference was not statistically significant. Erosion protection overwinter was much higher in the two minimum tillage systems with over 46% surface cover compared to 21% in the conventional tillage system. A substantial portion of the surface residue in the minimum tillage systems was carryover spring wheat residue. The trial will continue to be monitored through winter wheat harvest in 1997.

Table 1. Surface residue retention and pea yield in 1996 under minimum tillage and conventional tillage in a spring wheat-pea-winter wheat rotation, Wayne Jensen, Genesee, ID grower.

Tillage after 1995 spring wheat crop	%Surface residue (Post pea planting)	Pea yield (lb/A)	Post Harvest Residue (lb/A)			% Surface residue cover (Post winter wheat planting)
			Pea only	Wheat only	Pea + wheat	
Fall plow - spring cultivate - seed	10	1120	1169	105	1274	24
Fall chisel - fall cultivate - spring direct seed	59	1220	1860	1102	2962	51
Fall flail - fall chisel - fall cultivate - spring direct seed	52	1300	1485	728	2342	50
LSD (0.05) *	5	NS	689	310	861	10

*** Least significant difference among treatment means in a column at the 95% probability level.**

A repeat of Jensen's 3-year trial (except for the flail treatment) was established in the fall of 1996 in a nearby field after 70 bu/A spring wheat and will continue through the 1997 pea crop and winter wheat harvest in 1998. Overwinter surface residue cover was 11% with conventional plow system and 47 percent with the minimum tillage system.

A 1996-98 field trial was initiated with Art Schultheis near Colton, WA. A field of spring barley stubble was lightly disced in early fall 1996 and chiseled in late fall. Overwinter residue cover was 55%. After a tine harrow operation to smooth the field in spring of 1997, and a herbicide application, the trial was established to compare direct spring seeding after fall tillage versus the traditional system of two field cultivator operations for herbicide incorporation before seeding lentils. The trial will be continued through winter wheat harvest in 1998.

The UI Kambitsch Research Farm south of Moscow is the site of a large-scale trial to compare the effects of fall tillage practices after spring wheat and spring barley on surface residue retention and spring pea production. The following are surface residue levels (%) from spring barley in April 1997 for four fall 1996 tillage practices: 1) moldboard plow - <1%; 2) chisel-plow - 22%; 3) flail/ Paratill subsoiler - 21%; and 4) flail/no-tillage - 62%. Residue cover after spring wheat was not significantly different than after spring barley. The trial will continue through a spring pea crop in 1996 and harvest of winter wheat in 1998. A repeat of this trial will begin in 1997 with fall tillage treatments after harvest of spring wheat and spring barley.

Another large-scale trial at the UI Kambitsch Research Farm will begin in 1997 to evaluate the residue production of two spring pea and spring lentil varieties. The longevity of the residue on the soil surface will be compared under four tillage systems for establishing winter wheat. These will include: 1) Direct seed and fertilize with a no-till drill; 2) Direct-shank fertilize - conventional drill; 3) Direct-shank fertilize - cultivate/harrow - conventional drill; 4) Direct-shank fertilize - 2X cultivate/harrow - conventional drill. The trial will be monitored through winter wheat harvest in 1998. A repeat of the trial will be initiated in 1998.

Research on management options for herbicides to control weeds in minimum tillage systems for legumes was initiated in 1997. Trials to evaluate fertilizers and other crop management options to improve legume grain yield and residue production will begin in 1998. Both of these research efforts will be part of grower-managed on-farm tests on minimum tillage legume systems in the region.

Growers Invited to Be Involved in Additional On-Farm Trials

There is considerable variation in soils, and year-to-year climatic and production conditions across the grain legume production region. Field trials need to be conducted in as many of diverse production environments as possible to develop management systems that are applicable specific areas. At least eight additional field trials are planned over the next two years in the different grain legume production areas in Idaho and Washington. Growers interested in evaluating minimum tillage systems for grain legumes on their farm are encouraged to talk with one of the project researchers (coauthors of this article). For more information, your can contact Roger Veseth at 208-885-3686.

MODELING GROWTH OF IRRIGATED COVER CROPS FOR THE COLUMBIA BASIN

by

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Introduction. Wind erosion can be severe in the irrigated portions of the Columbia Basin. As much as 37 tons of soil can be lost per acre on fields following low residue crops such as potatoes, silage corn, dry beans, and onions. Seeding a fall cover crop can reduce wind erosion as much as 70% providing that enough cover is produced in the fall. Growth models for cover crops would enable producers to better select cover crop varieties and seeding dates to achieve adequate cover.

A project was initiated to either develop growth models for eight cover crops based upon growing degree days (GDD), or fit growth of each cover crop to existing models. The end product of this project will enable producers to estimate how much cover can be achieved for each of the eight cover crops using existing local, historical weather data (GDD).

Field Experiment: A study was seeded at the Othello branch Experiment Station on August 30, 1996. Leaf and tiller numbers, biomass production, and percent ground cover were evaluated for eight cover crops; '**Alpowa**' spring wheat, '**Arrostock**' winter rye, '**Stephens**' winter wheat, '**Breaker**' winter triticale, '**Celia**' winter triticale, '**Greenwave**' brown mustard, '**FS2-5008**' sorghum-sudangrass, and '**Moro**' winter wheat. An on-site datalogger equipped with a thermistor and an existing weather station were utilized to collect temperature data. Growing Degree Days were calculated using a base temperature of 32 F.

Soil samples were extracted to a depth of 6-feet prior to seeding and this spring to assess each crop's ability to recover deep nitrogen. J. Brunty and W. Pan are analyzing nitrate contents of the samples and comparing these results to previous nitrogen recovery studies. Portions of each plot were periodically clipped to estimate biomass production.

Leaf and tiller numbers for each cover crop were counted weakly throughout the fall. Fall leaf & tiller growth data, and cumulative GDD data have been entered into a spreadsheet and preliminary comparisons have been made.

Field Experiment Results: Simple graphs of the data indicate that leaf growth tends to have a linear response to cumulative GDD, while tiller growth tends to have a exponential response to cumulative GDD (Figure 1). Leaf development slowed considerably after the six leaf stage and tillering rapidly accelerated after the fifth leaf stage except for sorghum-sudangrass and brown mustard.

'Greenwave' brown mustard required the most growing degree days to develop the first leaf even though it was seeded much shallower than the other cover crops. The long lag period for the first leaf was attributed its lengthy cotyledon stage. After achieving its first leaf, 'Greenwave' required only 84.1 GDD to produce a new leaf, and 'FS2-5008' sorghum-sudangrass required the most, 110.8 GDD/leaf (Table 1).

The August 30 planting date proved to be too late for sorghum-sudangrass. It failed to develop more than 6 leaves prior to a killing frost in late October, and none of the plants reached a height of 12-inches. 'Alpowa' spring wheat performed well in the fall but as much as 50% winterkill was observed this spring. All the cover crops continued to acquire leaves & tillers after the first killing frost with the exception of the sorghum-sudangrass.

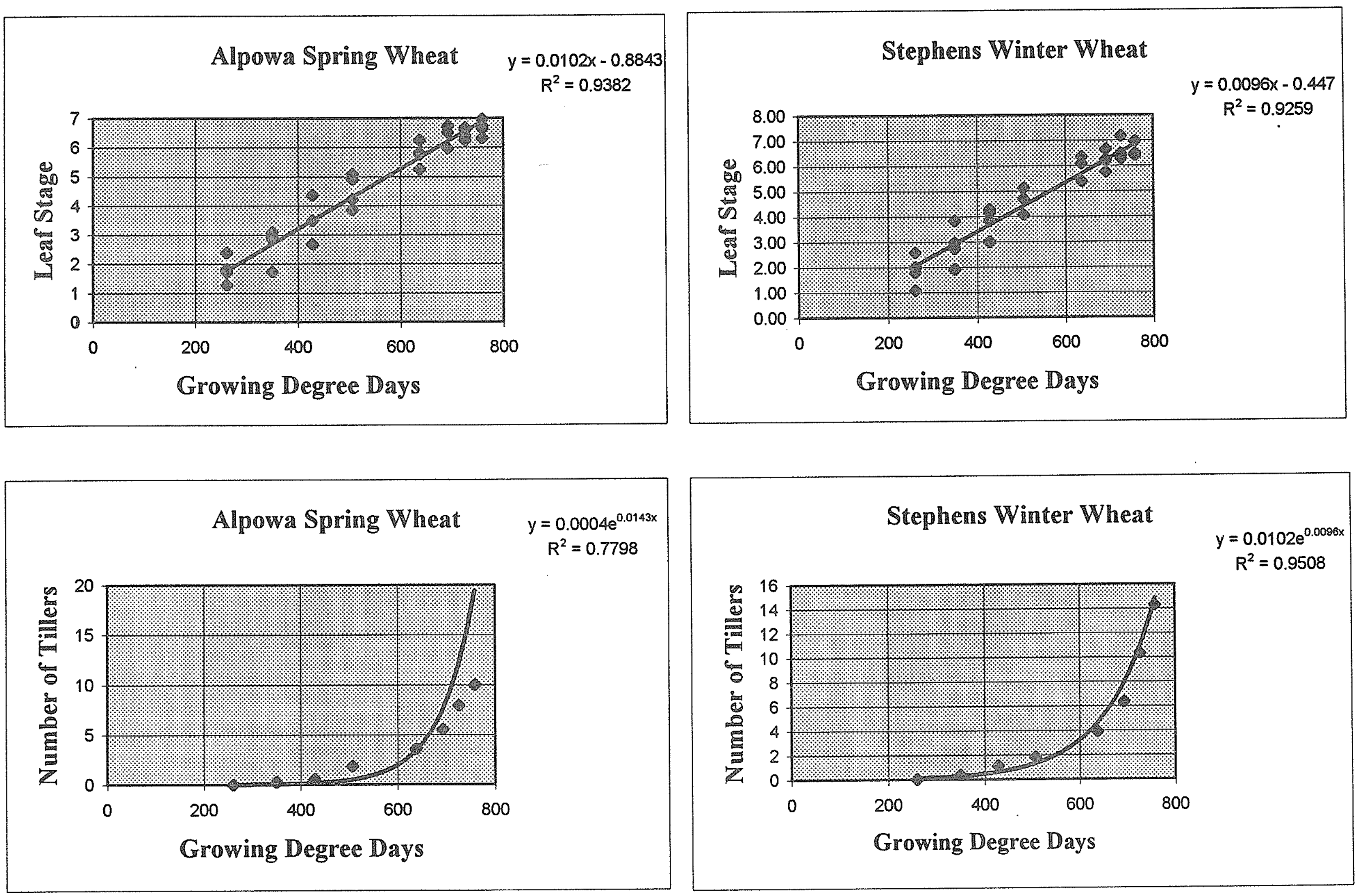
'Arrostock', a New York Plant Materials Center release, is a cover crop variety developed for following potatoes in the New England states. Its leaves were very long and biomass production was outstanding. It also tillered much more profusely than the other cover crops tested. 'Arrostock' rye would be an excellent cover crop for late fall seedings for irrigated growers who do not rotate wheat and could prevent it from establishing on waste areas. Plant height was 28-inches on April 4 which was greater than twice the height of the other cover crops on the same date.

The winter wheats and winter triticales performed similarly and soil protection was quite adequate. Winter wheats were more upright than the triticales but the triticales provided higher ground cover percentages.

Table 1. Fall growth performance of eight cover crops seeded at the Othello Experiment Station

Cover Crop	Growing Degree Day per Leaf	Biomass Production (gram/3ft row)		
		4-Oct	1-Nov	17-Dec
Arrostock rye	97.2	19.2	36.3	55.1
Alpowa spring wheat	91.7	3.6	21.4	49.6
Stephens winter wheat	96.4	5.5	15.9	15.6
Celia winter triticale	98.1	4.8	20.2	6.6
Moro winter wheat	108.3	3.3	17.5	7.6
Breaker winter triticale	104.5	5.4	24.2	18.8
Greenwave brown mustard	84.1	6.2	32.8	66.4
FS2-5008 sorgham-sudangrass	110.8	0.4	0	0

Figure 1. Examples of leaf and tiller development for 2 of the 8 cover crops tested.



CRP TAKE-OUT: A UNIQUE OPPORTUNITY FOR THE TRANSITION TO DIRECT SEEDING

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About 80% of the contracts on 2.5 million acres of Northwest cropland in the Conservation Reserve Program (CRP) are scheduled to expire in 1997. Although growers have offered much of this CRP acreage for enrollment in the 1997 CRP sign-up, a considerable amount of the acreage may not be accepted for new contracts in the national selection process. If CRP land is returned to crop production, growers should take advantage of this unique opportunity to make the transition to direct seeding or other minimum tillage systems. These systems can provide effective soil erosion control and water conservation, maintain more of the soil quality improvements gained over 10 years in grass, and the bottom line....improve profitability in a global market.

CRP May Eliminate the Direct Seeding "Transition Period"

There can often be a 3- to 5-year "transition period" during the change from intensive tillage systems to no-till direct seeding systems before soils begin to reach a new equilibrium in physical, biological and chemical processes and properties. Early in this transition period, crop yields can sometimes be similar to or lower than yields under intensive tillage. However, as the transition period progresses, growers and researchers across the Northwest and around the world have noted higher crop yields compared to intensive tillage, associated with improvements in soil organic matter, soil structure or "tilth," soil biological activity, and water infiltration, and a reduction in weeds and diseases with adequate crop rotations.

Improvements in soil quality during CRP may help growers eliminate or shorten this typical transition period and achieve enhanced yield potentials with direct seeding of CRP fields sooner than if converting cropland from intensive tillage to direct seeding. If growers have been considering direct seeding, CRP take-out is the time to start.

Northwest CRP Take-Out Research Effort

The results of a 3-year research project on CRP take-out for crop production in Washington State illustrate that direct seeding can provide similar economic returns to intensive tillage systems with other significant benefits to the environment and soil quality. The research effort included 10 large-scale, field research trials on crested wheatgrass CRP land in the low rainfall, crop-fallow regions, where the vast majority of CRP is in the State. Field trials were conducted in 7 counties in cooperation with 15 growers, 12 researchers and more than 25 other Ag support personnel. A variety of tillage and residue management systems were evaluated in three trials on CRP take-out with tillage for summer fallow - winter wheat, and seven trials on spring CRP take-out with direct seeding and/or tillage for spring crops. Some of the management options included: fall versus spring take-out; residue management practices such as flailing, harrowing, and burning; a range of tillage intensities, and direct seeding systems. This field research project used the large-scale, replicated, on-farm testing approach with farm-scale equipment operated by the growers.

The research was supported in part by two USDA-Cooperative Research, Extension and Education Service (CSREES) grant projects through Washington State University: 1) PNW STEEP II (Solutions To Environmental and Economic Problems) research and education program on conservation farming technologies; 2) Northwest Columbia Plateau Wind Erosion - Air Quality Project.

Results Highlight Direct Seed and Minimum Tillage Benefits

Intensive Fall Tillage Reduces Overwinter Water Storage

Fall discing reduced overwinter water storage by approximately 2 inches compared to leaving the grass undisturbed over winter because of increased evaporation. By winter wheat planting after fallow in the trials near Connell and Lind, available water storage in the fall disc system was still about 1 inch less than in take-out systems with no fall tillage. This water loss resulted in lower plant stands and a 3-5 bu/A yield reduction and lower profitability compared to spring take-out systems. Although fall versus spring CRP take-out trials were not conducted for spring cereals, yield reductions in spring wheat from water loss by intensive fall tillage could be 10 to 14 bu/A based on the 2-inch overwinter water loss in other trials.

Residue Management and Tillage Summary for Fallow

Burning -- The low to moderate surface residue levels with crested wheatgrass (generally 3,000-6,000 lbs/A) do not warrant the use of burning to achieve manageable residue levels at seeding time after fallow. Compared to other spring treatments, spring burning in the Franklin and Lincoln County sites did not result in significant differences in plant stand, yield, test weight, protein or net returns, and did not retain adequate surface residue for water conservation and erosion control.

Flailing -- Fall or spring flailing did not significantly affect surface residue cover or roughness after winter wheat seeding, improve plant stands or grain yield compared to other spring take-out treatments. Consequently, the additional cost of flailing was generally not recovered.

Harrowing -- Fall 2X harrowing - spring disc did not affect plant stands, surface residue and roughness after seeding, grain yield or net returns compared to two spring discings. It did, however, result in a slight reduction in downy brome population in the winter wheat crop due to increased weed seed germination before summer fallow establishment.

Maintaining Effective Erosion Protection -- All tillage and residue management combinations used in the three CRP take-out research trials for summer fallow-winter wheat were overly intensive, resulting in low surface residue levels that limited erosion protection and water conservation. All the systems included 2-4 rod weedings after primary tillage operations of discs, chisels or sweeps. The combination of fall harrowing and fall or spring undercutter or sweep would provide one of the most profitable and effective minimum tillage take-out systems for fallow. An application of Roundup RT before spring tillage on take-out trials for fallow helped reduce grass reestablishment, particularly under wet spring conditions. Chemical fallow and no-till seeding of winter wheat was not evaluated but may be an option in higher precipitation areas and years.

Direct Seeding Spring Cereals in CRP Take-out

Spray Rate and Timing for CRP Kill Before Direct Seeding -- Based on the results of cooperative small-plot research trials by Monsanto and The McGregor Co., a 48 oz/A rate of Roundup RT is generally recommended for a high percentage (90%+) kill of the crested wheatgrass for direct seeding systems without tillage. Application should be at least 21 days before direct spring seeding to reduce the potential for a **"green bridge"** of Rhizoctonia root rot and other root diseases that can be transferred from grass roots to the seeded crop. Because of crested wheatgrass dormancy in the fall, Roundup RT applications in the fall did not kill crested wheatgrass even with good fall regrowth and weather conditions.

Flailing Before Direct Seeding in Spring CRP Take-out -- Spring flailing ahead of direct-seeded spring wheat in 1996 spring CRP take-out trials near Ritzville and Waterville did not affect plant stands, root disease level or yield, and consequently was less profitable than direct seeding without flailing. Fall harrowing when grass residue was dry could provide a more cost effective alternative for spring crops after CRP. Under higher levels of grass residue, flailing of dry grass may provide a greater benefit for equipment operations and crop establishment.

Spring Burning Before CRP Take-out for Spring Crops -- In a direct-seeded spring wheat trial on crested wheatgrass near Ritzville, yields with burn - direct seed averaged about 3 bu/A higher than direct seeding into standing grass and about 3 bu/A lower than with a tillage comparison of disc - coil pack - fertilize and seed with conventional double disc drill. However, economic returns were not significantly different between the three systems.

Direct Seeding Versus Tillage Take-Out --Three spring take-out trials with direct-seeded hard red spring wheat were conducted in crested wheatgrass CRP in 11-inch rainfall areas in 1996: two trials near Ritzville and one near Waterville. Each trial compared several direct seeding systems with a reduced or conventional tillage system for comparison. Non-cereal crops were not evaluated in direct seeding for CRP take-out in the large-scale research trials, but could provide the advantage of being less susceptible to some of the root diseases and other pests encountered with cereals, which have more pests in common with CRP grass.

Yields of spring wheat in direct seeding systems were equal to or a few bushels per acre lower than yields of the tillage comparison systems. However, there were generally no significant differences in profitability. Higher grass survival was believed to be one of the main reasons for the small yield reductions in direct seed systems in some of the trials. The incidence of Rhizoctonia root rot as relatively high on the roots of both direct seeding and tillage take-out systems. Options to reduce grass survival and root disease potential could include spraying out the CRP grass the summer before spring planting or using non-inversion tillage, such as an undercutter or sweep, in the fall or spring before direct spring seeding. Harrowing when the grass residue is dry and brittle in the late summer or fall could provide an economical and effective residue management practice for spring seeding. Compared to intensive tillage, improved water conservation with direct seeding would increase yield potential if the crop can effectively utilize the increased available water.

Collaborative research under the direction of Ann Kennedy, USDA-ARS Soil Microbiologist in Pullman, WA, showed that direct-seeded CRP maintained soil quality parameters at a level more similar to CRP than did intensive tillage take-out. The amount of soil carbon (measured as readily mineralizable carbon) available for microbial growth was greater after direct seeding than after intensive tillage. Other national research shows that direct seeding can significantly build soil organic matter levels over time while tillage results in an increased loss of soil carbon as carbon dioxide released to the air by dramatically accelerating the rate of biological decomposition of plant residue and organic matter in the soil.

In addition to effective, early grass kill, an important factor in the success of direct seeding CRP would be the drill capability to effectively penetrate the grass residue and soil for good seed-to-soil contact and accurate seed placement. Deep banding of fertilizer below seeding depth near the seed row would also help reduce the impacts of root diseases and increase yield potential.

Copies of the CRP Take-out Research Summary

Detailed results from the 3-year CRP take-out research project are summarized in "*Returning CRP to Crop Production -- A Summary of 1994-96 Research Trials in Washington State*" -- the November 1996 *PNW Conservation Tillage Handbook Series* No. 16 in Chapter 2. Copies are available from the WSU Crop and Soil Sciences Dept. Cooperative Extension Office, P.O. Box 646420, WSU, Pullman, 99164-6420, phone 509-335-2915 or e-mail ce6025@coopext.cahe.wsu.edu. This *Handbook Series* publication on CRP take-out, and eventually all the *PNW Conservation Tillage Handbook*, can also be accessed on the World Wide Web Home Page (http://pnwsteep.wsu.edu) titled Pacific Northwest STEEP III Conservation Farming Systems Information Source. For more information, contact Roger Veseth, WSU/UI Conservation Tillage Specialist, at 208-885-6386 or e-mail (rveseth@uidaho.edu).

DIRECT SEEDING MOVEMENT AIMED AT GLOBAL COMPETITIVENESS, SOIL PRODUCTIVITY AND EROSION

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We are entering a new and exciting era of crop production across America and around the world. It is a time of phenomenal increases in the use of direct seeding systems, driven to a large degree by farm profitability and competing with direct seeding growers across this continent and in other major grain producing countries. On the other side of the direct seeding coin, is an increasing recognition of the tremendous potential benefits for improving soil quality and productivity. Add to that almost zero soil erosion with everyone benefiting in improved water and air quality, and it all sounds like a dream come true. But it is not a dream. It is happening all around us and Northwest growers can not afford to wait and be left in the dust. Albeit the learning curve can be steep and rocky at times, but direct seeding is a win-win opportunity, both short and long term, one that growers can't afford to pass up.

Competing with the Competition

Direct seeding and other minimum tillage systems offer the potential to reduce production costs, and increase profitability, helping growers become more competitive in an increasingly global marketplace. Northwest growers need to be aware of what production systems their national and international competitors are using. The Conservation Technology Information Center (CTIC) documents that the acreage of no-till in the U.S. has grown from 13 million acres in 1989 to over 42 million acres in 1996. They estimated that there were about 74 million acres of the world's cropland under no-till a couple years ago. This included 39 million in the U.S., 22 million in Brazil, Argentina, Australia and Western Europe, and more than 12 million in Canada....some major U.S. wheat producing competitors.

In 1996, direct seeding of annual cropping acreage in large grain producing Provinces of Alberta, Saskatchewan and Manitoba was estimated at 37%, 55% and 43%, respectively. Less that 6% of the small grain production in Idaho, Oregon and Washington was under no-till in 1996 according to CTIC surveys. One exception was winter wheat in Idaho at almost 10%. If we are going to compete economically and protect our cropland resources, we need to consider the production efficiency and productivity potential of no-till direct seeding and other minimum tillage systems.

Shaking off the Farm Bill Shackles

For decades, U.S. Farm Bills have been major obstacles to successful no-till and minimum tillage systems in the Northwest and across the country. Commodity program restrictions largely locking Northwest dryland growers into short crop rotations in order to maintain their wheat base acreage, and high proven yields for winter wheat. To help manage weeds and diseases, they were forced to rely on intensive tillage. When growers began in the 1970's to explore direct seeding and minimum tillage in their traditional 2-year rotations with winter wheat, many experienced reduced yields or crop failures due to soilborne diseases and winter annual weed. At that time there was also little research base or grower experience to guide growers in managing these new conservation tillage systems. Since then, great strides have been made in management technologies for direct seeding, and growers now have more cropping flexibility to develop crop rotations critical to the success of direct seeding and other minimum tillage systems with the 1996

"Freedom to Farm" Bill. Direct seeding and other minimum tillage system offers the greatest yield potential with spring crops. Now is the time to seriously begin exploring new options for crop rotations, equipment, and management technologies for direct seeding or other minimum tillage systems.

New Insights into Tillage Impacts and Direct Seeding Benefits

Intensive tillage largely serves as a pest management substitute for crop rotation and other pest management practices. For many growers, there was little choice when they were locked into short rotations with winter wheat under decades of Farm Programs. But intensive tillage has had some high costs, many of which have been overlooked because of gradual soil impacts. In addition to high production costs, cropland resource costs of intensive tillage systems have included 1) soil loss by water and wind erosion and the associated reduction in productivity, 2) loss of soil organic matter, which leads to deterioration of soil structure, tilth, fertility, water holding capacity and increased erodibility, and 3) low water storage efficiency because of high rates of evaporation and runoff -- resulting in a reduced yield potential. When growers change from intensive tillage to direct seeding and other minimum tillage systems they can change these costs into benefits.

Recent research lead by USDA-ARS scientists in Minnesota has begun to document carbon dioxide emission from the soil after tillage, and the effect that has on soil organic matter and productivity. The results are revolutionizing our understanding about the impacts of tillage on soils and the environment. Soil organic matter or soil organic carbon is critically important soil component directly related to soil fertility, water holding capacity and infiltration, aggregation and structure, erodibility, biological activity and a long list of other soil properties affecting soil productivity and soil quality.

The researchers point out that the reduction in soil organic carbon following tillage results from the addition of oxygen to the soil, similar to stoking a slow-burning fire. The increased oxygen level and higher soil temperature with bare soil after residue incorporation stimulate intense microbial activity under moist soil conditions. The result is accelerated loss of soil organic carbon as crop residue and soil organic matter is decomposed -- biologically burning it off. In one study, they found that carbon loss in 19 days after fall plowing under moist conditions was greater than the total carbon contained in the stubble of the previous wheat crop. Contrary to the common belief that returning crop residue to the soil with tillage build soil organic matter, the real impact of tillage is a continual decline in soil organic carbon. In their studies, no-till systems resulted in very low carbon loss and consequently have the potential for increasing soil organic carbon. Intermediate carbon losses occurred from minimum tillage systems. The greater and more frequent the soil disturbance, the greater the carbon loss.

Direct seeding systems offer the greatest potential in erosion control, soil quality improvements, water conservation and lower production costs, although 2- or 3-pass minimum tillage systems can also achieve significant improvements in these areas. Because of improved water conservation and soil productivity, no-till and minimum tillage systems also have a higher dryland yield potential than under intensive tillage. The challenge for growers and Ag support personnel is to develop the crop management systems for control of pests previously controlled by intensive tillage in order to take advantage of the higher yield potential.

A New Ball Game with Direct Seeding Technology

Much has changed since Northwest growers began trying no-till drills in the 1970's. Many of the pest problems that occurred during the past 25 years can now be largely avoided because of new research development in management technologies, and *NOW*, Farm Program flexibility in crop rotations. Northwest research has shown that are a number of important management components needed for successful conservation tillage systems. The ***MOST EFFECTIVE*** pest management tool under conservation tillage is crop rotation. For example, Northwest research on conservation tillage has shown that a 3-year rotation with 2 years out of winter wheat effectively minimizes crop losses from several winter annual grass weeds and soilborne diseases that commonly reduce winter wheat yields in shorter rotations.

Until now, a 3-year crop rotation, such as winter wheat - spring barley - fallow or legumes was often difficult for growers to change to if the farm had a high wheat base or limited barley base, or both. Recropping with spring crops, either for a couple years or longer term can also effectively control many pest problems associated with winter wheat production. Formidable challenges like jointed goatgrass are driving grower into spring cropping systems. Utilizing direct seeding or minimum tillage systems for establishing spring crops offers the greatest potential for efficient use of water for spring crop production, as well as soil conservation. Direct seed spring cropping is becoming an attractive production option to winter wheat-fallow in the lower precipitation areas when there is adequate soil water for recropping. Flex-cropping based on water is now a management option.

In addition to crop rotation, the success of no-till and minimum tillage systems are influenced by a number of other management practices identified by Northwest research. An important starting point is uniform combine residue distribution at harvest, particularly the chaff, which contains the weed and volunteer grain seeds. Control of weeds and volunteer grain that provide a "green bridge" root disease host for spring crops should begin in the fall, when possible, and early in the spring at least 2-3 weeks before seeding. Fertilizer placement below seed depth and near seed rows has been shown to make the crop more competitive under pressure from root diseases and grass weeds. New seed treatments and plant resistance also offer growers improved control of some disease and insect problems in conservation tillage systems.

The Team Effort Challenge Ahead

The agricultural industry and researchers are being challenged to expand and refocus research efforts to better address grower needs as they make the transition to direct seeding and minimum tillage systems with new crop rotations now possible under the new Farm Bill. Several new research projects are now underway through STEEP III, Washington Wheat Commission, the Columbia Plateau Wind Erosion Project, Monsanto, Conservation Districts and other sources. The projects are collaborative on-farm testing efforts to evaluate new crops and management strategies. More than ever before, there is a need to develop strong partnerships between growers, researchers, Ag service industry and Ag support personnel to help growers make a successful transition into direct seed intensive cropping systems....the farming systems of the future, here today.

LOW RAINFALL AREA WHEAT PRODUCTION
LATE FALL vs. SPRING SEEDING

Edwin Donaldson

In the low rainfall areas, early seeding of winter wheat is not always possible due to a lack of seed zone moisture or a field history of grassy weeds. As fall seeding is delayed, the yields of winter wheat decrease to a point where spring seeding is the best agronomic and economic option. Late seeded winter wheat has several problems which can be avoided by seeding spring wheat. Fields seeded to winter wheat late in the fall are susceptible to water erosion, particularly when the soil is frozen. These fields can be managed to reduce or eliminate the erosion if spring wheat is the intended crop. Also, late seeded winter wheat is subject to winter kill. Several diseases which can be devastating to fall sown wheat do not effect wheat seeded in the spring.

We initiated a study in 1995 to compare the grain yields and residue production of late seeded winter wheat with spring wheat.

Six winter wheats were planted on summer fallow on October 18, 1995 at the Dryland Research Unit near Lind, WA. Three rates of seeding were used: 15, 30, and 60 lbs/a with the same number of seeds being planted for each cultivar. Cultivars were: club wheats, 'Moro' and 'Hiller'; soft white common, 'Madsen' and 'Eltan'; hard red, 'Hatton' and 'Buchanan'. A deep furrow plot seeder with 16 in. row spacing was used. Seeding conditions were excellent.

On March 15, 1996, three spring wheats were planted at the same rates with a 6 in. row spacing double disc plot seeder. Butte 86, a tall hard red; Westbred 926, a semi-dwarf hard red; and Klasic, a very short hard white cultivar were used. The ground was cultivated once before seeding and a starter fertilizer was used during seeding.

Before harvest, a yard length of row (two rows for spring) was pulled from each plot of the four replication nursery for determining the number of plants and tillers. All other data was obtained from the harvested sample or calculated from a combination of the pulled and harvested sample. Straw was collected behind the plot combine with a tarp.

Results and Discussion

Summer fallow was prepared for the production of winter wheat, consequently there was more input into spring wheat production than there was into the production of winter wheat. This involved an additional tillage operation in the spring and the cost of starter fertilizer. No starter fertilizer was used on the winter wheat. Additionally, a rod weeded surface should not be left over winter where there is a possibility of water running off of frozen soil. Consequently, an additional operation in the fall, such as chiseling, should be done.

Westbred 926 yielded as high as the best winter varieties, Moro and Hiller (Table 1). Butte 86 yielded as high as Eltan and Madsen. Spring wheats had the most plants and tillers per unit area. The winter wheats had the most tillers per plant and the largest heads (kernels per tiller). With the exception of Hatton the spring wheats had equal or better test weight than the winter wheats (Table 2). The spring wheats had the highest protein (these were hard wheats) and the largest kernels.

Table 1. Yield and yield components for six winter and three spring wheats, averaged over three seeding rates

CULTIVAR	YIELD bu/a	PLANTS 3' row	TILLERS 3' row	TILLERS/ PLANT	KERNELS/ TILLER
Hatton	38.2 B	16.8 B	80.8 BC	5.2 B	29.5 B
Buchanan	27.9 E	11.4 C	76.8 CD	7.8 A	21.7 CD
Madsen	37.1 BC	15.6 B	72.9 CD	4.9 B	31.4 B
Eltan	35.9 BCD	15.6 B	71.8 CD	4.8 B	30.4 B
Moro	42.3 A	17.2 B	75.4 CD	4.6 BC	39.4 A
Hiller	42.4 A	16.3 B	70.6 D	4.6 BC	40.1 A
Butte 86	34.2 CD	30.0 A	103.1 A	3.7 CD	18.6 DE
Westbred 926	39.3 AB	27.9 A	88.3 B	3.4 D	23.2 C
Klasic	32.2 D	29.3 A	106.2 A	3.8 CD	15.7 E
LSD 10%	3.75	3.6	10.1	0.87	4.2

Values within a column followed by the same letter are not different

Table 2. Test weight, protein, and 1000 kernel weight of six winter and three spring wheats, averaged over seeding rate

CULTIVAR	Test Weight lb/bu	% Protein	1000 Kernel wt
Hatton	62.8 A	13.1 D	33.5 BC
Buchanan	59.4 DE	13.7 C	35.5 B
Madsen	59.0 E	13.0 D	35.4 B
Eltan	59.6 D	12.2 E	34.9 B
Moro	58.5 F	11.6 F	29.9 D
Hiller	57.6 G	11.7 F	31.2 CD
Butte 86	60.2 C	14.8 A	40.3 A
Westbred 926	59.6 D	14.6 AB	43.0 A
Klasic	61.2 B	14.3 B	42.4 A
LSD 10%	0.42	0.29	2.8

Values within a column followed by the same letter are not different

Butte 86 and Westbred 926 produced as much residue as the high residue producing winter wheats Eltan and Moro (Table 3). Klasic which is very short produced the least residue. High residue production is generally associated with the number of tillers per unit area. The spring wheats had the most tiller (Table 1).

Table 3. Residue production, averaged over seeding rates

CULTIVAR	Residue lbs/a	Plant Height inches
Hatton	1958 BC	32.6 A
Buchanan	1892 C	32.8 A
Madsen	1913 C	27.2 C
Eltan	2060 ABC	29.7 B
Moro	2182 AB	32.5 A
Hiller	1971 BC	27.0 C
Butte 86	2295 A	30.8 B
Westbred 926	2225 A	25.6 D
Klasic	1498 D	19.3 E
LSD 10%	237	1.2

Values within a column followed by the same letter are not different

Table 4. Seeding rate effect, averaged over six winter wheats and three spring wheats

Seeding Rate lbs/a		Yield bu/a	Test Weight lb/bu	% Protein whole grain	1000 Kernel grams	Residue lbs/a
Winter	15	31.0 C	59.1 D	13.0 D	32.9 B	1675 C
	30	38.7 B	59.5 CD	12.4 E	33.6 B	2038 B
	60	42.2 A	59.8 BC	12.1 F	33.6 B	2274 A
Spring	15	29.8 C	60.1 ABC	15.2 A	42.5 A	1650 C
	30	38.5 B	60.4 AB	14.4 B	42.0 A	2158 AB
	60	37.4 B	60.5 A	14.1 C	41.2 A	2209A
LSD 10%		2.6	0.59	0.24	3.3	150

Values within a column followed by the same letter are not different

The 15 lb/a seeding rate was too low for either late seeded winter wheat or spring wheat. In the fall seeding, the higher the seeding rate resulted in a higher yield. The 30 and 60 lb/a seeding rate produced the same yield in the spring and yielded equal to the 30 lb/a fall seeding rate (Table 4).

Residue production closely followed the grain yield relatively to the seeding rate. Test weight increased with increasing seeding rate while the whole grain protein content decreased. The kernel size was unaffected by seeding rate.

CONCLUSIONS

Based on the results from a single year.

1. Spring wheat will yield nearly as much as late seeded winter wheat.

2. Spring wheat produces as much residue as late seeded winter wheat.

3. Spring wheat has better stands (plants per unit area) than late seeded winter wheat at equal seeding rates.

NO-TILL ANNUAL SPRING WHEAT IN THE HORSE HEAVEN HILLS

Bill Schillinger, Bob Papendick, Ed Donaldson, Dave Evans, Keith Saxton, Steve Albrecht, Frank Young, Harry Schafer, and John Driessen.
WSU Department of Crop and Soil Sciences and USDA-ARS

The Horse Heaven Hills in Benton county receives an average of only 6-to 8-inches of annual precipitation, and is the driest wheat production region in the Pacific Northwest. Winter wheat - summer fallow is the dominant cropping system in the Horse Heaven Hills. Blowing dust from summer fallow is a major soil loss and air quality concern.

In collaboration with the Benton County Wheat Growers Association and grower Doug Rowell, we began a six-year research project in 1997 to compare no-till annual spring wheat to winter wheat summer fallow in the Horse Heaven Hills. At our test site on the Rowell farm, winter wheat yields have historically ranged from 3-to 30-bushels per acre with a long-term average of 20 bushels per acre.

In our study, we plant spring wheat with the USDA-ARS "cross-slot" no-till drill. This drill delivers seed and fertilizer in one pass and causes minimum surface disturbance. Throughout the six-year research period, we will compare annual no-till spring wheat to winter wheat - summer fallow for grain yield, production costs, and net income. In addition, we will measure and compare the two systems for water use efficiency, weed population dynamics, and soil biological and physical parameters.

If you have questions or would like to learn more about this project, contact WSU agronomist Bill Schillinger at 677-3673 or grower Doug Rowell at 894-5309.

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, *R. oryzae*, and *R. cerealis*, 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 these root diseases: the average increase in yield of winter wheat in response to soil fumigation has been 70, 22, and 7%, respectively, in commercial fields cropped every year, every other year, and every third year to wheat. Besides showing the importance of root diseases, the results with soil fumigation 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 region where the climate and soils 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 "one-pass" (direct seed or no-till) planting systems, is also the result primarily of root diseases, favored by: a) the moist conditions, typical of soil covered with straw; and b) better survival of the root pathogens, owing to slower decomposition of infested residue and more volunteer hosts. Yet one-pass (or two-pass) planting systems, where the field is tilled, fertilized, and planted into standing stubble 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). Root diseases must be controlled to achieve both the high yields and the fertilizer-use efficiency possible with conservation farming and frequent cropping to small grains.

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) 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 grain rotations 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;

3) Use current-year certified seed, or seed no more than 1 year old, to maximized seedling vigor and tolerance to *Pythium* infections;

4) Treat the seed for protection against seed infections by *R. oryzae* and *Pythium* species; and

5) 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 within the seed row and 2-3 inches below the seed at the time of planting 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 three very different species-- *Rhizoctonia solani* AG8, *R. oryzae* and *R. cerealis*. *R. solani* AG8 causes mainly root pruning and hence stunting of seedlings, whereas *R. oryzae* can cause seed rot and hence stand failure. *R. cerealis* causes root pruning and also infects the lower stems. Strains of *Rhizoctonia oryzae* can now 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 *R. solani* AG8. Barley in the rotation favors *R. solani* AG8, 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 *Pythium* and *Rhizoctonia*, especially *R. cerealis*. A treatment designed to control just one component can sometimes favor another member in the mixture. Our research program is continuing to a) identify and learn more about the species and subspecies of wheat and barley root pathogens; b) find out more about how soil conditions and practices favor different mixtures of these pathogens; and c) develop the means to control the entire mixture.

Seed treatment chemicals are available to control components but not all of the mixture responsible for seed infections and seed rot, and they do little to protect against any of the pathogens responsible for root rots. For example, Apron controls *Pythium* attack of seeds, but can leave the germinating seed vulnerable to attack by *Rhizoctonia*. A combination of Dividend + Apron controls both pathogens on seeds and very young seedlings but the plants are still vulnerable to take-all as well as root infections by *Rhizoctonia* and *Pythium* species. Thiram and Captan control seed-infecting pathogens only, although neither of these fungicides are as effective as Apron against *Pythium*. Dividend on seed controls seed infection and possibly some root infection by *Rhizoctonia* and take-all but has no affect on *Pythium*. We are continuing to test existing and new seed treatment fungicides for activity against one or more of the wheat and barley root pathogens.

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. We have obtained some of the best results against the combination of all three root diseases using select strains of microorganisms combined with one or more of the commercially available seed treatment fungicides all applied as a seed treatment. 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. A major breakthrough during the past year has been the discovery of a naturally occurring strain of rhizobacteria that is especially competitive and aggressive as a wheat root colonist. We have also learned a great deal about the process of root colonization, 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 at several locations in eastern Washington on spring as well as winter wheat and spring barley planted directly into stubble of these crops. In 1995, near Almota, winter wheat planted directly into spring wheat stubble averaged 17 and 21% higher yields in response to seed treatments with Dividend plus two select strains of microorganisms, respectively, while Dividend alone and each strain alone gave no yield response. 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%.

In greenhouse tests conducted in cooperation with Steve Jones, we have discovered a high degree of resistance to both take-all and Rhizoctonia root rot in the wheat relative *Dasapyrum villosum*. This could be the first breakthrough ever in finding a source of genes for use in wheat to help manage the root disease complex. We also have trials in cooperation with Steve Ullrich to develop useful sources of resistance in barley to Rhizoctonia root rot and with Kim Kidwell on development of spring wheats with resistance/tolerance to root diseases.

Future efforts will continue to concentrate on combining our best strains of biocontrol bacteria with the seed-treatment chemicals with best cultural practices for root disease control in no-till systems. We have begun the steps to scale-up and eventual commercial use of our seed treatments. Ultimately, we expect to have varieties of wheat and barley with resistance to at least some of the root pathogens to complete the package.

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.

BARLEY STRIPE RUST IN THE PACIFIC NORTHWEST IN 1997

Roland F. Line
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A new barley disease, barley stripe rust (Puccinia striformis hordei), has appeared in the Pacific Northwest and could cause wide spread damage to barley in Washington and adjacent states. The disease can cause losses as severe as the losses that occurred in wheat during the early 1960s when there were no resistant cultivars and no other available methods of control. A research program preventing such a disaster was started in 1993 at Washington State University.

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, powdery spores that are produced on the Foliage of the plants. Stripe rusts appears on young plants as golden-yellow blotches with powdery spores and later as long, narrow golden-yellow stripes on the leaf surface and glume. 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 (Puccinia striformis tritci); however, they are two different pathogens. Wheat stripe rust 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 is known to reduce barley yields by 30 to 100 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, as well as in the United States. Barley stripe rust was reported to be present in South America near Bogata, Columbia in 1975. It was postulated that the barley rust was introduced by people traveling from Europe, since the race that was detected in Columbia was the same as a race that was common in Europe. The rust soon spread to other South American countries and eventually to Mexico. It caused wide-spread devastating losses in each of the regions where it occurred. The disease was first detected in Texas in 1991, and since then it has been spreading north and west. It appeared in Oklahoma, New Mexico and 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. Barley stripe rust also appeared in Utah in 1994 and 1995 and caused severe damage. By the spring of 1995, the disease had appeared in western Washington and Oregon, and by July of the same year, it was detected in eastern Washington.

Also by July, the rust developed to severe disease intensities in southwestern Oregon and northern California. In 1996, barleystripe rust was widely destructive in California (causing a total loss of some fields) and was detected in both eastern and western Washington and Oregon. 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 rusts has been in fields of susceptible cultivars in the Pacific Northwest.

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 is highly favorable for the disease. Now that barley stripe rust has appeared in in Oregon, Washington, and northern Idaho, it will remain in the region and spread throughout the Pacific Northwest. Field research in the Pacific Northwest was not appropriate until the disease became widespread. Now that the disease is in the region, 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 rusts 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, we determined in 1994 that at least 14 races of the barley stripe rust pathogen exist in North America. Since then, more than twice that number of races have been identified.
Therefore, the barley stripe rust pathogen is extremely variable. Until 1994, we did not know how similar or different barley stripe rust and wheat stripe rust 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, 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 resistance and are conducting studies to determined what genes provide resistance. The current barley cultivars grown in the United States are susceptible, and it will take a few years to incorporate some types of rust resistance into locally adapted cultivars. Also, new races may circumvent some types of rust resistance. We know little about the types of resistance to barley stripe and how durable the resistance may be. There appears 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 the 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.

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.

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

Monitor your crop. The disease will continue to exist in Washington and other states in the PNW. The fall and winter weather was favorable for stripe rust. Cool wet spring weather will provide conditions that are even more favorable for the disease. The same weather conditions are favorable for wheat stripe rust and barley stripe rust; therefore, one clue that barley stripe rusts might be present is the presence of wheat stripe rust on early winter wheat. . The barley stripe rust 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. The rust will probably appear first on the lowest leaves of the biggest plants of winter barley and volunteer barley that survived the winter. It should appear first in southern Washington and adjacent barley growing areas of Oregon. First, look on the lowest leaves for small golden-yellow blotches with powdery spores. Later as the plants grow, look for small golden-yellow stripes. 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 of several diseased leaves to Roland F. Line, USDA - ARS Plant Pathologist, PO Box 646430, WSU, Pullman, WA 99164-6430 or call (509) 335-3755 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 becomes more severe, it is probably barley stripe rust.

Plant early in the spring. Early planting should enable the barley crop to get a head start on the disease. Stripe rust development at late stages of growth will cause less damage. The amount of rust that survives the winter is important because if little rusts survives, the disease will not develop until late in the season. Even though early planting is preferable, sometimes very late plantings may escape the disease if the months of June and July are very dry, but yield of the very late plantings will usually be lower.

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 than 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 rusts is expected. Best control should be before the rust develops on the upper leaves. Tilt (manufactured by Ciba) is the only systemic fungicide registered for control of barley stripe rust. Tilt cannot be used beyond the late jointing stage. New fungicides may be available later in the growing season. Determine the economical benefits before using the foliar fungicide.

STRIPE RUST, LEAF RUST AND STEM RUST OF WHEAT, 1997

Roland F. Line
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General Characteristics. Three rusts (stripe rust, leaf rust, and stem rust) occur on wheat in the Pacific Northwest. Stripe rust, caused by *Puccinia striiformis*, appears as golden-yellow, long, narrow stripes on the leaf surface and glumes; leaf rust, caused by *Puccinia recondita*, appears as small, red pustules on the leaf surface and leaf sheath; and stem rust, caused by *Puccinia graminis*, 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 70 percent. Since then, destructive epidemics of stripe rust that cause losses of more than 20% have occurred in fields of susceptible cultivars 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 several other years. Without development of resistant cultivars and emergency registration of a fungicide (Bayleton) for rust control, losses caused by stripe rust in Washington would have exceeded 50 percent in 1981. Omar, was completely destroyed in 1981. Stripe rust was especially severe in hard red winter wheat and club wheat in central Washington in 1996. A new form of *Puccinia striiformis* that attacks barley (barley stripe rust) is now present in the Pacific Northwest.. Barley stripe rust looks like wheat stripe rust but is a different pathogen that is more severe on barley and is not a destructive disease of wheat. We expect barley stripe rust to damage barley in the same manner that wheat stripe rust has damaged wheat in the past.

As we develop wheat cultivars 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. Leaf rust was severe in 1996.

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 1996. 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 cultivars that they attack, and new races of the pathogen frequently evolve to attack cultivars that were previously resistant. Fifty-seven stripe rust races have been identified of which 46 have been detected in eastern Washington.

In 1996, 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 in the United States in 1994 and 31 by 1995. There may be as many as 20 additional races based on 1996 data, but they have not been fully identified. All major spring barley cultivars and most winter barley cultivars 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 1995.

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 cultivars and some wheat cultivars are susceptible to stem rust .

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 (a green bridge) 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. Severe stripe rust epidemics and leaf rust were predicted and occurred in 1996. As of early May 1997, stripe rust and leaf rust epidemics were already developing in fields of hard red and club wheats in southern and central Washington.

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, 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 cultivars. 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 for regions throughout the world 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 cultivars, advanced breeding lines from breeders in the Pacific Northwest, and differential cultivars for resistance to stripe rust, leaf rust and stem rust. The information on resistance of germplasm and advanced lines has made possible the development and release of rust resistant cultivars 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 cultivars.

Use of Fungicides. Resistance to all disease problems may be difficult or impossible to incorporate into a single cultivar, 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, Alto, Govern, and Quadris 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 cultivars 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. However, several are expected to be registered in the near future. 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.

For more information visit our homepage at www.wsu.edu:8080/~wheaties.

THE SMUTS AND BUNTS OF WHEAT, 1997

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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.

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.

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 embryo. 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.

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 was not controlled by the seed treatments that were 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 and 1995. 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.

Karnal bunt. Karnal bunt (partial bunt), caused by *Tilletia indica*, is a new smut disease of wheat in the United States. Karnal bunt is a disease occurs under the environmental conditions that occur in India, Pakistan Nepal, and Mexico and is seldom severe and seldom affects grain quality even in those countries. The disease was detected in Arizona and California in regions adjacent to Mexico in March 1996. The smut spores survive in the soil and germinate when wet to produce a type of spore that is carried to wheat heads where infection occurs. Because of its environmental requirements for survival, germination, and infection, Karnal bunt is not expected to become a production problem in the Pacific Northwest or in regions of northern United States. It should not affect yield or quality in those regions. However, because of national and international quarantine regulations, the disease has an impact on the marketing of wheat. It is to the southwestern United States what dwarf bunt is to the Pacific Northwest. Some seed treatments reduce the spread of Karnal bunt, but none of the currently registered seed treatments provide 100% control of the bunt. Future control of Karnal bunt on seed will depend upon the ability of the seed treatments to kill all spores in and on the wheat seed or in the soil or to kill all germination spores. Some systemic foliar fungicides show great possibilities for preventing infection of the heads or for preventing disease development in the field. There is a need for research aimed at elucidating the epidemiological factors affecting the disease in order to understand its importance to the wheat industry and implement control methods.

General Comments Regarding Control of Smuts and Bunts. Quarantine regulations have proven to be ineffective and unnecessary for control of the smuts and bunts. Whereas, use of resistant cultivars, and management, has controlled the diseases. 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. Seed treatments and foliar fungicides have possibilities for control of Karnal 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. For more information visit our homepage at www.wsu.edu:8080/~wheaties.

FURTHER DEVELOPMENT OF THE EXPERT SYSTEM FOR INTEGRATED MANAGEMENT OF WHEAT DISEASES AND SUSTAINABLE WHEAT PRODUCTION

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An expert system for managing wheat diseases referred to by the acronym MoreCrop (Managerial Options for Reasonable Economical Control of Rusts and Other Pathogens) was developed in 1993 for the U.S. Pacific Northwest. The purpose of MoreCrop was to predict outcomes that may happen and present options for control. The user evaluates the provided information and by a process of reasoning determines the most economical control. MoreCrop was developed using the enormous knowledge base on wheat diseases together with tools from recent technological advances in the computer industry. It provides information, options, and suggestions to help the user make decisions regarding management of wheat diseases. MoreCrop predicts what diseases are more likely to occur based on selected geographical regions, agronomic zones, crop managerial practices, cultivar characteristics, prevailing weather, crop history, and disease history and provides the reasons for the disease outcome. 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 must exist for the disease to develop. It considers the diseases that are likely to occur and evaluates integrated disease management (IDM) options. It can suggest an IDM program or provide an opportunity to develop a customized IDM program. It evaluates the IDM program, provides a list of diseases that can and can not be controlled, and the rationale for control or absence of control. MoreCrop can use past decisions to reconstruct disease conditions, assist in reasoning which control option to select, and provide disease-related as well as cultivar-related information for teaching, research and extension. The concepts of MoreCrop can be extended to include fertility management and management of other pests. Thus, MoreCrop can serve as a prototype in developing a total wheat management program. Its programming structure, the visual controls, and the principles should be easily adapted for use in IDM of other crops or in other regions of the world. For details about MoreCrop, contact Roland F. Line, Agricultural Research Service, U.S. Dept. of Agriculture, PO Box 646430, Washington State University, Pullman, WA 99164-6430, Telephone: 509/335-3755. To purchase MCP22 MoreCrop, contact Washington Cooperative Extension Bulletin Office, Cooper Publication Building, PO Box 645912, WSU, Pullman, WA 99164-5912. For more information visit our homepage at www.wsu.edu:8080~/wheaties.