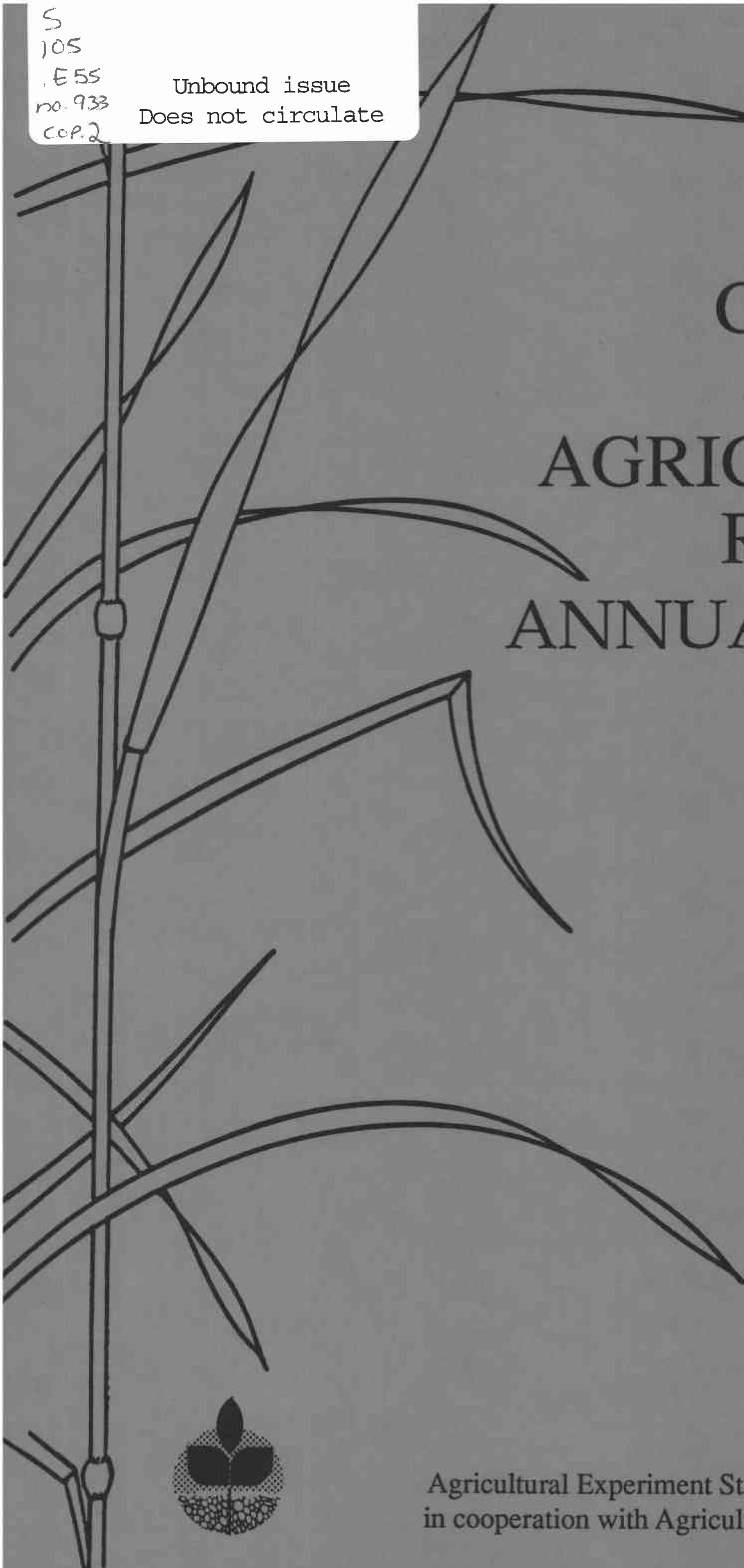

1994 COLUMBIA BASIN AGRICULTURAL RESEARCH ANNUAL REPORT

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COLUMBIA BASIN AGRICULTURAL RESEARCH

JUNE, 1994

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INTRODUCTION

Staffs of the Columbia Basin Agricultural Research Center (OSU, Pendleton and Sherman Stations) and the Columbia Plateau Conservation Research Center (USDA-Agricultural Research Service, Pendleton) are proud to present results of their research. This bulletin contains a representative sample of the work in progress at these Centers. A collection of bulletins over a three-year period will give a more complete assessment of the productivity and applicability of research conducted on behalf of producers in eastern Oregon and comparable agricultural regions. Changes in staffing, programming, and facilities at these Centers during the past year are summarized below.

PROMOTIONS AND AWARDS

Within the USDA staff, Clyde Douglas and Tami Toll were both promoted. Cash awards were given to Roger Goller, Clyde Douglas, and Dale Wilkins in recognition of special services.

STAFF CHANGES

David Sutherland resigned as Faculty Research Assistant in Pamela Zwer's wheat breeding program. Robert Luster carried responsibilities of that position while authorization was requested to hire another permanent employee. Other temporary employees who worked for extended periods during the year included Darrick Cope, Everine Harrington, Daniel McCarty, Tamara Simpson, Amber Wicks, Robert Erskine, Vicky Correa, Milne Purchase, Brian Washam, Keith Furgerson-Moses, Teresa Walenta, and Robin Thompson. We also thank the 22 summer and seasonal employees who provided excellent service to OSU research programs.

For the USDA staff, Jill Harris worked for an 8-week period last summer on a special ARS program for Research Apprentices in Agriculture. Brian Schimel from the Pilot Rock High School worked as a Teacher Fellow in a special ARS program designed to get more understanding of agricultural research to the high school students who will become tomorrow's scientists. Craig Cameron joined the staff as a permanent full time Physical Science Technician, working in the erosion program. Julie Bain was hired as a temporary full time technician in the plant science area. Other temporary employees who worked for extended periods include Shane Enright, Maralyn Horn, Ericka Miller, and Martha King.

NEW PROJECTS

The only new project by OSU staff involved initiation of winter hardiness nurseries near Ritzville, WA and Baker, OR. These nurseries are an extension of Pamela Zwer's club wheat breeding program.

The USDA-ARS staff has begun a new research program to define the environmental factors that allow downy brome to germinate and emerge under conservation tillage systems. The project is being done on three farms in the Pilot Rock area and at the Pendleton Station under the leadership of Dale Wilkins. Dale is also working with Clyde Douglas to evaluate field variation in grain protein across dryland areas of the Pacific Northwest. These two scientists are also collaborating with Joe Pikul and J. K. Aase, ARS, Sidney, Montana, using a combine with a stripper-header to determine the role that this new equipment might have in snow entrapment and to determine the grain loss at the header as related to grain yield and header speed. Paul Rasmussen, Bart Duff, and Richard Smiley have begun work under a new Wheat Commission Grant to examine the biological and economic sustainability of the wheat-pea rotation based on previous research done on the long-term plots on the experiment station. Paul has also initiated another project with Steve Albrecht to investigate nitrogen transformation, movement, and uptake by plants in soils of the dryland wheat-production areas. Using the stable isotope of nitrogen, N-15, they plan to follow nitrogen movement and biochemistry in the soil system.

FACILITIES

Routine maintenance was continued at both OSU stations. Additionally, a new building was constructed at Pendleton to satisfy requirements of the Worker Protection Standard of the US-Environmental Protection Agency. The building consolidates all records for experiments and farm management at the Center, pesticide and safety displays, notifications, records and equipment, a pesticide decontamination area, and storage lockers for personal protective equipment and clean clothing for pesticide applicators.

The USDA office building upgrades included an improved air filtration system, new circulating pumps and motors on the HVAC system, and major repairs to the roof. Garage and shop doors were all painted. The new microbiology laboratory was provided with three-phase electrical service, new tables and cabinets, and a deionized water system.

TRAINING

OSU staff continued to maintain certifications in their individual areas of responsibility. Clerical staff received training in word processing and accounting skills and field research staff participated in training sessions on wheat disease control and integrated pest management. Facility and experimental plot managers attended a safety and stewardship seminar. All staff were given additional training in first aid.

On the USDA staff, Sharron Wart received training on Federal Travel Regulations regarding temporary duty travel, eight employees took a one-day course in Word Perfect, Betty Klepper attended a course in "Total Quality Management", and three employees attended a "Life Balance Workshop for Working Women". The Administrative Officer, Phil Dailey, attended a workshop on dealing with news media. The Radiation Protection Officer, Steve Albrecht, received specialized training on changes in radiation protection laws and procedures. Paul Rasmussen took "Issues in Environmental Geology" at the Washington State University campus at Tricities to update technical skills. Five employees attended a course in Integrated Pest Management to maintain pesticide licensing. Six employees took the Advanced Neutron Gauge Operations Class from Corcoran Enterprises, Inc. Dale Wilkins took "Windows for PC's" at Blue Mountain Community College. All staff attended CPR and First Aid classes with instructors from Blue Mountain Community College.

VISITORS

Distinguished visitors hosted by staff at the Center included Dean Plowman, Administrator, USDA-ARS, and Acting Assistant Secretary of Agriculture, Washington, D.C.; Bob Reginato, Director, Phyllis Johnson, Associate Director, Ralph Nave, Assistant

Director, and Larry Rolle, Budget and Fiscal Officer, USDA-ARS, Pacific West Area Office, Albany, CA; Dick Amerman, USDA, National Program Staff, Beltsville, MD; Brad Baugh, USDA-ARS, Area Safety/Health Officer, Pullman, WA; Representative Chuck Norris, Hermiston, OR; Senator Gordon Smith, Pendleton, OR; Administrators Van Volk, Thayne Dutson, and Bruce Sorte, Oregon State University, Corvallis, OR; several visitors from 8 other countries, including Australia, Argentina, Ireland, Lithuania, Estonia, Latvia, Romania, and Egypt; Fred Grey, Univ. of Wyoming, plus 10 faculty and students for a plant pathology tour; 38 members of the Kiwanis Club for a tour of the facilities; Heidi Dobson, Whitman College, Walla Walla, plus a class of 12 students.

Other visitors included numerous representatives of equipment and supply companies, news media, wheat producers, extension agents, and faculty and staff from research, SCS, and extension programs in Washington, Idaho, and Oregon.

SEMINARS

The seminar series at the Center was coordinated by Ron Rickman. Seminars included the following speakers and subjects: Leon Reese (Agricultural and social change in Armenia); Paul Rasmussen, Clinton Reeder, and Bart Duff (Social and economic implications biological and economic stability of agricultural soils); Shaun McKinney (Watershed analysis of the Tucannon River basin); Paul Rasmussen (Sustainable agriculture symposia, England and Australia); Steve Albrecht (Nitrogen fixation by cyanobacteria); Kathy Ward, Craig Cameron, and Sandy Ott (TDR and neutron meter cross calibration for field water content measurement).

LIAISON COMMITTEES

The Pendleton and Sherman Station Liaison Committees have region-wide representation and provide guidance in decisions on staffing, programming and facilities and equipment improvement at the Stations. Membership is by appointment by the Director of the Oregon Agricultural Experiment Station and also, at Pendleton, by the Director of the Pacific West Area, USDA-ARS. These committees provide a primary communication link among growers and industry and the research staff and their parent institutions. The Committee Chairman and OSU and USDA administrators encourage and welcome your concerns and suggestions for improvements needed in any aspect of the research centers or their staffs.

The Pendleton Station Liaison Committee is led by Chairman John Rea (Touchet, WA.: 509-394-2430). The Sherman Station Liaison Committee is led by Chairman Steve Anderson (Arlington: 503-454-2513). The committees met for a joint session at Pendleton on March 3, 1994, and additional sessions are anticipated during the summer. Members of the Sherman Station Endowment Fund Sub-committee met on numerous occasions to coordinate the fund raising activity, including a public auction held at The Dalles on March 7.

EXPRESSIONS OF APPRECIATION

The staff wishes to express their appreciation to individuals, associations and corporations who have given special assistance for the operation of experimental plots on or associated with the Center during 1992-1993.

The Oregon Wheat Commission and USDA-STEEP II research program continue to provide critical support upon which many of the Center's projects are founded. Thanks are also given to those who donated equipment for long-term use by the Center (Kaye McAtee, and John Rea), funds, seed, and/or chemicals (Monsanto Chem. Co., CIBA, duPont, Wilbur-Ellis Co., Sandoz, American Cyanamid, SeedTec International, Blue Mountain Seed, Inc., InterMountain Canola Company, Valent, Ag Research Inc., Miles, Inc., BASF Corporation, Hill Brothers Chemical Co., Rhone-Poulenc, Blue Mountain Green Pea Industry, Boise Cascade Corp., Mid Columbia Producers, Hoest-Roussell, Lloyd Rhinhart, and Frank Tubbs Ranches).

We also wish to thank the 44 farmers who have allowed us to work on their property during the past year. They have often gone the extra mile by performing field operations, loading equipment, donating chemicals, and adjusting their practices to accommodate our plots. The locations of these outlying sites are shown on the map that follows.

We thank those who donated labor, supplies, equipment or funding for the Pendleton Station Field Day: Inland Empire Bank, First Interstate Bank, Farm Credit Services, Steele's Bar & Grill, American Cyanamid, BASF Corporation, CIBA, Dow-Elanco, duPont, Farm Equipment Headquarters, Inc., FMC Corporation, Huntington-Price, Inland Chemical Service, Inc., InterMountain Canola Company, McGregor Co., Miles, Inc., Monsanto Chemical Co., Pendleton Flour Mills, Inc., Rohm and Haas Company, Rhone-Poulenc, Sandoz Agro, Inc., Smith Frozen Foods, Inc., Tri-River Chemicals Company, Inc., Uniroyal Chemical, Valent USA Corporation, Walla Walla Farmers Coop Inc., Western Farm Services, Inc., Wheatland Insurance, Pendleton Grain Growers, Pendleton Senior Center, Main Street Cowboys, and Umatilla County Wheat Growers League.

We also thank donors to the Sherman Station Field Day, at Moro: Cargill, Inc., Cascade Ranchers, Gustafson, Kaseberg's Wheatacres Irrigation, Klickitat Valley Grain Growers, M & S Farm and Home Supply, Mid-Columbia Bus Company, Monsanto, Morrow County Grain Growers, Mid-Columbia Producers, Inc., Northwest Chemical, Richelderfer Air Service, Sherman Aviation, SeedTec International Inc., Sherman Farm Chemicals, Sherman County School District, The Halton Company, Wilbur-Ellis Co., Western Tillage Equipment Co., and Kathleen Neihart.

Cooperative research plots at the Center were operated by Warren Kronstad, Patrick Hayes, Chris Mundt, and Russ Karow. Additionally, we are very thankful for the ever-present assistance from the Extension Service and SCS personnel in all counties of the region, and especially from Umatilla, Union, Sherman, Morrow, Gilliam, Wallowa, and Wasco Counties and from Columbia and Walla Walla Counties in Washington.

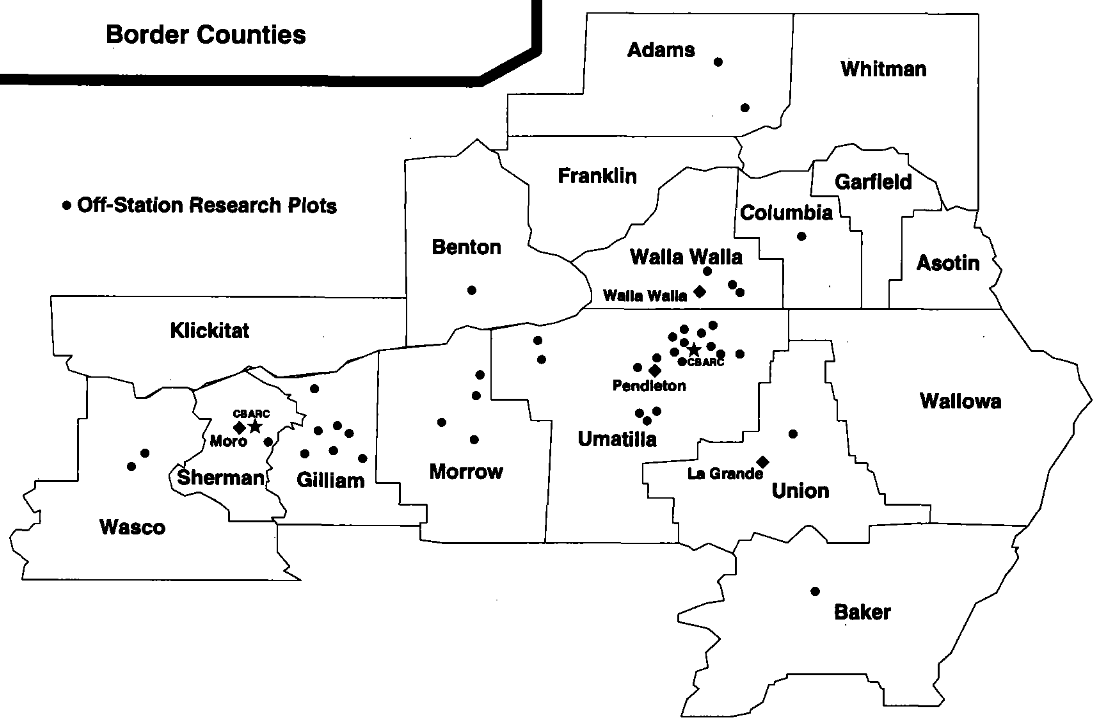
We truly appreciate the support and encouragement of growers, organizations, and businesses with a mission common to ours: to serve in the best manner possible the crop production needs of our region. We welcome your suggestions on how we may continue to improve our attempts to reach this goal.

Richard Smiley	Betty Klepper
Superintendent	Research Leader
OSU-CBARC	USDA-ARS-CPCRC

RESEARCH PLOT LOCATIONS

Eastern Oregon - Eastern Washington

Border Counties



ADAMS, WA
Harold Clinesmith
Don Wellsandt

BAKER, OR
Craig Ward

BENTON, WA
Greg Smith

COLUMBIA, WA
Eric and Elizabeth Thorn

GILLIAM, OR
Charlie Anderson
Steve Anderson
Richard Harper
Vince Hill
Jordan Maley
Jack Osterlund
Tom Rietmann
Van Rietmann
Henry Wilkins

MORROW, OR
Eric Anderson
Doug Drake
Frank Mader
Lyle Peck
Ken Turner

SHERMAN, OR
Don Miller
Sherman Station

UMATILLA, OR
Cliff Bracker
Berk Davis
Ted Gilliland
Greg Goad
Todd Goad
Doug Harper
Chuck Hemphill
Hermiston Station
Bob Johns
Pendleton Station
Clint Reeder
Paul Reeder
Leon Reese
Sherman Reese
Jeff Shaw
Jerry Simpson
Joe Temple
Jim Williams

UNION, OR
John Cuthbert
Steve Galloway

WALLA WALLA, WA
Jay DeWitt
J. Nowogroski

WASCO, OR
Fred Schrieber
Buck Underhill

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AUTHOR AFFILIATIONS

Albrecht, Stephan L., Soil Microbiologist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Ball, Daniel A., Assistant Professor, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Collins, Harold P., Microbiologist, Michigan State University, WK Kellogg Biological Station, Hickory Corners, Michigan

Darnell, Tom, Umatilla County Extension Agent, Oregon State University, Milton-Freewater, Oregon

Douglas, Clyde L. Jr., Soil Scientist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Goller, Roger H., Biological Technician, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Jacobson, Erling, Biological Science Research Technician, Columbia Basin Agricultural Research Center, Oregon State University, Moro, Oregon

Klepper, Betty, Research Leader and Supervisory Plant Physiologist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Karow, Russ, Associate Professor and Extension Cereal Specialist, Department of Crop and Soil Science, Oregon State University, Corvallis, Oregon

Ott, Sandra, Biological Science Research Technician, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Patterson, Lisa, Faculty Research Assistant, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Rasmussen, Paul E., Soil Scientist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Rhinhart, Karl E., Faculty Research Assistant, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Rickman, Ronald W., Soil Scientist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Ruddenklau, Helle, Faculty Research Assistant, Department of Crop and Soil Science, Oregon State University, Corvallis, Oregon

Smiley, Richard W., Superintendent and Professor, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Tuck, Brian, Sherman County Extension Agent, Oregon State University, Moro, Oregon

Sutherland, David L., Faculty Research Assistant, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Uddin, Wakar, Research Technician III, Extension Plant Pathology, University of Georgia, Athens, Georgia

Walenta, Darrin L., Faculty Research Assistant, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Wilkins, Dale E., Agricultural Engineer, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Wysocki, Don, Associate Professor, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Zuzel, John F., Hydrologist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Zwer, Pamela K., Assistant Professor, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

LONG-TERM EXPERIMENTS AT THE PENDLETON AGRICULTURAL RESEARCH CENTER

P. E. Rasmussen and R. W. Smiley

The Pendleton Agricultural Research Center has several ongoing long-term experimental sites. The earliest was started in 1931, the latest in 1982. The earliest experiments are among the oldest replicated research experiments in the western United States. All have a documented history of crop variety, tillage, date of seeding, fertilizer use, and grain yield. The studies are representative of most of the cropping systems in the Pacific Northwest intermountain cereal region that receives less than 18 inches of precipitation. All research activities on the long-term experiments are presently monitored by an oversight committee consisting of four members from Oregon and one each from Washington and Idaho. The long-term experiments and their date of initiation are shown in Table 1. The location of experiments is shown on an aerial view of the station (Fig. 1). Details of experimental design and treatment history are described under their appropriate headings.

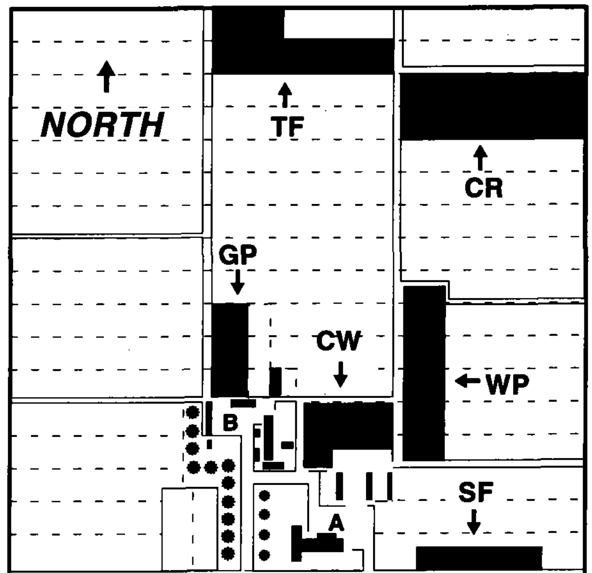

Figure 1. Location of long-term plots on Pendleton Agricultural Research Center property.
A. USDA-ARS facilities.
B. OSU facilities.

Table 1. Long-term research sites at Pendleton.

Initiated	Symbol	Name	Variables
1931	GP	Grass Pasture	None
1931	CW	Continuous Cereal	None
1931	CR	Residue Management	Nitrogen, Manure, Burning, Pea Vines
1940	TF	Tillage-Fertility	Tillage, Nitrogen
1963	WP	Wheat-Pea	Tillage
1982	SF	No-till Wheat	Nitrogen

DESCRIPTION OF EXPERIMENTS

Grass Pasture (GP):

This site contains no experimental variables, but has been maintained since 1931. It approximates near-virgin grassland and serves as a base-line for evaluating changes in the other systems. It is periodically reseeded with introduced-grass selections, occasionally fertilized, and infrequently irrigated. The dominant grass species is tall fescue *(Festuca arundinacea* Scheeber) with lesser amounts of bulbous bluegrass (*Poa bulbosa* L.), green foxtail (*Setina viridis* (L.) P. Beauv.) and yellow foxtail (S. *pumila* (Poiret) Roemer & Schultes). This site received limited grazing from 1931 to 1985. It has not been grazed since, but vegetation is clipped once or twice during summer growth.

Continuous Cereal (CW):

This experiment was established in 1931 and cropped annually to winter wheat (*Triticum aestivum* L.) from 1931 to 1982. The site was modified in 1982 to accommodate winter wheat, spring wheat, and spring barley, each grown every year in the same location. The site is conventionally tilled (moldboard plowed), and receives both chemical and mechanical weed control. The original experiment consisted of eight plots, each 38 x 284 feet, with no replication. The eight plots received different N fertilization (0 to 150 lb N acre^{-1} yr^{-1}) from 1943 to 1951. No fertilizer was applied from 1952 to 1959, and 80 lb N acre^{-1} has been uniformly applied to the entire area since 1960. The experiment has periodically received P and S fertilization since 1982. The N rates created a difference in soil pH (1:2 soil:0.01 *M* $CaCl_2$) that ranges from 5.2 for low N to 4.6 for high N. This site currently serves as a cereal monoculture baseline for comparing changes in crop rotation systems.

Table 2. Treatment history of the residue management (CR) experiment at Pendleton.

TRT NO.	ORGANIC-N ADDITION	1931-66		1967-78		1979 +	
		RT[a]	N[b]	RT	N	RT	N
1	---	--	--	--	--	--	--
2	---	FD	0	NB	40	SB	40
3	---	SD	0	NB	80	SB	80
4	---	NB	30	NB	40	NB	40
5	---	NB	30	NB	80	NB	80
6	---	FB	0	FB	0	FB	0
7	---	SB	0	SB	0	SB	0
8	MANURE[c]	NB	0	NB	0	NB	0
9	PEA VINES[d]	NB	0	NB	0	NB	0
10	---	NB		NB	0	NB	0

a Residue treatment: FD = fall disk, SD = spring disk, NB = no burn, FB = fall burn, SB = spring burn.

b Nitrogen rate (lb acre^{-1} crop^{-1}); applied early October of crop year.

c Manure = 10 tons acre^{-1} crop^{-1} wet wt; 50.8% dry matter; 1322 lbs C and 99 lbs N acre^{-1} crop^{-1}; applied in late March of fallow year.

d Pea Vines = 1 ton acre^{-1} crop^{-1}, 89.7% dry matter; 708 lbs C and 30 lbs N acre^{-1} crop^{-1}; applied in late March of fallow year

Residue Management (CR):

This is the most comprehensive of the long-term experiments. It was established in 1931 and has had only two major revisions (1967, 1979). The rotation is winter wheat/fallow and the tillage is conventional (moldboard plow). The experimental design is an ordered block consisting of nine treatments (10 originally) and two replications. The experiment contains duplicate sets of experiments that are offset by 1 year so that data can be obtained annually. Plot size is 38 x 132 feet. Treatment history is shown in Table 2. Spring burns are implemented and organic amendments applied in the spring of the fallow year (late March - early April). All plots are then plowed 8 inches deep and smoothed with a field cultivator. Weeds are controlled by tillage during the fallow phase and with herbicides during the crop phase. Nitrogen fertilizer is applied 5-15 days prior to seeding of wheat.

The C and N content of the upper 24 inches of soil has been determined about every 10 years (1931, 1941, 1951, 1964, 1976, and 1986). Straw yield, grain, and straw N content, and the nutrient content of organic amendments have been determined since 1977. Straw yield and nutrient uptake from 1931 to 1976 has been estimated by utilizing variety-trial data coupled with periodic measurements in this experiment.

Tillage-Fertility (TF):

These plots were established in 1940 and have had major revisions in 1952, 1962, and 1988. The rotation is winter wheat/fallow. This experiment has only one set of plots, thus yield is obtained only in odd years. The experimental design is a randomized block split-plot, with three replications. Main plots consist of three primary tillage systems (moldboard plow, offset disk, and subsurface sweep) and subplots of six fertility levels (currently, N rates from 0 to 160 lb N acre^{-1} in 40 lb increments, with one duplication) (Table 3). Individual plot size is 18 x 132 feet. Primary tillage is performed in April. Secondary tillage and other cultural operations are the same for all treatments. All plots are smoothed 4-6 inches deep with a field cultivator and harrow following primary tillage. They are then rodweeded four to five times between April and October to control weeds and maintain seed zone moisture. Nitrogen fertilizer is applied about October 1 and winter wheat seeded about October 10. Nitrogen was broadcast as ammonium nitrate (21-0-0-24S) from 1963 to 1987, and thereafter as urea-ammonium nitrate (32-0-0 solution) shanked 6 inches deep with 10-inch band spacing. The experiment relies on both mechanical and chemical weed control, but the stubble mulch treatments have occasionally received extra chemical treatment when grassy weeds have been a problem.

The replicates differ in soil depth by virtue of landscape position. Replicate 1 (6.9 ± 0.3 feet deep) is located on a north-facing 3 percent back slope, Replicate 2 (4.4 ± 0.8 feet) on east-west facing foot slopes of 0 to 2 percent, and Replicate 3 (3.7 ± 0.3 feet deep) on an east-facing 2 percent back slope. Medium-tall soft white winter wheat was grown from 1940 to 1962, and semi-dwarf soft white winter wheat since. Straw yield and grain and straw N content have been determined since 1977. Soil N, C, and pH were determined in 1984 in 3-inch increments to a depth of 12 inches.

Wheat/Pea (WP):

This experiment was established in 1963, with modifications in 1972, 1976, and 1989. Crop rotation is winter wheat/pea. The experimental design is a randomized block with four replications. Each replication contains eight plots (four treatments duplicated within each replication). Duplicate treatments allow yearly data collection for both wheat and peas. Individual plot size is 24 x 120 feet. Tillage intensity ranges from maximal- to minimal-inversion of crop residue. The current tillage treatments are (1) fall roto-till, (2) fall plow, (3) spring plow, and (4) minimum-tillage (Table 4). Semidwarf soft white winter wheat is seeded after October 10 whenever soil moisture is sufficient for germination and early crop growth. Peas are seeded in late March or early April, and harvested in June or July. The type of peas grown was changed from fresh-green processing to dry-edible seed in 1989. From 1963 to 1988, wheat received 40-80 lb N $acre^{-1}$ as ammonium nitrate (34-0-0) broadcast prior to seeding. Since 1989, each wheat plot

Table 3. Treatment history of the tillage-fertility (TF) experiment at Pendleton.

PRIMARY TILLAGE SYMBOL	TYPE	TILLAGE DEPTH	RESIDUE COVER AT SEEDING (%)
		(inches)	
MP	MOLDBOARD PLOW	9	7
DI	ONEWAY DISK	6	34
SW	SUBSURFACE SWEEP	6	43

TREATMENT		NITROGEN RATE (lb $acre^{-1}crop^{-1}$)			
NO.	SYMBOL	1941-52	1953-62	1963-88	1989 +
1	40-	0	0	40	0
2	40+	10	30	40	40
3	80-	0	0	80	80
4	80+	10	30	80	80
5	120+	10	30	120	120
6	160+	10	30	160	160

Nitrogen applied as ammonium sulfate from 1941-1962, ammonium nitrate from 1963-1988, and urea-ammonium nitrate since 1989. Nitrogen broadcast from 1941-1988, and banded 6 inches deep with 10 inch row spacing since 1989. Nitrogen applied 7-14 days prior to seeding. Treatments with a minus symbol have no history of sulfur application.

Table 4. Treatment history of the wheat/pea (WP) experiment at Pendleton 1989-94.

TREATMENT NO.	TILLAGE
1	Maximum tillage (rototill)
2	Normal tillage (fall plow)
3	Normal tillage (spring plow)
4	No-till

receives 20 lb N acre^{-1} as 16-20-0-14S; one half then receives 80 lb N acre^{-1} and the other half receives no additional N. Nitrogen application reverses in succeeding wheat crops, with the half receiving 80-N for one crop receiving no additional N two years later. Peas traditionally receive 20 lb N acre^{-1} as either ammonium sulfate (21-0-0-24S) or ammonium phosphate-sulfate (16-20-0-14S) broadcast every second pea crop. The east half of the experiment received 1,800 lb lime acre^{-1} in 1976. A 24 x 24 foot area on the western edge of certain plots was fumigated in the early 1980s.

No-Till Wheat (SF):

This experiment was established in 1982 and modified in 1983 and 1988. The initial crop rotation was winter wheat/spring wheat, but this was changed in 1988 to winter wheat/fallow. The experimental design consists of 10 treatments and four replications. Original treatments consisted of two sets of five N rates (0, 50, 100, and 150 lb N acre^{-1} banded below seed, and 100 lb N acre^{-1} surface (Sep. broadcast) (Table 5). It included a

Table 5. Treatment history for the SF No-till experiment at Pendleton.

Treatment no.	1982-1988		1990-1992		1994-	
	N Rate[a]	Stubble Burned	N Rate[a]	Seeding Date	N Rate	Seeding Date
	lb/ac		lb/ac	month	lb/ac	month
1	0	no	0	Sep	0	Sep
2	0	yes	0	Oct	0	Oct
3	50	no	50	Sep	40	Sep
4	50	yes	50	Oct	40	Oct
5	100	no	100	Sep	80	Sep
6	100	yes	100	Oct	80	Oct
7	150	no	150	Sep	160	Sep
8	150	yes	150	Oct	160	Oct
9	100bc	no	100bc	Sep	120	Sep
10	100bc	yes	100bc	Oct	120	Oct

a bc = broadcast; all other N applications banded 2-inches below seed at seeding.

residue-burning variable from 1983 to 1988; straw was burned on one set of N plots and left standing on the other. The burning variable was discontinued in 1989 after conversion to a wheat/fallow rotation and dates of seeding10 and Oct. 10) superimposed upon the N rates. The broadcast N treatment was terminated in 1993 and N rates adjusted to align with those in other long-term experiments. Plot size is 8 x 100 feet. Tillage is strictly no-till, with no tillage other than for seeding and stubble flailing. Herbicides are used to control weeds in both fallow and crop. This experiment was implemented to evaluate N fertilizer effects on crop yield and soil quality under no-till cropping.

Scope of Research on Long-Term Experiments:

Grain yield is determined on all plots each year. In recent years, straw yield and nutrient uptake have also been determined. Total N and C (organic matter) in soil are determined periodically. Studies of biological diversity, microbial dynamics, and microbial biomass were conducted from 1988-1991. Effects of long-term management practices on soil-borne plant diseases were investigated from 1988-1990. Weed seed ecology and persistence studies were initiated in 1991. Other research on the long-term experiments includes studies of silica movement, enzyme activity, and changes in physical properties of soil. The influence of stubble burning on wheat yield and soil properties is examined periodically. Tillage, soil depth, and precipitation effects on N fertilizer response and N utilization were determined in a tillage-fertility experiment. Studies of soil quality are presently in progress. Nutrient mineralization potentials and N release studies are being conducted. Sulfur and phosphorus adequacy and soil acidity-liming relations will be addressed in the near future, with some treatment modifications planned for 1995-1996.

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WHEAT DISEASES AND YIELD IN LONG-TERM AGRONOMIC EXPERIMENTS AT THE COLUMBIA BASIN AGRICULTURAL RESEARCH CENTER (PENDLETON)

Richard W. Smiley, Harold P. Collins, Paul E. Rasmussen, Wakar Uddin, Karl E.L. Rhinhart and Roger H. Goller

INTRODUCTION

Most information on effects of crop and soil management practices on diseases of winter wheat has been developed from short-term experiments. Effects of management variables in more-stabilized environments of long-term (>30 yr) experiments are generally not known. Five long-term experiments at the Columbia Basin Agricultural Research Center represent a unique agricultural resource. Three are among the 13 oldest active long-term agronomic studies in North America.

Diseases of winter wheat on the long-term experiments were evaluated for three years; 1989, 1990, and 1991. Cropping systems included annual winter wheat and wheat-pea and wheat-summer fallow rotations. Inversion and conservation tillage systems were examined in the wheat-pea and wheat-fallow rotations, and nitrogen fertilizer rates, organic amendments, and stubble burning were examined in a wheat-fallow rotation. Data were examined for relationships between diseases and soil organic carbon and N, soil pH, soil microbial biomass, and grain yield. Results averaged over the 3 years are presented in this report.

METHODS

Tests were conducted on Stephens winter wheat planted into a Walla Walla silt loam with pH values of 4.4-6.4.

Annual winter wheat. The continuous winter wheat experiment began in 1931. Nitrogen is currently applied at 80 lb/ac. Primary tillage is with a moldboard plow. Planting dates were Oct. 25, 1988, Oct. 25, 1989, and Nov. 10, 1990.

Wheat-pea rotation. A winter wheat-green pea rotation with four tillage treatments was initiated in 1963. Two treatments were sampled during this survey; conventional vs. conservation tillage. Conventional tillage consisted of moldboard plowing in the spring before planting peas and again in autumn before planting wheat. Conservation tillage consisted of wheat stubble busting before planting peas and shallow sweep tillage after pea harvest. Wheat and peas receive 70 and 20 lb N/ac, respectively, before planting. Planting dates were Oct. 25, 1988, Oct. 25, 1989, and Nov. 10, 1990.

Wheat-fallow rotation: residue management experiment. The crop residue management experiment was established in 1931 and includes duplicate, offset sets of treatments that allow winter wheat to be produced each year in a rotation with summer fallow. All treatments are moldboard plowed in the spring and rod-weeded during the summer. Planting dates were Oct. 25, 1988, Oct. 6, 1989, and Nov. 13, 1990. Eight treatments sampled for this survey included: no fertilizer applied since 1931; application of 40 or 80 lb N/ac/crop, with the 0, 40, and 80N treatments repeated except that the wheat stubble was burned in the spring; cow manure

(10 ton/ac/crop, averaging 100 lb N/ac) applied 1 to 6 days before plowing; and pea vines (1 ton/ac/crop, averaging 30 lb N/ac) applied 1 to 6 days before plowing.

Wheat-fallow rotation: tillage-fertility experiment. This experiment was established in a winter wheat-fallow rotation in 1940. Wheat is harvested in odd-numbered years. The experiment contains three tillage variables and six levels of N application. Tillage treatments include moldboard plow, offset disk, and subsurface sweeps. Fertilizer rates include 0, 40, 80, 120, and 160 lb N/ac. Planting dates were Oct. 10, 1988 and Oct. 11, 1990.

Disease survey. The experiments were sampled each spring (April-May). Disease parameters included the incidence (percent of plants or plant parts affected) and/or severity of Rhizoctonia root rot, Pythium root rot, take-all, strawbreaker foot rot, and Fusarium crown rot.

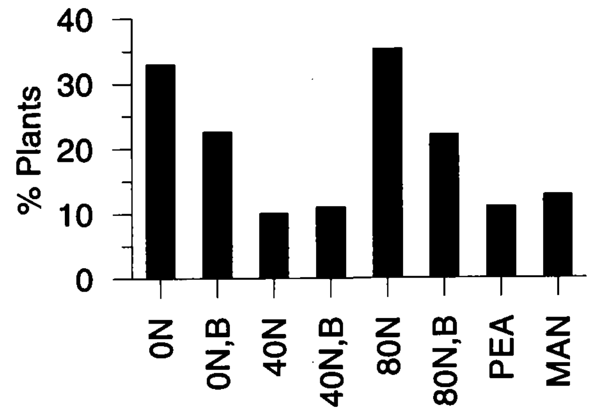

Figure 1. Percentage of wheat plants with severe Rhizoctonia root rot (3-yr means) in the residue management experiment in a wheat-fallow rotation; treatments are described in Table 1.

RESULTS

Environmental conditions. Two of the winters (crop years 1990 and 1991) were significantly drier than normal, and one (1989) was wetter than normal. Autumn precipitation was always below the long-term mean and spring precipitation was always above the mean. The winter and spring of 1990-1991 were colder than for other years.

Rhizoctonia root rot. Rhizoctonia root rot was present on most plants each year (Table 1). It was most prevalent and severe during the driest years, particularly those that were dry during the autumn and winter, but not spring. Disease incidence was not affected by tillage or stubble burning, but was higher with inorganic nitrogen compared to pea vines or manure. The percentage of plants with severe root rot was higher with 80 lb N/ac than with 40 lb N/ac, pea vines, or manure (Figure 1). Stubble burning reduced root rot severity when disease was most intense (0 and 80 lb N/ac) in the 3-year mean (Figure 1), but this was related solely to a response to burning during the wettest year (1989). Root rot was more severe in the wheat-fallow rotation than in the wheat-pea rotation or annual winter wheat with equal nitrogen fertilization (Figure 2 and 3).

Severity of Rhizoctonia root rot in the tillage-fertility experiment during 1989 was lower in plow and disk tillage than in the sweep treatment. Root rot was more severe at N application rates of 80-160 than at 0-40 lb N/ac in the disk and sweep treatments, but not with moldboard plowing.

Pythium root rot. Yearly incidence of Pythium root rot did not differ in any of the experiments except annual wheat, where root rot was more prevalent in 1990 than 1991. In the residue management experiment, Pythium root rot was highest in treatments with

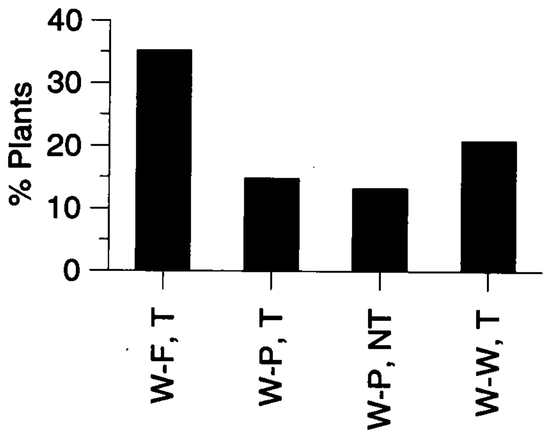

Figure 2. Percentage of wheat plants with severe Rhizoctonia root rot (3-yr means) in three long-term experiments either tilled (T) by moldboard plow, or minimum tilled (NT); W-F = wheat-fallow rotation (80 lb N/ac), W-P = wheat-pea rotation, W-W = annual winter wheat.

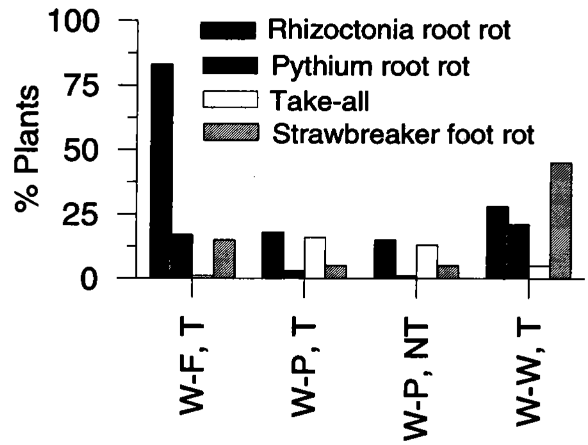

Figure 3. Percentage of wheat plants with symptoms of four diseases (3-yr means) in three long-term experiments either tilled (T) by moldboard plow, or minimum tilled (NT); W-F = wheat-fallow rotation (80 lb N/ac), W-P = wheat-pea rotation, W-W = annual winter wheat.

inorganic N fertilizer, and lowest in unfertilized and organically amended treatments (Table 1). Burning the stubble had no effect on incidence of Pythium root rot. Pythium root rot was more prevalent in annual wheat and wheat-fallow rotation than in a wheat-pea rotation (Figure 3).

Take-all. Incidence of take-all was low in the residue management experiment (Table 1), with the exception of a high incidence in the stubble-burn 80N treatment in the 1989 crop. The 1989 crop experienced the wettest autumn and winter of the three years surveyed. Take-all was generally more pronounced in the wheat-pea rotation than in annual wheat or the wheat-fallow rotation (Table 1 and Figure 3).

Strawbreaker foot rot. Disease incidence in the residue management experiment was highly dependent on weather and crop management (Table 1). Strawbreaker foot rot was more prevalent during the wettest (1989 and 1991) than driest (1990) spring periods. Foot rot was significantly greater in burned than unburned treatments during 1989 (wettest crop year) and 1991 (wettest spring), but not during 1990 (driest spring and crop year). Foot rot was consistently low in the unfertilized, unburned treatment, but increased significantly when N was applied.

Strawbreaker foot rot was much more prevalent in annual winter wheat than wheat-pea and wheat-fallow rotations (Table 1 and Figure 3). Foot rot in annual wheat was also more prevalent during the wettest crop year. The incidence of foot rot in the tillage-fertility experiment during 1989 was higher in plow than disk or sweep treatments. Increasing N application increased strawbreaker foot rot in all tillage systems. Whiteheads became more prevalent as the N rate increased.

Fusarium Crown rot. Discoloration and rotting of sub-crown internodes and plant crowns was generally minor. Nevertheless,

Table 1. Wheat disease incidence[a] in the crop residue management, annual wheat, and wheat-pea rotation experiments at Pendleton; data are averaged for crops harvested in 1989, 1990 and 1991.

Treatment[b]	Rhizoctonia root rot[c]	Pythium root rot[c]	Take-all root rot[c]	Strawbreaker foot rot[d]	Fusarium crown rot[e]
Wheat-fallow rotation					
crop residue					
0N	63 bc	6 bc	<1 b	7 c	0
0N, burned	56 c	6 c	<1 b	15 ab	5
40N	82	13	<1	21	3
40N, burned	78	15	1	16	2
80N	83 a	17 a	<1 b	15 abc	2
80N, burned	73 ab	12 ab	7 a	24 a	0
pea vine	65 bc	5 c	3 b	12 a	0
manure	57 c	2 c	<1 b	23 ab	0
Wheat-pea rotation					
plowed	19	3	15	5	2
minimum till	14	1	12	6	4
Annual winter wheat	28	22	5	45	6

[a] Numbers followed by the same letter, within each column for each treatment, are not significantly different (P=0.05) according to the Student-Neuman-Kuels test.

[b] Application rate for inorganic nitrogen fertilizer (0, 40, or 80 lb N/ac), pea vines (1 ton/ac), or cow manure (10 ton/ac), and either burning or not burning stubble from the previous wheat crop.

[c] Percentage of seminal and coronal root main axes with symptoms of Rhizoctonia root rot, Pythium root rot, or take-all (ratings of 0.1-0.4 were listed as <1).

[d] Percentage of culms with strawbreaker foot rot lesions.

[e] Percentage of plants with dark-brown subcrown internode lesions caused mostly by Fusarium graminearum but including other Fusarium spp. and Bipolaris sorokiniana.

[f] Multiple range separations are not applicable to 40N treatments, for which only two years of data were collected.

crown rot was more prevalent in annual wheat than in wheat-pea rotation or comparable wheat-fallow rotation (Table 1). The disease was most important during the season with the wettest, coolest spring. Fusarium crown rot caused whiteheads in the tillage-fertility experiment during 1991, with intensity significantly affected by both N and tillage. More heads died prematurely with increasing N rate; 4, 5, 6, 10, and 9 percent of heads for 0, 40, 80, 120, and 160 lb N/ac. Disease was more prevalent with higher surface residue (4, 8, and 8 percent whiteheads for plow, sweep, and disc treatments).

Overall wheat health. The most common management system for the region (80 lb N/ac and stubble incorporated by

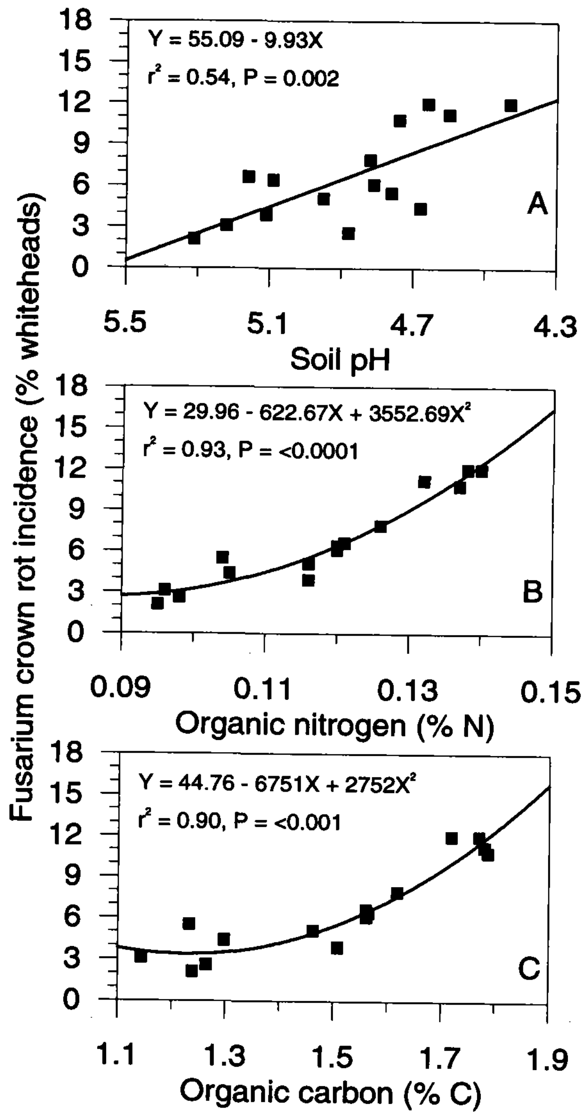

Figure 4. Relationship of soil pH (A), soil organic nitrogen (B), and soil carbon (C) to incidence of Fusarium crown rot in 1989. Wheat-fallow tillage-fertility experiment; treatments are described in Table 2.

moldboard plowing) generally had the highest prevalence of disease. Burning stubble did not affect overall incidence of diseases present. Diseases were collectively least prevalent where no N was applied or when pea vines or manure were the only source of added nutrition in the wheat-fallow rotation. The collective spectrum of diseases was less in wheat-pea rotation than in wheat monoculture, either annually or in wheat-fallow rotation.

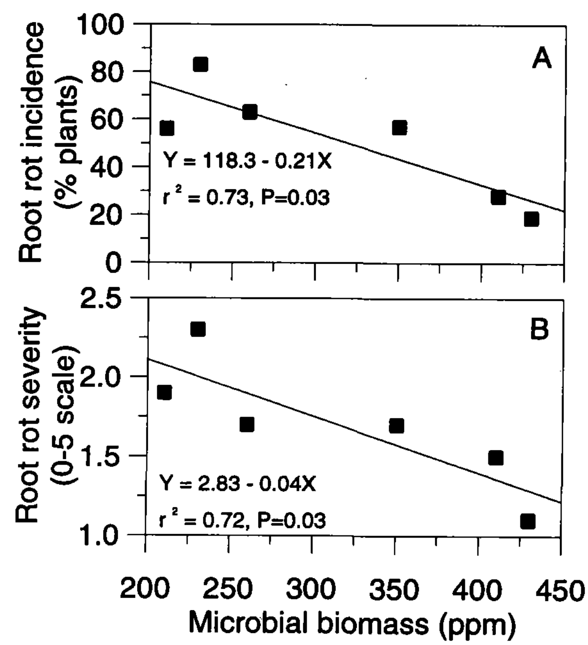

Figure 5. Relationship of soil microbial biomass in 1988 to severity of Rhizoctonia root rot (3-yr mean) on wheat seminal roots; wheat-fallow, wheat-pea, and annual winter wheat experiments.

Relationships Between Diseases and Soil Chemical Properties. Soil pH (in 0.01 M $CaCl_2$) in the tillage-fertility experiment varied from 4.6 to 5.2, and was inversely proportional to the rate of applied N. Soil pH was also inversely proportional to dryland root rot during 1991 (Figure 4A) and to percentages of tillers with strawbreaker foot rot during 1989. Organic N (Figure 4B) and carbon (Figure 4C) were directly proportional to percentages of whiteheads caused by Fusarium crown rot, but only because organic N and C were higher with higher N rates that increased late-season drought stress in wheat. Microbial biomass was inversely correlated with incidence and severity of Rhizoctonia root rot (Figure 5).

Wheat Yield. Grain yields in the crop residue experiment (Table 2) were approximately proportional to the amount of N added

Table 2. Wheat grain yields[a] in long-term plots at Pendleton; data are the average for 1989, 1990 and 1991 except for the tillage x fertility experiment (1989 and 1991)

Experiment and treatment	Yield (bu/ac)	Experiment and treatment		Yield (bu/ac)
Wheat-fallow rotation; crop residue		Wheat-fallow rotation: tillage-fertility		
0N	49 e	Plow:	0N	59 c
0N, burned	47 e		40N	76 b
40N	77 cd		80N	92 a
40N, burned	72 d		120N	87 a
80N	94 b		160N	96 a
80N, burned	85 bc	Sweep:	0N	54 c
pea vine	73 d		40N	70 b
manure	106 a		80N	81 a
			120N	79 a
Wheat-pea rotation			160N	78 ab
tilled	85	Disk:	0N	60 c
minimum till	77		40N	78 b
			80N	86 ab
Annual winter wheat	63		120N	90 a
			160N	87 ab

[a] Yields followed by the same letter, within each column for each experiment, are not significantly different (P=0.05) according to the Student-Neuman-Kuels test.

from organic or inorganic sources. Highest yields always occurred in the manure treatment, which supplied the highest rate of N. Application of inorganic N increased grain yield; mean yields for 0, 40, and 80 lbs N/ac were 48, 74, and 90 bu/ac, respectively ($LSD_{0.05}$=2). The effect of burning was significant, with yields higher in unburned than burned plots (means of 73 vs. 68 bu/ac; $LSD_{0.05}$=2).

Wheat in the wheat-pea rotation always yielded higher than annual wheat. Tillage influenced yield in the wheat-pea rotation only in 1991, the wettest year of the three years; yields were 91 and 76 bu/ac in plowed and minimum-till treatments, respectively.

In the tillage-fertility study, moldboard plowing produced higher yield (73 bu/ac) than disk (71 bu/ac) or sweep (64 bu/ac) tillage ($LSD_{0.05}$=7.0). Yield for the 0N (51 bu/ac) and 40N (66 bu/ac) rates were lower than those for 80, 120, and 160N (76-77 bu/ac)($LSD_{0.05}$=3). Tillage did not significantly affect yield at the 80N rate, which approximates commercial practice in the area.

Wheat yield was inversely correlated with both soil pH and incidence of strawbreaker foot rot during 1989 (increasing N rate = lower pH = greater foot rot and lower yield), but was not correlated with whiteheads caused by Fusarium crown rot during 1991.

Table 3. Synopsis of management and seasonal precipitation effects on grain yield and principal diseases occurring in long-term annual wheat and wheat/fallow (W/F) and wheat/pea (W/P) rotations (stubble burning caused variable or no effect for all diseases).

Disease	Common symptoms	Highest incidence and severity	Lowest incidence and severity
Rhizoctonia root rot	brown root rot; roots severed or missing; stunting; delayed maturity	driest season high rate of inorg. N W/F rotation sweep tillage low microbial population	wettest season organic N W/P or annual wheat plow or disk
Pythium root rot	brown root rot; roots severed or missing; stunting; delayed maturity	driest season inorganic N W/F or annual wheat	wettest season organic N W/P rotation
Take-all	blackened roots or blackened root cylinder; stunting; whiteheads	wettest season W/P rotation	driest season W/F or annual wheat
Strawbreaker foot rot	lesions in central culm, near base of stem; whiteheads	wettest spring highest N rates annual wheat plow low soil pH	driest spring lowest N rates W/F or W/P disk or sweep
Fusarium crown rot	brown dry rot of crown or subcrown internode; whiteheads	highest N rates annual wheat disk or sweep low soil pH	lowest N rates W/F or W/P plow
Overall wheat health		inorganic N W/F or annual wheat (esp. 80 lb N/ac with plowing)	organic N W/P rotation
Grain yield		wettest season stubble retained W/P rotation plow tillage	driest season stubble burned annual wheat sweep tillage

DISCUSSION

This survey of wheat diseases in long-term agronomic experiments provided unique insights into relationships between wheat diseases and crop and soil management (Table 3). Some relationships could not have been identified in any other way, and were the reverse of those expected based on short-term experiments.

Rhizoctonia root rot is generally considered to be most damaging in management systems that retain high amounts of residue at or near the soil surface. In this study, Rhizoctonia root rot was more severe with stubble mulch than with inversion tillage in the wheat-fallow rotation, but was unaffected by tillage in the wheat-pea rotation. This discrepancy appears related to the inverse correlation between microbial biomass and Rhizoctonia root rot. Likewise, relatively minor damage by Rhizoctonia root rot in annual winter wheat either indicates the presence of Rhizoctonia root rot decline (comparable to take-all decline), or the influence of plowing every year.

Burning the stubble did not affect Rhizoctonia root rot except in one instance. During the season with the wettest autumn and winter, burning reduced the incidence and severity of infected plants by 62-77 perdent. However, the value of this knowledge is limited since seasonal rainfall is unpredictable, burning stubble had no effect on Rhizoctonia root rot during the drier years, and the disease was more severe in dry than wet years.

Pythium root rot was less prevalent in a wheat-pea rotation than in wheat produced annually or rotated with fallow. Pythium root rot was much more prevalent when high rates of N were supplied by inorganic fertilizer compared to organic sources (pea vines or animal manure), possibly in response to soil acidified by inorganic N fertilizer. Suppression of Pythium root rot was associated with a combination of greater microbial biomass plus more diverse microbial species distribution in wheat-pea compared to annual wheat or wheat-fallow systems.

Pythium root rot did not increase with less intensive tillage in the wheat-pea rotation or decrease with stubble burning in the wheat-fallow rotation. This contrasts with reports from short-term experiments in eastern Washington, where disease was less damaging in tilled than untilled cropping systems, and when residue was burned rather than retained. Precipitation at the Washington site was 22 inches compared to 17 at Pendleton, and root rot was more severe in the Washington studies. Comparable amounts of straw were burned in each study, but the method of fallow differed. Plots at Pendleton were plowed and those in Washington were fallowed by using herbicides between wheat crops. It is possible that reduced microbial biomass and less diverse microbial composition in long-term burn treatments at Pendleton increased activity of *Pythium* species in a manner that negated advantages gained by reducing the *Pythium* population when straw was burned in the shorter-term experiments in Washington.

Take-all was most prevalent during the wettest year of this study, as was predicted from a vast literature base. However, it was surprising that take-all in the crop residue experiment became damaging only at the 80 lb N/ac rate where stubble was burned. Stubble burning typically either does not affect or slightly suppresses damage from take-all in short-term experiments. Repeated burning may have modified the microbial biomass and soil chemical and physical qualities of soil to the extent that microbial-host-parasite interactions were quite different than those in short-term investigations. For instance, soil crusting and depth of freezing may be greater after repeated burning than when residue is incorporated into the soil.

Take-all was higher in the wheat-pea rotation with more intensive tillage when spring rainfall was higher than normal, but not in other years. These results are opposite the relationship between tillage and take-all reported in eastern Washington, but consistent with many contradictory reports worldwide. Take-all was more prevalent in the wheat-pea rotation than in annual wheat or wheat-fallow rotation. "Take-all decline" presumably suppressed development of take-all in annual winter wheat. Survival and virulence of the pathogen appears to have been higher in wheat-pea than in wheat-fallow rotation. The pathogen survives as mycelium in infested straw and survives for longer periods in N-enriched than N-depleted environments.

Strawbreaker foot rot was most prevalent where one or more of the following criteria were met; stubble was burned, a high rate of N was applied, inversion tillage was practiced, wheat was produced annually, or the autumn and/or spring season was very wet. It is well known that development of strawbreaker foot rot is favored by cool, wet springs, early planting date, high N fertility, high humidity near the soil surface, presence of recurrent host crops, and an absence of surface residue. This appears to be the first report of an inverse relationship between strawbreaker foot rot and soil pH. Application of N fertilizer over the past 40 years is causing soil in the Pacific Northwest to become more acid. The rate of acidification depends on the rate of N applied, rainfall, and soil buffering. Soil pH values measured in this study (in 0.01 M $CaCl_2$) were as low as 4.6. Soil pH in $CaCl_2$ is traditionally 0.7 units lower than pH in water. Thus a pH of 4.6 in $CaCl_2$ would equal a pH of 5.3 in water. Wheat growth becomes impeded as soil pH (water values) become less than 5.3.

We do not know whether the foot rot pathogen survives longer in acid soils or is more virulent on wheat culms, or both. It is important to determine whether strawbreaker foot rot is an early biological indicator of reduced plant vitality, which may be measurable before low soil pH directly reduces plant growth and yield. If so, foot rot would be comparable to Cephalosporium stripe, which is considered an early indicator of acid soil stress on winter wheat.

The winter wheat-fallow system is generally considered to be more conducive to strawbreaker foot rot than annual crop systems, primarily because planting dates are earlier due to favorable soil moisture. In the present study, strawbreaker foot rot was more prevalent in annual wheat than in either of the rotations. A common planting date was used for each system in this study, and results were related directly to the frequency with which a susceptible host was planted.

Formation of whiteheads is the most conspicuous symptom of Fusarium crown rot, caused by *F. culmorum, F. graminearum*, or both. Whitehead counts indicate the effect of crown rot on grain yield. Whiteheads caused mostly by *F. graminearum* in this study increased in proportion to both the amount of surface residue and the rate of N applied. A direct relationship between increasing surface residue and pathogen damage has been reported in Australia. Crown rot caused by *F. culmorum* in eastern Washington also becomes more damaging with increasing rates of N fertilizer. Our results appear to be the first report of an inverse relationship between crown rot and soil pH. Long-term studies have established that N application is increasing soil C and N content while decreasing soil pH, which in turn affects disease incidence.

Fusarium crown rot in our study was most damaging in 1991, when the spring season was much wetter than the other two years. More recently, a high level of crown rot also coincided with a wet spring in 1993, although a cool, moist summer led to relatively few whiteheads. Moderate to severe crown rot is also present in early-planted wheat seedlings for the 1994 crop, which attempted to establish crowns in a prolonged (3 month) dry mulch overlying the moist seed zone. Very moist and very dry soils have each led to intense rotting of wheat crowns.

The terms "dryland root rot" and "dryland foot rot" are common names used only in the Pacific Northwest. "Crown rot" and "crown and root rot" are accepted international names for diseases caused by species of *Fusarium.* Crown and root rot caused by *F. graminearum* in Australia, Europe, and the northeastern Unites States is most common in regions where rainfall is abundant during the summer, when winter wheat plants are maturing. The disease causes most yield loss when plant water stress occurs between *F. culmorum* in eastern Washington is also most damaging when late-season or annual rainfall is low. Our observations indicate that this disease causes crown and root rot in wet as well as dry seasons in the Pacific Northwest. As such, crown rot is a more descriptive name and alleviates misperceptions associated with the term dryland root rot.

Annual winter wheat was affected more by crown rot than wheat rotated with fallow or peas. This was presumably a response to higher inoculum potentials in annual wheat compared to alternate year cropping. *F. graminearum* survives between susceptible-crops mostly as mycelium in infested wheat tissues. Crop rotation is recommended for reducing damage from crown rot caused by *F. graminearum* but not *F. culmorum.* These practices correspond to known differences in the duration of chlamydospore viability for these pathogens.

Rhizoctonia and Pythium root rots and take-all are now known to cause yield reductions once attributed to lower temperature, higher moisture, and phytotoxins from straw in conservation tillage systems. R.J. Cook (USDA-ARS, Pullman) devised a procedure to determine the relative importance of these root-infecting pathogens in different wheat production areas of North America. This was accomplished by examining the ratio of wheat yields in moldboard plow vs. yield in mulch tillage systems. When plotted against a precipitation-evaporation index, ratios above one occur in the driest regions and below one in the wettest regions. A yield ratio of 0.85 was reported for Pendleton. In the present study, the yield ratio was 0.91 in the wheat-pea rotation and 0.88 in the tillage-fertility experiment. Although yield was generally not correlated with individual diseases, the yield ratio suggests that soilborne pathogens restricted potential yield by 3 to 12 percent. At current wheat prices, this represents an annual reduction of potential income by $8 to $34 per acre. Better strategies are clearly needed for managing root, crown, and culm diseases of winter wheat.

WHEAT AND BARLEY DISEASES IN CONSERVATION CROPPING SYSTEMS

Richard Smiley and Lisa Patterson

INTRODUCTION

Small grain production systems in the semi-arid (<20-inch precipitation; winter dominant pattern) Pacific Northwest were developed to produce maximum economic returns. Farming systems evolved to produce high yields with minimal season-to-season risk. Soil erosion led to concern over sustainability of the soil and water resources. Farming systems are evolving to alleviate this concern and each component of each production system is being re-assessed to determine how change in one component affects the other components. Studies on biology of pathogens and control of diseases are important aspects of this process.

Foliar diseases were the first to be studied intensively in the Pacific Northwest. Rusts and smuts were given particular attention. Some continue to cause routine economic loss but most are generally of minor importance because integrated genetic, chemical, and cultural management practices have been developed to reduce their damage. Root- and crown-infecting fungi are now the primary constraints to yield. Nearly every root disease, soilborne pathogen, or nematode problem known to affect wheat is economically important somewhere in the region. Each of the diseases can be of local importance and requires continual oversight to protect the integrity of the wheat and barley industries. This is particularly challenging because combinations of climate, soils and precipitation are highly variable and strongly influence the damage potential from each disease. Thirty wheat and barley diseases are of specific concern in the Pacific Northwest. Management systems for selected diseases are summarized in this paper.

SMUT DISEASES

Smuts in the Pacific Northwest include common bunt (*Tilletia tritici*), dwarf bunt (*T. controversa*), flag smut (*Urocystis agropyri*), and loose smut (*Ustilago tritici* on wheat; *U. nuda* on barley). *Ustilago* species are disseminated as internal parasites of seed. Other smut fungi are external contaminants of seed and also survive as spores in soil.

Common bunt, flag smut, and loose smut pathogens infect seedlings before the coleoptile emerges from soil. The short time interval between planting and infection allows these diseases to be controlled with fungicide seed treatment. Resistant cultivars are available, but in the absence of chemical control, the pathogens have been notorious for their ability to develop virulent new races soon after each resistant cultivar was released. Control of these diseases was stabilized with combined use of resistant cultivars, fungicide seed treatment, and manipulation of planting dates to select soil temperatures least favorable for infection. Nevertheless, these diseases can become very damaging if growers plant a susceptible cultivar for several successive crops, without applying a fungicide seed treatment. Unfortunately, the excellent and inexpensive control of smuts by fungicides caused plant breeders to turn their attention to more cost-effective breeding objectives. Many cultivars released during the past decade are susceptible to all of the smuts. As a result, common bunt, flag smut, and loose smut occur on a few plants in many crops, presumably in response to widespread presence of the fungi and nonuniform application of the fungicide seed treatment. A constant vigil is required to assure that new races or fungicide-resistant strains of the pathogens do not circumvent currently available genetic resistance and fungicides.

Dwarf bunt, known locally as TCK smut, reduces yields and is responsible for restricted export of Pacific Northwest wheat to selected countries. The time and extent of soil cooling required for infection by *T. controversa* is greater than for *T. tritici*. The dwarf bunt pathogen therefore infects autumn-sown wheat seedlings during winter. Resistant cultivars are available, but have not been well-accepted by growers because yield potential is typically higher for susceptible than resistant cultivars during years when dwarf bunt is not severe. Fungicide seed treatments have not been effective, presumably because of the long time period between planting and infection. Dividend, a newly registered fungicide, is highly effective for controlling dwarf bunt.

RUST DISEASES

Rusts were among the first diseases recognized on wheat in the Pacific Northwest. Stripe rust (*Puccinia striiformis*), leaf rust (*P. recondita*), and stem rust (*P. graminis*) of wheat continue to cause losses. Stripe rust causes the greatest and most frequent damage in the region; by some estimates the disease becomes destructive in three of every four years. Stripe rust of barley is also expected to enter the region during 1994. Leaf rust is becoming increasingly important as a consequence of controlling stripe rust, increasing the intensity of wheat management, and increasing the area of irrigated wheat, which enhances the leaf rust pathogen's survival and spread. Stem rust becomes highly damaging in localities where crop maturation occurs during late summer, or during cool, moist summers that delay maturation.

Breeding for resistance to all three rust diseases has been a principal objective of plant breeding programs for many decades. Tremendous progress has been made but there is much left to be accomplished to meet challenges from the ever-evolving rust pathogens. A recent advance involves the use of genetic multi-lines and cultivar mixtures to slow the rate of rust deveopment. Application of the fungicides Bayleton or Tilt are required during severe outbreaks. Planting as late as practicable during autumn reduces time for exposure of plants to spore showers and also increases the time from harvest, thereby breaking the green bridge (an overlapping presence, or bridging, of green plant tissue, allowing transfer of the pathogen from a more mature living host to a seedling). The need to predict and manage rusts led to development of the MORECROP expert system (by Roland Line, USDA-ARS, Pullman), which integrates climate and cropping system variables to suggest control options for the most important diseases of winter and spring wheat in the Pacific Northwest.

VIRAL DISEASES

Barley yellow dwarf is the principal viral disease of small grains in the Pacific Northwest. Corn is an important over-summering host for the aphid vectors of this virus, and damage is increasing as areas of irrigated corn expand and as growers move winter wheat planting dates earlier to reduce the potential for soil erosion. The primary management procedures include monitoring and reporting aphid populations weekly for multiple sites across the region, controlling volunteer plants to break the green bridge, and planting as late as practicable during autumn to minimize exposure of young plants to high populations of aphids. Genetic tolerance is available but is very limited.

Wheat streak mosaic is vectored by the wheat curl mite and also causes periodic damage in some areas of the Pacific Northwest. Management practices rely mostly on eradication of volunteer wheat plants and planting late in the autumn to minimize exposure of young plants to high populations of the leaf curl mite.

FOLIAGE DISEASE OF UNKNOWN ETIOLOGY

Physiologic leaf spot is a wheat disease of unknown cause. In heavily affected fields it may kill much of the flag leaf and all older leaves. Physiologic leaf spot is often incorrectly diagnosed as Septoria leaf blotch or tan spot. Crop damage can be reduced by growing wheat cultivars with low to moderate susceptibility and by planting as late as possible. Wheat is more severely affected when grown annually than in wheat-fallow, wheat-pea, or other rotations. Fungicides do not reduce the severity of physiologic leaf spot.

CULM-INFECTING FOOTROT PATHOGENS

Eyespot *(Pseudocercosporella herpotrichoides)* is known locally as Cercosporella foot rot or strawbreaker foot rot and is highly damaging to winter but not spring wheat. The pathogen survives on residue from plants infected while alive. Spores are produced on residue at the soil surface and are splashed by rain onto culms of seedlings. Mild winters and cool, wet springs favor full development of eyespot. Crop management strategies have a strong influence on disease incidence, and time of planting is an especially important component of eyespot control. Late-autumn seeding dates reduce the size of plants during the autumn, which reduces the plant surface area and numbers of tillers exposed to infection. Early planting dates favor a dense crop canopy, and high humidity and longer wetting periods in the infection court at the base of the culm. Eyespot is typically less important in fields with minimum- or no-till management than inversion tillage, but it may still be very damaging in high-residue systems. Seedlings in high residue systems develop more slowly and are smaller during winter than seedlings in low-residue seedbeds planted at a comparable time. Two-year rotations of winter wheat and fallow are particularly conducive to eyespot in low-residue seedbeds. Tillage or soil disturbance in established crops during the spring also increases eyespot severity. Nitrogen application rates have little influence on eyespot. Wheat cultivars differ in tolerance to infection, and two cultivars (Madsen and Hyak) with moderately high resistance are available. Benzimidazole fungicides (Benlate, Mertect, or Topsin) have been used to reduce disease severity and increase yield for more than a decade. Strains of *P. herpotrichoides* with high tolerance to these fungicides emerged from the native fungus population. As a result, these fungicides are no longer effective in many fields where they have been applied five or more times.

Sharp eyespot (*Rhizoctonia cerealis*) also commonly occurs on small grains. It is difficult or impossible to distinguish the identity of sharp eyespot and eyespot without assistance of clinical diagnostic procedures. The importance and prevalence of sharp eyespot is currently being studied on eyespot-resistant cultivars. There is evidence suggesting that the incidence of sharp eyespot increases when a fungicide or eyespot-resistant cultivar is used to control eyespot. This could explain instances in which "eyespot" purportedly damaged eyespot-resistant cultivars, or where properly applied fungicides failed to control "eyespot" in fields where fungicide resistance is not documented.

ROOT-INFECTING PATHOGENS

Take-all (*Gaeumannomyces graminis* var. *tritici*) becomes acute in irrigated wheat and barley and causes chronic damage in nonirrigated fields where small grains are planted annually. The pathogen survives in infested crop debris and colonizes roots of young plants. Sources of genetic resistance are not available and variable results have been obtained by treatment of seeds with the fungicide Baytan.

Soil and crop management practices continue to be primary means for reducing damage from take-all. Rotations involving nonhosts such as annual legumes suppress take-all if grassy weeds are thoroughly controlled throughout the rotation. Deficiency of phosphorus and possibly other nutrients suppresses optimal root growth and predispose seedlings to infection. Fertilizer banded below the seed at planting allows plants growing in pathogen-infested soil to yield more grain than when fertilizer is applied in any other manner or time. Practices favoring root absorption of ammonium ions more than nitrate ions reduce damage from take-all in high rainfall sites and irrigated fields. Such practices include treating ammonium-supplying fertilizers with a nitrification inhibitor or a competitive inhibitor of nitrate absorption, such as a chloride salt. Maintenance of soil pH in the moderately acid range (5.0 to 5.5) reduces take-all without significantly reducing nutrient availability. Delayed planting in the autumn suppresses damage by the pathogen during the winter months and often allows plants to escape severe damage. Take-all becomes most severe in fields with large amounts of crop residue on or near the soil surface. Removing residue by deep inversion tillage or stubble burning reduces damage but is incompatible with techniques to control soil erosion. Frequent application of small amounts of water leads to a higher incidence and severity of take-all than infrequent application of larger volumes of water on irrigated fields. Take-all decline is a phenomenon that occurs in many but not all fields planted annually to wheat or barley. The term "decline" refers to a reduction in damage compared to the most severe expression of take-all, which typically occurs during the third, fourth, or fifth year. However, even if or when take-all decline develops, subsequent crops continue to suffer low to moderate damage and yield loss. More important, recognition and study of the take-all decline phenomenon led to strong interest among scientists to develop biological agents for controlling take-all. The reliability and efficacy of biocontrol agents is improving but none are commercially available.

Rhizoctonia root rot (*R. solani* and others) is a chronic disease of small grains and often constrains yield without causing visible symptoms in the crop canopy. An acute form called "bare patch" or "barley stunt" causes stunting, patchiness, and severe damage to grain yield. Barley is more severely affected than wheat, and spring plantings are often damaged more than autumn plantings. Even though most rotational crops are also susceptible to infection by *R. solani*, legumes, canola, and other non-cereal crops appear to reduce the inoculum potential. Strategies to reduce soil erosion are especially favorable to occurrence of Rhizoctonia root rot. The disease is typically most damaging in fields managed without tillage or with minimal tillage. Complete burial of infected roots, crowns, and straw reduces damage by allowing seedlings to become well-established before roots become heavily infected. Infections that sever root axes near the seed or crown are more damaging than those occurring further from the origin of the root axis. Root rot near the crown can be reduced by minimizing the amount of infested residue near the seed zone and soil surface. As with take-all, banding fertilizer directly below the seed at planting increases plant tolerance to infection. The disease is not adequately controlled by fungicides or genetic tolerance, but may be ameliorated by continuous cropping. Several soil-active herbicides, such as the sulfonylurea family, predispose wheat to more severe damage from root rot. Rhizoctonia root rot also becomes more severe when wheat or barley is planted several days after killing weeds and volunteer cereals, without intervening tillage, as compared to killing undesirable vegetation two or more weeks before planting, with or without tillage.

Diseases caused by *Pythium* are widespread and include seed rot, seedling damping off, and browning root rot. *P. ultimum* var. *sporangiiferum* and *P. irregulare* are the primary species causing root rot. They frequently infect so rapidly as to even enter the embryo of germinating seeds, and very young root tissues. Seed quality has a strong influence on susceptibility of seedlings to these diseases. Pythium root rot is difficult to diagnose and affected plants are easily confused with nitrogen-deficient plants. Soil fumigation and fungicides were used to define the importance of *Pythium* in regions where annual precipitation exceeds 16 inches. Root rot was particularly severe in fields under minimum- or no-till management, especially when cropped annually and seeded late. Crop rotation is not useful for controlling this disease. Fungicides are available for suppressing seed rot and damping off stages, but are less effective against root rot. Cultivars with potential for rapid replacement of damaged roots appear to possess a higher ability to withstand debilitation caused by *Pythium.*

ROOT-INFECTING VASCULAR PATHOGEN

Cephalosporium stripe (*C. gramineum*) causes severe damage to winter wheat, minor damage to winter barley, and does not damage spring-planted cereals. This disease is especially damaging during seasons when plants become large in the autumn and are then exposed to a very cold winter. Multiple freeze/thaw cycles in soil during winter and a high population of wireworms cause root injuries that enable *C. gramineum* to penetrate the vascular system of roots. Crop and soil management strategies have strong influence on severity of Cephalosporium stripe. Late-autumn planting dates reduce susceptibility to infection by restricting coronal root development prior to winter, but also delay plant development and reduce yield potential. The disease becomes severe in fields managed with the standard 2-year rotation of winter wheat and summer fallow. Since *C. gramineum* survives only in undecomposed wheat tissue colonized while the plant was living, a three-year rotation of a winter cereal, spring cereal, or legume, and summer fallow greatly reduces disease potential by limiting production of spores to only once in 3 years. Most inoculum of the fungus dies within 2 years, especially when infested straw is buried. Another effective control strategy in

2-year rotations is to reduce the amount of infected crop residue remaining near the soil surface. Deep burial by inversion tillage, burning, and eliminating susceptible grassy weeds from the crop rotation sequence are each effective, but may have a negative effect on soil sustainability. Infection of roots by *C. gramineum* may also be reduced in no-till systems that increase snow retention during winter. Additional snow depth insulates soil from extreme low temperatures and reduces the number and magnitude of freeze/thaw cycles in the root zone. Acidification of soil by nitrogen fertilizer contributes to the increasing importance of Cephalosporium stripe, possibly by enhancing pathogen survival and/or virulence. Fungicides have not proven reliable for controlling this disease. Sources of genetic resistance are known and attempts are being made to incorporate resistance into agronomically acceptable wheat cultivars. Commercial cultivars differ in tolerance to infection by *C. gramineum*, but reasons for these differences are not known.

NONSPECIFIC ROOT-, CROWN-, AND CULM-INFECTING PATHOGENS

A complex of nonspecialized pathogenic fungi cause severe damage to wheat and barley throughout the region. The complex includes but is not limited to *Fusarium culmorum*, *F. graminearum*, *F. avenaceum*, and *Bipolaris sorokiniana* (*Cochliobolus sativus*). Fusarium foot rot is caused by species of *Fusarium*, common root rot is caused by *B. sorokiniana*, and dryland foot rot is a nonspecific name for all of these pathogens. Each member of the complex is capable of infecting roots, subcrown internodes, scutella, crowns, culms, leaves, and heads, but prevailing environmental conditions in the Pacific Northwest usually restrict infections to subterranean plant tissues.

Members of the complex cause similar symptoms and it is difficult or impossible to determine the dominant member by visual inspection without clinical diagnostic procedures. Nevertheless, this distinction is important because the fungi vary in important aspects of survival, pathogenicity, geographic region of dominance, and response to genetic, chemical, and cultural control strategies. *F. graminearum* occurs throughout the region in irrigated as well as nonirrigated fields, and is dominant in the driest and warmest areas where the mean July daily high temperature is 88 °F or greater. *F. culmorum* is the principal pathogen where mean July daily high temperatures are less than 86 °F, and *F. avenaceum* is present throughout the region, but dominates only in the coolest, wettest areas. *B. sorokiniana* is also widely distributed, but causes severe damage only in localized areas that are not well defined. *B. sorokiniana* and one or more *Fusarium* species may co-exist as a complex in some fields and individual plants.

Fusarium foot rot is most damaging under conditions that cause plant water stress between anthesis and maturation. These conditions include early seeding dates, high nitrogen fertility, and high plant density. *F. culmorum* survives freely in soil as persistent chlamydospores. The principal infection sites for *F. culmorum* are the emerging crown roots and crown tissue wounded by emerging roots. Residue placement has little influence on the vertical distribution of chlamydospores in tilled soils. In contrast, *F. graminearum* persists mostly as mycelium in host debris. The abundance and placement of infested straw in the soil profile therefore influences the site of infection by this pathogen. The principal infection sites for this fungus are the crown and basal stem in high-residue systems, and the scutellum, subcrown internode, and lower crown in low-residue systems. Damage from *F. graminearum* is greater in high- than low-residue management systems, and the risk for increasing damage with high rates of nitrogen is increased in high- but not low-residue systems. Fungicides and genetic resistance are not available for suppressing Fusarium foot rot. Cultivars of winter wheat exhibit modest differences in tolerance and can be used to reduce damage in areas heavily influenced by this disease.

Common root rot was among the earliest root and crown rots described in the region but has not been investigated more recently. The disease is apparently more damaging to barley than wheat, to spring- than autumn-sown cereals, and to cereals cropped annually than in rotation with other crops or fallow. *B. sorokiniana* survives as spores in soil but can also be seedborne. Yield reductions occur when common root rot is severe, but damage assessments and knowledge of the geographic distribution are not available for the Pacific Northwest.

PARASITIC NEMATODES

Cereal cyst nematode (*Heterodera avenae*) occurs in several production regions. Yield of annual winter or spring wheat may be reduced 50 percent or more by *H. avenae*. Crop rotations of 2 or more years reduce the nematode population and maintain near-optimal wheat yields if grass weeds and volunteer cereals are eliminated from the rotation crop or fallow. Sources of genetic resistance are not available in wheat cultivars developed for the Pacific Northwest, and nematicides are not registered for commercial use on small grains.

Lesion nematode (*Pratylenchus thornei*) also damages wheat and barley, but little is known about its economic importance or management.

INTEGRATED MANAGEMENT STRATEGIES AND REMAINING CHALLENGES

Fundamental aspects of disease etiology and epidemiology remain unknown for many diseases and must be determined before more precise disease management recommendations can be developed.

Crop residue and soil management strategies have a strong influence on wheat and barley diseases in the semi-arid regions. High priority must be focused on controlling diseases favored by conservation cropping systems as well as smuts and rusts that require continual oversight. Root, crown, and culm diseases that may become highly damaging in minimum- or no-till cropping systems include Pythium root rot, Rhizoctonia root rot, and take-all. Cephalosporium stripe and Fusarium foot rot have a variable response to tillage systems, and eyespot and sharp eyespot often are more severe with inversion tillage. Stubble burning and/or inversion tillage are often effective for reducing disease risk, but are usually considered counter-productive to principals and practices for sustaining the soil, water, and air resources. Society is therefore mandating that these practices be minimized.

Many diseases are strongly influenced by planting or emergence date. Early planting is defined as a date that allows plants to develop tillers and crown roots before winter. Late planting is defined as a date that causes the plant to overwinter in the 3- to 4-leaf stage. Very late planting, or emergence, causes seedlings to emerge, or have less than three leaves during winter. Delayed emergence, as in "dusted in" seed during a dry autumn, is equivalent to late or very late planting. Diseases favored by early planting include barley yellow dwarf, Cephalosporium stripe, eyespot, flag smut, Fusarium foot rot, sharp eyespot, stripe rust, take-all, and wheat streak mosaic. Diseases favored by late planting include common bunt, dwarf bunt, Pythium root rot, Rhizoctonia root rot, and snow molds. Highly diverse climatic and edaphic conditions in the Pacific Northwest, and the many other production considerations faced by growers make it difficult to prepare recommendations for specific planting dates to control diseases and achieve maximum yield potential in each field or location. In general, late planting dates are usually unacceptable because they often lead to soil erosion and/or reduced grain yield, and early planting dates are unacceptable because they greatly increase the risk associated with diseases and insects.

Much of the winter wheat in the region is produced in a wheat-fallow rotation. Disease management programs would become much more efficient if rotations could be lengthened by introducing profitable alternative crops. Three-year rotations with a single winter wheat crop are more effective than 2-year rotations for reducing damage from diseases. However, climate, lack of adapted and profitable alternative crops, and economics of winter wheat production have restricted this option. Long rotations are generally unpopular because they reduce wheat acreage and farm income from the wheat price-support subsidy. Spring wheat or barley are occasionally planted annually, but are usually more prone to root rots than cereals rotated with fallow. Spring wheat following fallow or winter wheat generally produces half the yield attainable with winter wheat in a 2-year rotation with fallow.

Genetic resistance is available for smuts, rusts, eyespot, and physiologic leaf spot. Cultivars with limited tolerance are also available to reduce damage by Cephalosporium stripe and Fusarium foot rot. There is increasing interest in cultivar mixtures or multi-lines to reduce the rate of disease development. This approach to genetic diversification is particularly applicable to rusts and other foliar diseases caused by pathogens that sporulate abundantly on surfaces of infected hosts during the growing season. Mixtures have been used for several decades to balance high productivity with tolerance to winter damage; seed of cultivars featuring each attribute is mixed before planting. Further participation in international germplasm improvement programs will continue to supply new sources of genetic resistance to combat diseases, and description of wheat and barley genomes will enhance development of improved cultivars.

Foliar-applied fungicides are used on less than 10 percent of irrigated and non-irrigated wheat and barley produced in semi-arid regions of the Pacific Northwest. These applications consist mostly of Bayleton, Benlate, or Tilt applied as curative measures for rusts and eyespot. Applications are influenced by disease potential (incidence and severity of an existing infection), stage of plant growth, projected yield and grain price, fungicide cost, weather forecast, factors affecting method of application (wet soil, wind, rain, potential for drift from the target crop to crops on which there is no registration), and other considerations. Economic responses are almost always limited to a single fungicide application per crop; multiple applications are rare. Although introduction and acceptance of cultivars with improved tolerance or resistance is further reducing the need for foliar fungicides, profitable production of small grains on some fields may always require availability and periodic application of fungicides. Advances in control of insect and mite vectors will also assist in reducing severe occurrences of viral diseases.

Recent advances in chemical control of wheat and barley diseases have focused mostly on improvement of seed treatments. Before Vitavax was registered, winter wheat cultivars became susceptible to new races of smut fungi within 5 years after their release. During the past 20 years most seed has been treated with Vitavax alone or in combination with Apron, Imazalil, PCNB, Thiram, or others. Vitavax greatly stabilized wheat health and productivity throughout the region, in that resistance has not been broken on cultivars treated with this fungicide. It remains to be determined if this stability will continue in view of the recent release of smut-susceptible cultivars for the region. Registration of Dividend during 1994 will also increase options available to growers. Compared to Vitavax, Dividend improves seedling establishment especially in drier seedbeds, improves crop yield and spectrumof diseases controlled, and reduces the active ingredient application rate by 80-90 percent. Further tests are being conducted to more fully define potential uses and benefits for Dividend.

Finally, additional integration of all cropping systems information into computerized "expert" systems will continue to refine our understanding and control of complex interactions among hosts, environments, vectors, and pathogens. These advances will enable farmers and advisors to more skillfully customize crop management programs for individual fields.

EFFECT OF METHANOL APPLICATION ON CROPS IN EASTERN OREGON

S. L. Albrecht, C. L. Douglas, Jr.,
E. L. Klepper, P. E. Rasumssen,
R. W. Rickman, R. W. Smiley, D. E. Wilkins
and D. J. Wysocki.

INTRODUCTION

In the fall of 1992, Arthur Nonomura and Andrew Benson published a paper in the Proceedings of the National Academy of Science of the USA (Nonomura and Benson, 1992c) on the beneficial effects of methanol applications on certain crops. They reported that, in the hot, arid Arizona climate, applications of aqueous methanol solutions could dramatically boost plant growth and crop yield. They attributed the increased growth and yield to the action of methanol as a carbon nutrient and as an inhibitor of photorespiration (Benson and Nonomura, 1992; Nonomura and Benson, 1992a; Nonomura and Benson, 1992b). Nonomura has said, "We're not testing methanol as much as we're testing photorespiration. Our findings were consistent with inhibition of photorespiration." (Daines, 1994)

Nonomura and Benson noted that carbon assimilation, growth rates and yields are greatest under high temperatures and high solar radiation, and showed that reduced light could damage methanol treated plants. They claimed that the positive effects of a single application of methanol are long term. During their field trials, Nonomura and Benson observed rapid plant growth and, concerned about possible nutrient deficiencies induced by increased growth, supplemented their methanol solutions with nutrients (Nonomura and Benson, 1992c). They also reported that, because their methanol-treated plants matured sooner, the treated plants appeared to require less water. The implications for water conservation are important in areas of low rainfall, such as eastern Oregon. If methanol could reduce water requirements of wheat, it might allow growers the opportunity to eliminate the wheat/fallow rotation and adopt annual cropping.

Methanol, commonly called wood alcohol, is highly flammable, highly toxic, and is extremely dangerous if not handled properly. It is generally used as a solvent, a fuel or as antifreeze. In 1993 the Arizona Department of Agriculture persuaded the EPA to allow use of methanol as an unregulated plant nutrient.

Nonomura and Benson (1992c) reported phytotoxic effects after spraying with methanol concentrations greater than 50 percent. Nonomura (Daines, 1994) recommends conducting a "dose response curve" for each crop. He recommends spraying small plots with six concentrations of methanol, from 0 to 50 percent at 10 percent increments, and recording any observations of leaf damage.

Reports in scientific journals (Nonomura and Benson, 1992a, 1992b, 1992c) and the popular press (Mauney, 1993) of increased yield from methanol applications have generated significant interest in the agricultural community. Field trials were initiated to provide regional information to growers about the practicality of methanol application in the Pacific Northwest. The objective of the experiments was to compare plant growth and yield in methanol treated and non-treated plots.

EXPERIMENTAL

Trials were conducted at the Columbia Plateau Conservation Research Center, nine miles north of Pendleton, OR during the spring and summer of 1993. The soil type at the

Center is a Walla Walla silt loam. Four species, representing major dryland crops in eastern Oregon, were chosen for the trials: winter wheat (cv. Stephens), spring wheat (cv. Penawawa), peas (cv. Dual), and spring barley (cv. Steptoe). Methanol applications were scheduled to coincide with distinctive stages in the growth of the cereal grains, flag leaf emergence, late boot, and anthesis. The peas were sprayed at the same time as the winter wheat and their developmental stage (number of nodes) recorded. There was a three- to five-day window surrounding each projected spray date to allow application during times of maximum light and temperature. The winter wheat was sprayed with two methanol concentrations, 20 and 40 percent, while the barley, peas and spring wheat received only the 20 percent concentration. Triton X-100 was used as a surfactant or "wetter." However, the other additives (e.g. urea, micronutrients, and amino acids) present in Nonomura and Benson's formulations were omitted, so that the direct effects of methanol could be examined without the complications that may be caused by foliar application of fertilizer. The methanol solutions were applied with a CO_2 pressurized backpack sprayer equipped with a hand-held 8-foot boom fitted with flat-fan nozzles and operated at 35 psi. Leaves were sprayed to wetness with the appropriate methanol concentration. The rates were calculated to be 25 gallons/acre at flag leaf emergence, 35 gallons/acre at late boot, and 55 gallons/acre at anthesis. Peas were sprayed at the same time as the cereals, corresponding to the 6.5, 9.5, and 15 node growth stage. The experimental design was a randomized complete block with four replications. All crops received fertilizer applications consistent with recommended fertilization practices in eastern Oregon. Seeding rate, row spacing and pesticide treatments were uniform across each trial.

Unusually cool weather in the spring and early summer of 1993 prevented methanol applications during the high temperatures normally found at this time in eastern Oregon. However, methanol applications were always made in bright sunlight. As recommended by Dr. Nonomura, a "dose response curve" was generated for each crop. They consisted of six small plots for each cultivar; each plot was sprayed with 10 to 60 percent methanol in 10 percent increments.

During the growth of the crops, several measurements were made, including canopy temperature, single leaf temperature, stomatal conductance, and transpiration; and leaf, stem, and grain sugar content (winter wheat only). Photosynthetic rates were estimated by changes in pea leaf specific weight. At maturity several yield parameters were determined, including grain yield, total yield, and harvest index. Test weight, kernel weight, number of heads per square foot, and grain water content was measured for the cereals and a tenderometer value was determined for the peas.

RESULTS AND DISCUSSION

In contrast to the reports by Nonomura and Benson (1992c), no leaf toxicity or necrosis was observed on any crop with applications up to 60 percent methanol. An additional dose response curve, utilizing methanol concentrations of 60 to 90 percent in 10 percent increments, was conducted on the winter wheat and peas. The peas showed no damage even at methanol concentrations of 90 percent. However, the winter wheat showed some necrotic lesions at 80 percent and slightly more at 90 percent. It is not clear why plants grown in eastern Oregon should be less susceptible to methanol damage than plants grown in Arizona.

The amount of methanol solution suggested for use, 20 to 25 gallons per acre, was inadequate to cover the canopies as the crops matured. Fifty-five gallons per acre were required to provide sufficient solution to spray to leaf wetness at flowering. The non-aerial application of any chemical to grain fields late in the growing season is difficult. Most current management practices utilized by growers in the Pacific Northwest make the application of aqueous methanol at 55 gallons per acre impractical.

There were no visual differences among the treatments for any crop at any time during the growing season. The parameters measured during plant growth were not influenced by methanol treatment. The canopy temperature for winter wheat is shown in Table 1. Canopy temperature values for different methanol treatments are very similar. If methanol opens the stomates, as suggested by Nonomura and Benson (1992c), then a reduction in canopy temperature should be observed in the methanol-treated plants as a result of increased transpiration. Individual leaf temperature, conductance, and transpiration (Table 2) measurements did not show differences between treated and non-treated plants and are consistent with the canopy temperature measurements. If methanol applications can open stomates, as reported by Nonomura and Benson (1992c), this action may benefit a wilted plant in an irrigated agroecosystem. It would allow increased transpiration, the subsequent reduction of leaf temperatures, and possibly a concomitant increase in photosynthetic activity. However, the opening of closed stomates may not be advantageous for dryland wheat in the Pacific Northwest. Dryland wheat production in this area is limited by the amount of water available to the crop. The water can be used either to produce leaves during vegetative growth or for grain production after flowering.

Table 1. Canopy temperatures of winter wheat following methanol applications.

Treatments	Methanol Concentration 20%	Methanol Concentration 40%
Control	21.4 ± 0.4[1]	20.8 ± 0.8
FLA[2]	20.9 ± 0.4	21.4 ± 0.8
LA[3]	20.7 ± 0.8	20.7 ± 0.3
FL[4]	20.3 ± 0.7	20.7 ± 0.7
F[5]	20.4 ± 0.6	20.8 ± 0.7
L[6]	20.4 ± 0.4	20.4 ± 0.4
A[7]	20.2 ± 0.3	20.8 ± 0.9

[1] Degrees centigrade, mean ± standard deviation

[2] FLA -- Methanol applied after flag leaf emergence, late boot and flowering (3 applications)

[3] LA -- Methanol applied after late boot and flowering (2 applications)

[4] FL -- Methanol applied after flag leaf emergence and late boot (2 applications)

[5] F -- Methanol applied after flag leaf emergence (1 application)

[6] L -- Methanol applied after late boot (1 application)

[7] A -- Methanol applied after flowering (1 application)

If methanol applications opened stomates that were closed in the vegetative stage of growth by a drought stress then the water lost through the open stomates would not be present if needed for grain production, provided the drought stress was not eliminated by adequate rainfall.

To estimate changes in photosynthetic activity, the changes in leaf specific weight during the day (peas), and sugar concentrations (winter wheat leaves, stems, and heads), were made at differing times following methanol applications. Leaf specific weights, measured at two times after the third methanol application, are given in Table 3. No differences in

Table 2. Transpiration of Winter Wheat Plants after Methanol Application.

Treatments	Methanol Concentration 20%	40%
Control[1]	5.72 ± 0.96	6.13 ± 1.54
L[2]	4.40 ± 0.95[4]	5.44 ± 1.11
FL[3]	5.09 ± 1.81	5.26 ± 2.22

[1]Control plants were not sprayed with any formulation
[2]L -- Sprayed after late boot only
[3]FL -- Sprayed after late boot and flag leaf emergence
[4]$\mu g\ H_2O\ m^{-2}\ s^{-1}$, mean ± standard deviation

Table 3. Leaf Specific Weights[1] after 20% Methanol Application.

Treatments	1 Day After Application	6 Days After Application
Control[2]	584 ± 266[6]	941 ± 376
FLA[3]	558 ± 324	531 ± 235
LA[4]	565 ± 194	707 ± 428
A[5]	471 ± 64	698 ± 266

[1]Leaf specific weight is the difference in weight of dry leaf tissue taken during a diurnal period of high solar radiation.
[2]Control plants were not sprayed with any formulation
[3]FLA -- 20% methanol applied at flag leaf emergence, late boot & anthesis.
[4]LA -- 20% methanol applied at late boot and anthesis.
[5]A -- 20% methanol applied at anthesis
[6]$\mu g\ cm^{-2}$, mean ± standard deviation.

these parameters between treated and non-treated plants were found at any time. Daines (Daines, 1994) reports that J. Nishio at the University of Wyoming found that a 15 percent methanol solution stimulated photosynthetic rates in spinach and sugar beets. Our results differ from the findings of Nishio. The spring and summer of 1993 in eastern Oregon was one of the coolest and wettest in the past decade. These conditions undoubtedly contributed to lower than normal rates of photorespiration. If, as Nonomura claims, the action of methanol is only evident in high temperatures and water-stressed conditions, the full effect of any methanol applications made near Pendleton may not have been apparent in the 1993 crop year. However, if methanol is actually inhibiting photorespiration as suggested, then some increase in plant biomass should be expected, even at the temperatures found near Pendleton during the spring and summer 1993. Although this increase in biomass may not be as dramatic as in areas with higher mean temperatures, some increase should have been evident.

We found no significant differences in harvest index (Table 4), kernel weight, number of heads per square foot, or grain water content in any of the grain crops. Nor were there statistically significant differences among treatments for grain or pea yield, grain test weight, or pea tenderometer measurements. Usually the coefficient of variability was very low and uniform. There were some very slight yield increases associated with a few of the methanol treatments; however, the magnitude of the yield increase observed generally was not correlated to quantity of methanol applied. No deleterious effect of methanol applications was found. Over all treatments, grain yields averaged 108.14 ± 9.12 bu/ac for winter wheat, 42.88 ± 2.59 bu/ac for spring wheat, 5,221.61 ± 494.46 lb/ac for spring barley, and 6,141.56 ± 453.13 lb/ac for peas. Test weight averages of 58.34 ± 0.59, 62.0 ± 0.29 and 49.8 ± 0.52 lb/bu were found for winter wheat, spring wheat, and spring barley, respectively. Tenderometer values for the peas averaged 91.8 ± 3.73. While our findings do not support the research

Table 4. Harvest index[1] of spring cereals.

Treatments	Spring Wheat	Spring Barley
Control	0.473 ± 0.005	0.558 ± 0.010
FLA[2]	0.475 ± 0.006	0.544 ± 0.013
LA[3]	0.474 ± 0.009	0.557 ± 0.010
A[4]	0.481 ± 0.004	0.546 ± 0.007

[1]Harvest index is the dry weight of grain divided by the dry weight of all above ground material.
[2]FLA -- 20% methanol applied at flag leaf emergence, late boot & anthesis.
[3]LA -- 20% methanol applied at late boot and anthesis.
[4]A -- 20% methanol applied at anthesis

of Nonomura and Benson, they are consistent with reports from field experiments at other locations. Daines (Daines, 1994) reports that extensive field testing during 1993 year in California has shown that, under normal cultural practices, methanol sprays provided no benefit for warm-season vegetable production. In the Pacific Northwest under cooler conditions, experiments at the University of Idaho and Washington State University (Albrecht et al., 1994), and on-farm trials in eastern Oregon (Wysocki, 1993) showed no beneficial response to methanol applications. However, crops such as winter wheat may not be good candidates for methanol use because they typically put on much of their growth during the cool part of the season.

CONCLUSIONS

There was neither a beneficial nor a detrimental response to methanol applications in any of the crops tested near Pendleton in 1993. Our interpretation of the 1993 results is that methanol applications probably will not benefit growers in the Pacific Northwest.

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SULFONYLUREA HERBICIDE RESISTANCE IN THE COLUMBIA BASIN OF NORTHEASTERN OREGON

Daniel A. Ball and D. L. Walenta

INTRODUCTION

Since the introduction of the sulfonylurea class of herbicides in the mid-1980s, use of these compounds has increased dramatically in wheat production in the United States. The U.S. Department of Agriculture, National Agricultural Statistics Service estimates that sulfonylurea herbicides were applied to over 60 percent of the 825,000 harvested winter wheat acreage in Oregon in 1992, and over 50 percent of the 2 million acres of harvested winter wheat in Washington in 1992 (U.S.D.A. National Ag. Stat. Service, 1993). In addition, several products in the sulfonylurea class are used for weed control along right-of-ways such as roads, highways, railroads, and industrial sites. This group of compounds includes such currently available products as Glean, Finesse, Oust, Amber, Harmony Extra, Express, and Ally. The widespread use of these materials can be attributed to their high level of effectiveness against many common weeds, low rates of application per acre, low potential for crop injury, and extremely low toxicity to non-target organisms including humans.

However, several weed species have developed resistance to this group of compounds due to their widespread use, high level of effectiveness, and because this group of compounds has a very specific site of action in the plant. The sulfonylurea herbicides work by inhibiting a single enzyme, acetolactate synthase (ALS) which is involved in the biosynthesis of several branched chain amino acids used for building proteins in plants. Through repeated use of the sulfonylureas in the field, individual weeds have been selected with an altered ALS enzyme. The altered enzyme is not inhibited by the sulfonylurea herbicides, thereby conferring herbicide resistance to plants. Over a period of time this has resulted in the development of weed populations resistant to sulfonylurea herbicide. Resistance to the sulfonylurea class of herbicides has been reported in common weeds including kochia (*Kochia scoparia* L.), Russian thistle (*Salsola iberica*), and prickly lettuce (*Lactuca serriola* L.) in several states adjoining Oregon.

MATERIALS AND METHODS

In cooperation with DuPont Ag. Products Inc., a preliminary survey was conducted in May of 1993 to confirm the presence of sulfonylurea herbicide resistant kochia, Russian thistle, and prickly lettuce in the Columbia Basin counties of northeastern Oregon. Samples of kochia, Russian thistle, and prickly lettuce were collected in Wasco, Sherman, Gilliam, Morrow, and Umatilla counties from fields where lack of herbicide efficacy led to suspicions of sulfonylurea herbicide resistance by local fieldmen. Plants in the early vegetative stage were collected from several sites as indicated (Figures 1 and 2), and two plants per site were tested for resistance. Live plant specimens of kochia and Russian thistle were collected, packaged, and shipped to a commercial laboratory (Minnesota Valley Testing Laboratories, Inc.).

Determinations of susceptibility were obtained by callus assay on live plant material. Samples of prickly lettuce were similarly collected, returned to the greenhouse, and allowed to grow to maturity. Seeds were collected from the greenhouse grown plants, and later planted. Greenhouse grown prickly lettuce seedlings were treated with metsulfuron (Ally) at 4.4 g. active ingredient/ha using a procedure described previously (Mallory-Smith, et al. 1990). Plants were rated for visible herbicide injury at 14 and 28 days after treatment to determine susceptibility. Susceptible plants were completely killed after 28 days while resistant plants had growth similar to untreated control plants.

RESULTS AND DISCUSSION

Results from this preliminary survey confirm that suspected herbicide resistant populations of kochia, Russian thistle, and prickly lettuce are common in the Columbia Basin region of Oregon. A total of six kochia sites were sampled and all six were determined to have a sulfonylurea herbicide resistant population. A total of six Russian thistle sites were collected and five determined to have a resistant population. A total of nine prickly lettuce sites were collected and all were determined to have a resistant population. All locations had been in a winter wheat-summer fallow rotation for several years and had received repeated applications of one or more of the following sulfonylurea herbicides for at least four of the last cropping seasons: Glean, Finesse, Amber, Harmony Extra, and/or Express. Further testing is necessary to determine the frequency and distribution of resistant weeds.

The management of sulfonylurea herbicides can help reduce the spread of resistance, thereby increasing the effective life of these compounds. Several practices should be employed to reduce the potential for resistance development. Useful practices include:

- avoiding year-after-year use of herbicides that have the same mode of action,
- use of herbicides that do not persist in the soil for long time periods and are not applied repeatedly within a growing season,
- rotation of crops that rotates types of herbicides used on a particular field, as long as dissimilar herbicides are used in the rotation,
- use of mechanical cultivation in row crops and fallow tillage operations in cereal grain production, and
- monitoring fields for weeds that escape herbicidal control.

For more information on herbicide resistance management, refer to the Pacific Northwest Extension Publication "Herbicide-Resistant Weeds and Their Management" (PNW 437) available through local county Extension Service offices.

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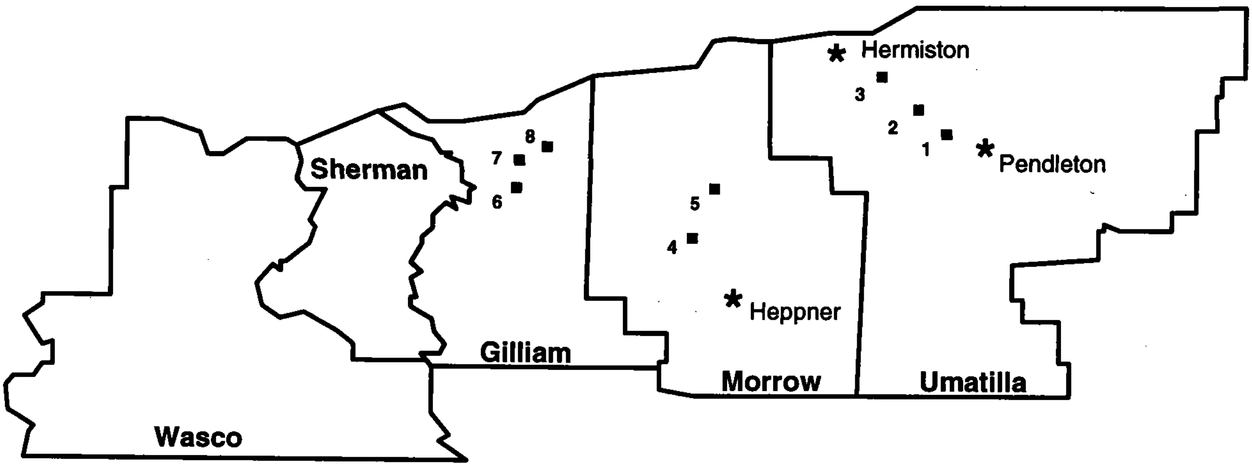

Figure 1. Confirmed sites of sulfonylurea herbicide resistance in the Columbia Basin region of northeastern Oregon. Sites 1 through 6 contained resistant kochia, and sites 2,3,4,5,7, and 8 contained resistant Russian thistle.

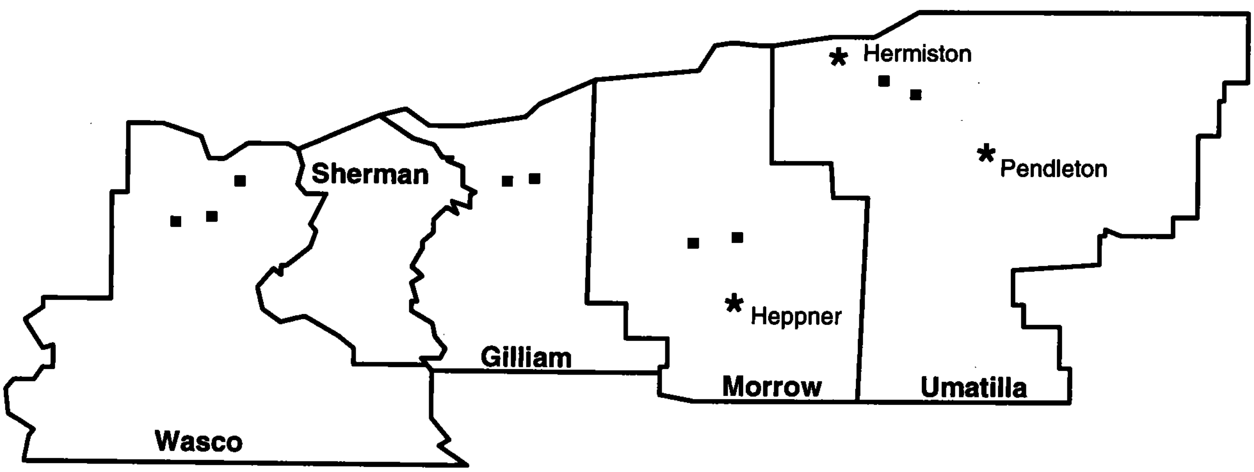

Figure 2. Confirmed sites of sulfonylurea herbicide resistant prickly lettuce in the Columbia Basin region of northeastern Oregon.

NITROGEN FERTILIZER TIMING INFLUENCE ON DOWNY BROME AND WINTER WHEAT

Daniel A. Ball, D. J. Wysocki,
and D. L. Walenta

INTRODUCTION

Winter wheat growers in the Pacific Northwest have changed tillage practices to meet conservation compliance regulations designed to decrease soil erosion. These changes in tillage have often led to increased levels of downy brome (*Bromus tectorum* L.) and have placed serious constraints on the successful adoption of conservation tillage systems in winter wheat. Timeliness of tillage, herbicide applications, and wheat planting become more critical in conservation tillage systems compared to that required by conventional moldboard plow-based crop production systems. Less than ideal timing of operations may result from poor weather, equipment constraints, or poor management, and may lead to increased downy brome populations. It has also been shown that downy brome problems can be influenced by N fertilization practices (Anderson, 1991). It would be desirable to optimize N-fertilization practices in conservation tillage systems to prevent further increases in the downy brome problem. For this reason, studies were conducted at the Pendleton and Moro Experiment Stations to evaluate N fertilizer placement, rates, and timing, and weed management inputs on wheat and downy brome population dynamics in the dryland wheat-fallow region.

A new type of fertilizer applicator, a spoke-wheel injection system, was also evaluated for applying N as a sub-surface top dressing to growing wheat with minimum plant disturbance. This implement uses a rotary valve and spoke arrangement on a wheel to inject liquid fertilizer solutions below the soil surface (Figure 1). This paper reports on the influence of N fertilizer timing and placement with a spoke wheel injection system on downy brome density and dry matter production, and wheat yield.

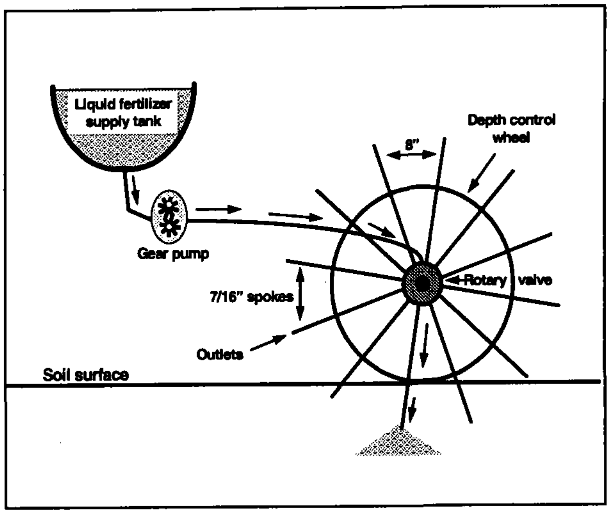

Figure 1. Spoked injector for applying fertilizer through crop residues in conservation tillage farming.

MATERIALS AND METHODS

Experiments were established at the Columbia Basin Agricultural Research Centers near Pendleton and Moro, OR in fall 1992 on summer fallow ground being prepared for planting of winter wheat. Plots were arranged as a split-plot design with main treatments consisting of N-fertilizer rates and application timings. Main plot treatments at the Pendleton site consisted of the following N management strategies: (1) 40 lb N in fallow as anhydrous NH_3; (2) 80 lb N in fallow as anhydrous NH_3; (3) 40 lb N at planting as solution 32 with seed; (4) 80 lb N at planting as solution 32 with seed; (5) 80 lb N as topdress with point injection; (6) 40 lb N anhydrous + 40 lb N topdress with point injection; (7) 40 lb N solution 32 with seed + 40 lb N topdress with point injection; (8) 20 lb N solution 32 with seed + 40 lb N topdress with point injection; and (9) an unfertilized control. Rates at the Moro site were half of the Pendleton rates due to the lower rainfall environment at this location. Sub-treatments at both sites consisted of a high level of downy brome (low weed management) or a negligible level of downy brome (high weed management).

At Pendleton, anhydrous ammonia was applied with a commercial type shank injection system on August 28, 1992. Nitrogen as solution 32 was applied on October 6, 1992 with a spoke-wheel injection system immediately before planting to simulate an at-planting application with the seed. The high weed management sub-treatment received a preplant incorporated (PPI) application of Hoelon at 2.7 pt/A on October 7 with a hand-held CO_2 backpack sprayer delivering 16 gpa H_20 at 35 psi. This was followed by incorporation with a rod weeder, then by a rolling harrow set to 2 in. depth. The low weed management sub-treatment was seeded with downy brome on October 7 at 38 lb/A and seed incorporated with the same procedure described for Hoelon incorporation. The wheat variety 'Madsen' was seeded into moisture with a Great Plains no-till disk drill on October 8, 1992. A topdress application of solution 32 N was applied on March 29, 1993 with a spoke-wheel injection system to place N approximately 2 to 4 in. below the soil surface. Plots were 10 x 22 ft in size with four replications. Measurements of percent downy brome cover were made on April 16, and downy brome dry weight per hectare was determined on May 19. Wheat head counts and plant heights were taken on July 2, 1993. Wheat grain was harvested on July 21, 1993 with a Hege 140 plot combine and converted to bu/A yields on a 60 lb/bu basis.

At the Moro site, anhydrous ammonia was applied with a commercial type shank injection system on September 10, 1992. The high weed management sub-treatment received a PPI application of Hoelon at 2.7 pt/A on September 28 with a hand-held CO_2 backpack sprayer delivering 17 gpa H_20 at 30 psi. This was followed by incorporation with a field cultivator set to a 3 in. depth and then a rod weeder passing at a 90 degree angle to the first incorporation. The low weed management sub-treatment was seeded with downy brome on September 28 at 17 lb/A and the seed was incorporated with the same procedure described for Hoelon incorporation. Nitrogen as solution 32 was applied on October 1, 1992 with a spoke-wheel injection system immediately before planting to simulate an at-planting application with the seed. The wheat variety 'Madsen' was seeded into moisture with a Great Plains no-till disk drill on October 1, 1992. A topdress application of solution 32 N was applied on April 2, 1993 with a spoke-wheel injection system to place N below the soil surface. Plots were 8 x 20 ft in size with four replications. Measurements of downy brome plant density were made on April 29, and downy brome dry weight was determined on June 3. Wheat head counts and plant heights were taken on June 30, 1993. Wheat grain was harvested on August 4, 1993 with a Hege 140 plot combine and converted to bu/A yields on a 60 lb/bu basis.

RESULTS AND DISCUSSION

Split N applications and N applied at seeding or as a topdress using spoke-wheel injection improved yield at Pendleton in the absence of downy brome interference (Table

Table 1. Influence of N-Fertilization Methods on Wheat and Downy Brome . Pendleton 1993.

	Treatment	Downy Brome Cover Low	Downy Brome Cover Hi	Downy Brome Dry Weight Low	Downy Brome Dry Weight Hi	Wheat Yield Low	Wheat Yield Hi	Difference
		----%-----		----kg/ha---		---bu/A---		bu/A
1	Control	30	2	1270	120	43	52	9
2	40 Anhydrous	36	3	1540	160	60	71	11
3	80 Anhydrous	44	5	1210	200	65	72	7
4	40 Planting	42	3	1320	130	54	68	14
5	80 Planting	41	18	2060	470	66	76	10
6	80 Topdress	39	6	2170	220	56	79	23
7	20 PL + 40 Tp	48	9	2720	230	57	76	19
8	40 PL + 40 Tp	42	3	2240	77	61	88	27
9	40 An + 40 Tp	33	7	1760	160	63	79	16
	sign. level FERT	NS		.06		.0001		
	HERB	.0001		.0001		.0001		
	F x H	NS		NS		NS		

Weed Management Level: Low / Hi

PL - planting, Tp - topdress, An - anhydrous

1). The benefits from split applications of N, or N applied at seeding or as a topdress were diminished in the presence of downy brome. Wheat yield was reduced by downy brome from 7 to 11 bu/A in plots receiving anhydrous NH_3, and from 16 to 27 bu/A in plots with split applications of N (Table 1). Downy brome dry weight measured late in the season was increased by N applications made at-planting and as a topdressing, and more than doubled from the control when split N applications were made at-planting and as a topdressing (Table 1). From the grower's perspective, if downy brome is a problem, fertilizer benefits to wheat yield are greatest from N applied as anhydrous in the summer fallow period. The benefits from topdressing and split applications that are apparent without downy brome interference were diminished when downy brome was present at levels high enough to reduce yields.

Unlike the study at Pendleton, downy brome populations at the Moro site, even in the low management treatment, were not high enough to cause a reduction in yield (Table 2). However, split N applications and N applied at seeding, or as a topdress using point injection, increased the late season dry weight of downy brome, more than doubling it

Table 2. Influence of N-Fertilization Method on Wheat and Downy Brome. Moro 1993.

	Treatment	Downy Brome Density Low	Downy Brome Density Hi	Downy Brome Dry Weight Low	Downy Brome Dry Weight Hi	Wheat Yield Low	Wheat Yield Hi	Difference
		-----#/m²-----		-----kg/ha-----		-----bu/A----		
1	Control	105	9	238	55	51	51	0
2	20 Anhy	152	5	366	9	65	66	1
3	40 Anhy	95	2	154	6	66	70	4
4	20 Planting	109	13	205	41	64	65	1
5	40 Planting	147	11	384	12	69	71	2
6	40 Topdress	107	11	412	42	64	64	0
7	10 PL + 20 Tp	97	9	329	67	66	59	-7
8	20 PL + 20 Tp	131	5	501	26	66	70	4
9	20 An + 20 Tp	129	7	428	7	59	62	3
sign. level	FERT	NS		NS		.0007		
	HERB	.0001		.0001		NS		
	F x H	NS		.042		NS		

Weed Management Level: Low / Hi.

PL - Planting, Tp - Topdress, An - Anhydrous

compared to the control when split applications at planting and topdress were made (treatment 7). All N treatments improved wheat yield over the control, but there were no clear interactions with downy brome infestation.

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FROZEN SOIL TILLAGE FOR SOIL EROSION CONTROL

Dale E. Wilkins and John F. Zuzel

INTRODUCTION

In the dryland farming region east of the Cascade Mountains of the Pacific Northwest (PNW), often there is not sufficient crop residue for erosion control, particularly where summer fallow is practiced. Crop residue on and near the soil surface is effective in reducing soil erosion. Tillage buries crop residue and reduces surface cover. Although no-tillage summer fallow is ideal for erosion control, it will result in excessive seed zone drying during the fallow year (Hammel et al., 1981). In years when surface cover is insufficient for controlling erosion, other protection measures are needed.

Even in the presence of normally adequate residues, frozen soil layers reduce infiltration and increase the risk of runoff and soil erosion. This risk is especially high during winter and early spring in fields with winter wheat (*Triticum aestivum* L.) seedlings, long-steep slopes, and limited crop residue cover on the soil surface. Damaging runoff and erosion events associated with frozen soil are triggered by snowmelt or rain (Zuzel et al., 1982). If soil erosion protective measures are to be useful, they must remain effective during erosion events in the presence of frozen soil layers.

Wilkins et al., (1991) developed a tillage tool for ripping frozen soil to enhance infiltration and reduce erosion. The slot produced by ripping the soil, intercepted runoff from rain or melting snow, temporarily stored water and provided an infiltration pathway through the frozen layer into the soil beneath it. Frozen soil tillage increased infiltration without reducing wheat yield (Wilkins and Zuzel, 1994). This article summarizes research conducted to evaluate ripping frozen soil to enhance water infiltration and reduce erosion in the dryland farming region of the PNW.

MATERIALS AND METHODS

Six experimental sites in northeast Oregon near Pendleton were established during 1990 to 1993 on fields seeded to winter wheat to evaluate tilling frozen soil for enhanced water infiltration. Experimental sites 1 and 2 in 1990, site 5 in 1991, and site 6 in 1993 were in areas that typically have a wheat-summer fallow rotation and receive from 10 to 14 in. of annual precipitation. The soil for these sites was Walla Walla silt loam (coarse-silty, mixed, mesic Typic Haploxeroll). Sites 3 and 4 in 1991 were areas where annual precipitation exceeds 16 in. and peas (*Pisum sativum* L.) are grown in rotation with wheat. Site 3 was on a Palouse silt loam (fine-silty, mixed, mesic Pachic Ultic Haploxeroll) and site 4 was on a Waha silty clay loam (fine-loamy, mixed, mesic Pachic Argixeroll).

Treatments were no tillage and no traffic (NTNT), traffic and no tillage (T), tillage with shank (S), tillage with shank plus rotary subsoiler (SR), and tillage with only rotary subsoiler (R). Experiments had either four or five replications. A tool designed for tilling frozen soil with a minimum of soil disturbance (Wilkins et al., 1991) was used for the tillage treatments. In 1990, 1991, and 1993 winter wheat was seeded in October. Tillage was done after the soil had frozen about 4 in. deep. Wheat was in the seedling stage of development. Tillage depth was 11 in. and on contour. In 1992, the winter was warm and treatments were not installed because the soil did not freeze more than 2 in. deep.

In 1990 (Wilkins et al., 1991) and 1991, 20 or more plants were excavated from treatments NTNT, T, and SR at sites 1-4 to assess the impact of frozen soil tillage on root diseases. Plants were excavated adjacent to the tillage slot (less than 2 in. from the center of the slot) in treatment SR and from tracked areas in treatment T. Plants were taken to the laboratory and rinsed with water to remove soil from root systems. Each plant was evaluated for the percent of seminal roots with Pythium, root rot, or take-all, percent of plants with eyespot, and severity of Rhizoctonia root rot on seminal and coronal roots. Wheat was winter killed in 1991 at site 5.

Grain yield and heads per unit area were determined for all plots by hand harvesting ripe plants from 16 ft^2. The harvest area in each plot was a 2 by 8 ft. The 8 ft. dimension was centered over the tillage slot and extended across tracks made by the tractor pulling the tillage tool.

Water infiltration was measured at site 5 after tillage when the soil was frozen. Infiltration was measured in 6 in. wide by 3 ft. long areas parallel to a frozen soil tillage mark. Metal plates 18 in. square were driven into the frozen soil 3 ft. apart and perpendicular to the direction of tillage. Gaps between the plates and soil were sealed with bentonite. These plates and ridges between wheat rows made by planting equipment defined a 6 in. by 3 ft. infiltration reservoir. The quantity of 0 °C water required to maintain a 1 in. hydraulic head above the soil surface was recorded at 5 minute intervals. Measurements were made for 1 hour in three replicates of SR and NTNT treatments.

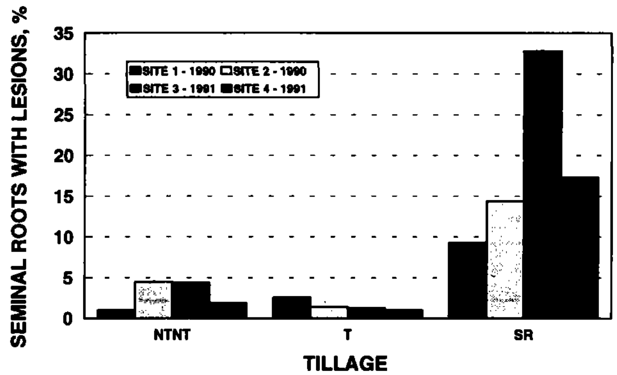

Figure 1. Effects of frozen soil tillage on incidence of take-all lesions on winter wheat seminal roots (adapted from Wilkins and Zuzel, 1994). NTNT = no tillage and no tracks, T = tracks with no tillage, and SR = shank plus rotary subsoiler..

RESULTS AND DISCUSSION

Tillage treatment S made a narrow slot that remained open during the winter. The SR treatment made a narrow slot with pock marks approximately 3 ft. apart. Pock marks were observed to serve as small reservoirs for intercepted runoff and provided access for surface water to enter channels created by the shank. The rotary subsoiler (R) used alone did not consistently penetrate frozen soil.

Take-all was the only plant disease observed to be consistently influenced by mechanically damaging roots with frozen soil tillage. Fig. 1 shows the impact of frozen soil tillage in 1990 and 1991 on take-all incidence.

Tilling frozen soil increased the percent of seminal roots with take-all lesions by as much as 9 fold. Take-all infection occurs through root contact with the fungus (Wiese, 1977). It is possible that the tillage tool spread the fungus to root systems as the tool passed through the soil. Severe infestations of take-all can reduce wheat yields by as much as 50 percent (Wiese, 1977). The only other observed incidences of wheat diseases that were significantly influenced by frozen soil tillage or traffic were Pythium at site 1, which was higher in the tilled plots than either NTNT or T plots (9, 13, and 20 percent of seminal roots infested in NTNT, T, and SR plots, respectively) and Rhizoctonia root rot which was slightly higher at site 4 in SR plots as compared to NTNT and T plots (4.2, 4.2 and 4.5 rating for NTNT, T, and SR, respectively). A rating of 4 = lesions on 1 or 2 main axes, and a rating of 5 = lesions on 3 or more main axes.

Wheat yields were not depressed by frozen soil tillage (Fig. 2). Only at site 4 were there significant differences where rotary subsoiling (R) increased the yield over the control (NTNT), traffic (T), and ripping with a shank (S). Site 3 was located in the same field and within 1/4 mile of site 4, but there were no significant yield differences at site 4. Heads produced per unit area were not significantly influenced by the five treatments at any of the sites. Disease injuries were not manifested in yield reductions. Most wheat plants can withstand mild infections of take-all without yield reductions (Wiese, 1977). These results suggest that frozen soil tillage in the PNW can be done in fields with wheat seedlings without reducing grain yield.

There was more water infiltration into tilled (SR) than non-tilled (NTNT) plots (Fig. 3). After one hour of infiltration the mean accumulated infiltration in the tilled plots was 0.5 in., which was 150 percent higher than the non-tilled plots. Although this rate of infiltration is low, the infiltration rate of these soils is approximately 0.8 in./hour in an unfrozen state (Pikul et al., 1992). The slopes of the curves in Fig. 3 indicate infiltration rates. Straight lines were fitted to the curves for the period with uniform infiltration (20 to 60 min). The infiltration rates were 0.3 and 0.1 in./hour for tilled soil and non-tilled plots, respectively.

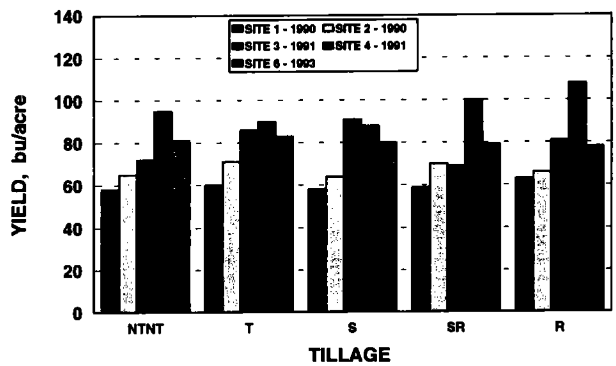

Figure 2. Influence of frozen soil tillage on winter wheat yield (adapted from Wilkins and Zuzel, 1994). NTNT = no tillage and no tracks, T = tracks with no tillage, S = shank, SR = shank plus rotary subsoiler, and R = rotary subsoiler.

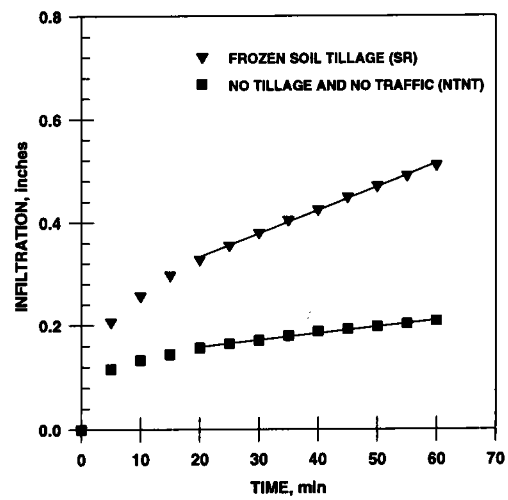

Figure 3. Cumulative water infiltration for no tillage and frozen soil tillage for a Walla Walla silt loam in the PNW (adapted from Wilkins and Zuzel).

SUMMARY

In the dryland PNW east of the Cascade mountains tilling frozen silt loam soil for erosion control increased water infiltration during the critical period when there was a layer of frozen soil. The tillage did not reduce grain yields despite observed increases in incidence of take-all lesions and stand reduction.

ACKNOWLEDGMENT

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DECOMPOSITION OF CANOLA RESIDUE

C. L. Douglas, Jr., and D. J. Wysocki

INTRODUCTION

Many producers are interested in finding a crop to use in rotation with winter wheat in agronomic zones 3, 4, and 5 of the dryland Pacific Northwest (Douglas, et al., 1990). Wysocki, et al., (1992) indicated that in 1992 only 5 percent of the dryland acreage in Oregon was used for non-cereal crops. One crop that is being considered for these areas is canola (*Brassica napus*). Wilkins and Haasch (1992) evaluated drill opener modifications for seeding canola, and Wysocki, et al., (1992) studied variety and planting date effects on dryland canola. However, there have been no studies in the Pacific Northwest evaluating decomposition of canola residue. It is important to know the decomposition rate of canola residues, especially since a certain amount is required on the soil surface to help control soil erosion by wind and water. The purpose of this research report was to show one season's information (September, 1991 to September, 1992) on canola residue decomposition in a fallow cropping system.

METHODS

Winter canola residues (var. '*Arabella*') were collected after harvest in 1991. The equivalent of 1,500 lbs of canola residue per acre was put into fiberglass cloth bags and either left on, or buried 4 inches below, the soil surface on September 25, 1991. Fiberglass cloth was placed on the soil surface, approximately 0.5 inch of soil was put on the cloth, residues were placed on the soil, and held in place by netting. Buried samples were totally enclosed by the fiberglass bag. Residue samples were taken in December 1991, and March, June, and September 1992. Samples were dried at 104 °F and held until they could be washed. After careful washing, to remove soil and retain plant tissue, the samples were again dried at 100 °F, then weighed to determine weight loss.

RESULTS AND DISCUSSION

Decomposition of canola pods and stems is shown in Figures 1 and 2, respectively. Both figures show that buried residues, regardless of plant part, decompose faster than residues left on the surface. Decomposition of buried pods (Figure 1) and stems (Figure 2) are similar because of their relatively similar nitrogen contents (0.81 percent for pods and 1.16 percent for stems). Only about 10 percent of either buried pods or stems are left by the end of the fallow period (Figures 1 and 2),

On the soil surface, stems decompose slower than pods (Figure 2). This is probably a result of the low nitrogen content of the outer part of the stems. The outside, stiffer part of the stem has only 0.46 percent nitrogen. Overall stem decomposition slows after the pith inside is decomposed. Also, pods are covered by soil more easily than stems. Thus, soil surface coverage is provided primarily by stem material.

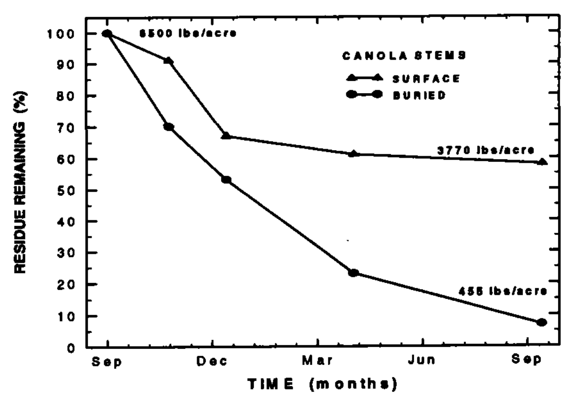

Figure 1: Canola stem decomposition after 12 months

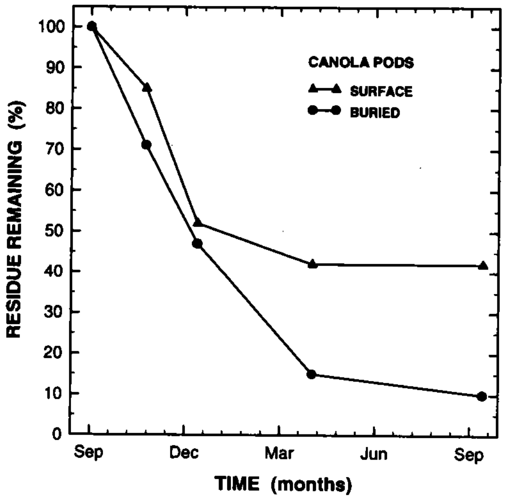

Figure 2: Canola pod decomposition after 12 months

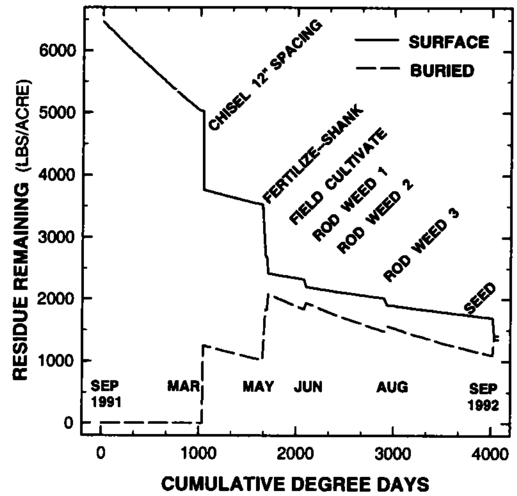

Figure 3: Canola residue remaining, both on the surface and buried, throughout a typical tillage sequence during the fallow season.

Preliminary evidence indicates that stems constitute 55 percent, by weight, of the above ground portion of the canola plant. If the initial weight of the canola stems was 6,500 lbs/acre, Figure 2 would indicate that 58 percent, or 3,770 lbs of canola stems, were left on the surface after the fallow period when there was no tillage involved.

Figure 3 illustrates the probable fate of canola residue (both buried and on the surface) throughout a typical tillage sequence from canola harvest through a fallow year to seeding. Values of residue buried by tillage used to develop figure 3 were the maximum amounts of residue left on the surface from Table 2, in the "Residue Management Guide" from the Conservation Technology Information Center (1992). This table is based on a tractor speed of 4.5 mph or less. The amount of residue left on the surface by any tillage implement will change with tillage speed (increase speed--increase burial), implement setting, and soil moisture (increase moisture--increase burial). About 1,300 lbs/acre of canola residue is projected to remain on the surface, which would cover approximately 50 percent of the soil. However, decomposition and tillage burial do not estimate the brittleness of the canola stems. We anticipate there would be less than 50 percent of the soil surface covered because the smallest stems, and oldest, most decomposed stem parts would fracture and be covered with soil.

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WATER USE BY DRYLAND WINTER CANOLA

Don Wysocki and Sandra Ott

INTRODUCTION

Water is most often the limiting factor in dryland crop production. Much research has focused on water use and production of dryland wheat. Such studies have lead to relations between available water and expected yield. A common generalization for winter wheat is that each inch of stored soil water will contribute about 7 bushels/acre to yield. The water usage of canola, a relatively new crop to the region, has not been studied. The relationship between available water and expected yield is not known. If canola acreage continues to increase in the region, more knowledge on water usage and expected yield is needed. This knowledge will permit development of the most reliable and profitable crop management recommendations for canola production. Also important is the observation that wheat often shows improved yields when grown in rotation with canola. This effect, sometimes called the rotation effect, is probably due to a number of factors. One possible contributing factor is reduced exploitation of soil water by canola, thus leaving additional water for the following wheat crop. To understand the rotation benefits of canola, it would be useful to know how extensively canola depletes soil water. With these objectives in mind, we have been studying water use by winter canola.

MATERIALS AND METHODS

For the past two crop seasons (1991-1992 and 1992-1993), we have studied water usage of winter canola on a Walla Walla silt loam using gravimetric and neutron probe techniques. Winter canola was sown on summer fallow on September 27 and September 1, respectively, for the 1991-92 and 1992-93 crop seasons. Plots were sown with a John Deere HZ drill with 14-inch row spacing. During the 1991-1992 crop season, the September 1 seeding was lost because of heat stress during emergence. In March, neutron probe access tubes were installed in 12 plots (three different nitrogen rates to a depth of 4 feet and four replicates of each treatment). Basalt rock was encountered below this depth, so the root zone was assumed to be 4 feet. During installation, gravimetric soil samples were collected to establish the initial water content of the soil. Soil water measurements were made at 1-foot increments at 2-week intervals throughout the growing season. Daily precipitation was taken from the research center weather station. Water available to the crop is the amount of rainfall received during the growing season plus the amount removed or used from water stored in the soil profile at the start of the season. Water removed or used from the soil is the difference between the initial neutron reading and the final reading after harvest. Evaporative losses from the soil surface are included in the crop water use in this study.

During the two seasons of that study, growing season (March through July) precipitation differed greatly (Table 1). The 1991-1992 season precipitation was below normal, while the 1992-1993 value was above normal. The average precipitation for the growing season at Pendleton is 6.48 inches. Water removed from the soil profile by canola for each of the crop seasons is presented in Table 1 and in Figures 1 and 2. These data are averaged from all 12 access tubes.

Table 1. Growing season[1] precipitation for two crop seasons at Pendleton, Oregon.

Month	1991-1992 crop season	1992-1993 crop season
	-inches of precipitation--	
March	0.85	2.32
April	1.29	2.67
May	0.20	1.58
June	0.90	2.01
July (to harvest)	1.74	0.47
Total	4.98	9.05

[1] For the purpose of this study the growing season is March 1 until the day of harvest, precipitation in July includes only that until harvest.

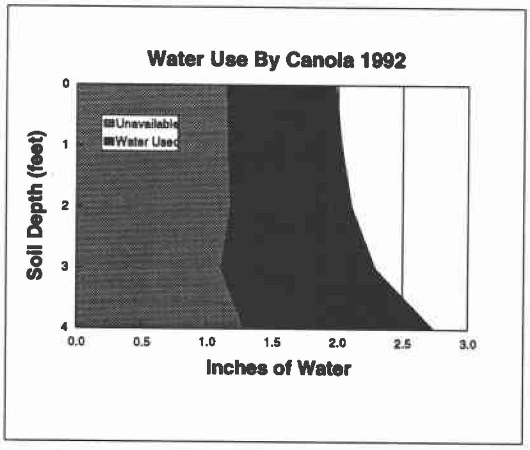

Figure 1. Soil water use by winter canola, Walla Walla silt loam, Pendleton, OR. Yield was 1871 lbs/A, soil water used was 4.43 inches.

To compare water use of canola to winter wheat, soil moisture extraction was measured on winter wheat plots at another location on the station. Soil depth on the wheat plots was greater than 6 feet making direct comparison difficult. The extraction profile for wheat in 1991-1992 is shown in Figure 3. Comparing

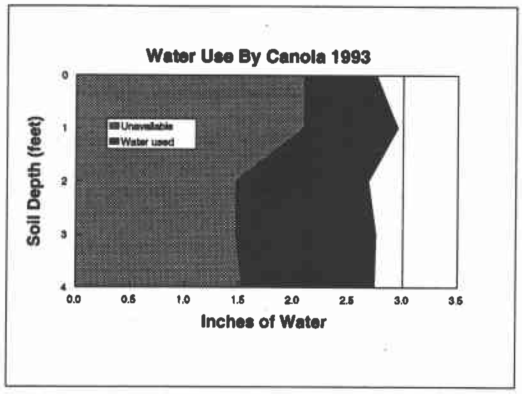

Figure 2. Soil water use by winter canola, Walla Walla silt loam, Pendleton, OR. Yield was 2154 lbs/A, soil water used was 4.36 inches.

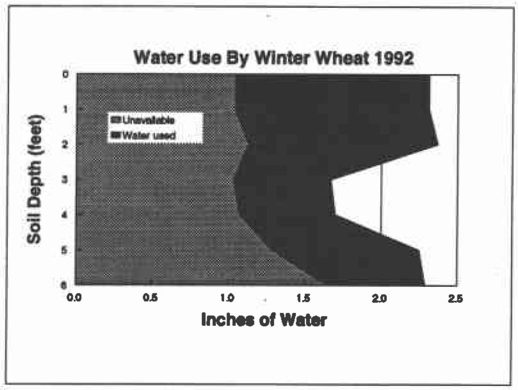

Figure 3. Soil water use by winter wheat, Walla Walla silt loam, Pendleton, OR. Yield was 70 bu /A, soil water used was 5.38 inches.

soil water extraction of Canola and winter wheat (Figures 1 and 3) in the top 4 feet of soil, shows that both crops remove water to about the same level of dryness. Wheat dries the soil to about 1 inch of water/foot and canola dries it to about 1.1 inches/foot. These graphs show that water extraction for canola is similar to wheat at least in the top 4 feet of soil. The somewhat wetter soil in Figure 2 is a result of the very much wetter growing season in 1992-1993. Without measurements of canola water use on deeper soils, we don't know how canola would use water in the 5th and 6th foot. We speculate that it would be very similar to, but slightly less than, wheat because we have excavated canola roots from as deep as 5 and 6 feet in deeper soils. We conclude that canola uses nearly the same amount of water from the soil as does winter wheat. Thus the rotation effect from canola is probably not from water remaining in the soil after canola is harvested.

A general relationship between available water and canola yield can be determined by calculating water use efficiency. A simple method of doing this is to divide yield by the amount of available water to give an estimate of the expected yield per inch of available water. Soil water use, growing season precipitation, available water, yield, and water use efficiency are shown in Table 3. Results of the past two seasons show expected yields of about 160 to 200 lb/inch of available water. The average of expected yield for the 2 years is about 180 lb of grain/inch of available water.

The 1992-1993 crop was subjected to several problems including herbicide damage, heat during late bloom, and severe infestation of cabbage seed pod weevil. These problems lowered the yield and the water use efficiency for that year. We had anticipated yields above 3,000 lb/acre. A relationship between expected yield and available water for winter canola is that each inch of available water results in about 200 lb/acre of grain yield. Since canola has a 50 lb bushel weight, that's 4 bushels per acre for each inch of water.

Table 2. Water Use from the soil profile by winter canola from two growing seasons at Pendleton, Oregon.

Soil depth	1991-1992 crop season	1992-1993 crop season
feet	inches of water used	
0-1	0.87	0.66
1-2	0.93	1.21
2-3	1.18	1.28
3-4	1.45	1.21
Total	4.43	4.36

Table 3. Soil water use, growing season precipitation, available water, yield and water use efficiency of winter canola for two crop seasons at Pendleton, Oregon.

Crop season	Soil Water Usage	Growing Season Precipitation	Available Water	Yield	Water Use Efficiency
	----------------inches--------------			lb/acre	lb/inch
1991-1992	4.43	4.98	9.41	1871	198.8
1992-1993	4.36	9.05	13.41	2154	159.1
Average	----	----	-----	----	178.9

SPRING WHITE LUPIN PRODUCTION TRIALS

Brian Tuck and Erling Jacobsen

INTRODUCTION

Research has shown that crop rotation as a disease and weed management tool has potential for benefitting small grains production in low rainfall areas. Rotating to crops unrelated to wheat, such as legumes or canola, can disrupt weed and disease life cycles that reduce grain yields when wheat is grown in a conventional winter wheat-fallow rotation.

One such rotational crop with potential for production in the low rainfall (10-14 inches annually) small grains production areas of the Northwest is white lupin (*Lupinus albus*). This large-seeded grain legume is commonly grown in Australia, Eastern Europe, and increasingly in the northern states of Minnesota, Wisconsin, and Michigan. White lupin grain traditionally is used as a protein source for animal feeds. Since livestock and poultry industries in the Pacific Northwest are dependent on Midwest soybean meal for protein supplement, local production of white lupin to supply this market could be a competitive enterprise. An average protein level of 35 percent, fat content of 7 percent, and an amino acid balance similar to soybean meal makes lupin an attractive soybean meal substitute. Lupin grain also has potential in human food products such as snack foods, sprouts, sauces, fermented foods, tofu, beverages, and as a source of dietary fiber. The price of soybean meal, which can average approximately $220 per ton, also makes lupin an attractive, alternative crop for local production. A white lupin crop with an average of 35 percent protein and a yield of 1,700 lbs would have a value of $145 per acre.

Since lupins are legumes, they fix atmospheric nitrogen by the process of biological nitrogen fixation. In a study conducted at Pullman, Washington, lupins contributed an average of 43 lbs of nitrogen per acre. Growing white lupin may allow growers to reduce fertilizer costs, and at the same time experience an increase in grain yields due to reduced disease.

Although considered to be less important than the benefits from breaking disease cycles and nitrogen fixation, lupins have been shown to reduce soil compaction, resulting in increased yields of subsequent grain crops. Weed control benefits are possible with lupin due to reduced infestations of grass weed problems in winter wheat such as downy brome. Broadleaf weed control in lupin is still presenting a problem, particularly with Russian thistle, due to a lack of suitable herbicides. Several other production problems exist that can limit white lupin yield including disease, insects, and weeds. Current research in eastern Oregon is addressing these problems.

CURRENT RESEARCH

Two trials were conducted at the Columbia Basin Agricultural Research Center (Sherman Experiment Station) in Moro, OR during the 1993 growing season. This station is located in a low rainfall winter wheat-fallow production area. Average annual precipitation at the site is approximately 12 inches. Replicated plots were established in an area that had previously been cultivated as conventional summer fallow. Trials conducted included a spring lupin variety evaluation, and a spring lupin seeding rate trial.

SPRING LUPIN VARIETY EVALUATIONS

This trial focused on variety selection of spring white lupin for the dryland (10-14 inches annual precipitation) small grain producing areas of the Columbia Basin. Plots were 5 ft by 20 ft in size with four replications. Lupins were seeded on April 16, 1993 with a hoe type experimental plot drill in 12 inch rows at a constant seeding rate of 9 seeds per ft^2. A standard pre-plant herbicide was applied for weed control, and incorporated immediately prior to seeding lupins. Dry lupin yield was collected by combining the standing, mature crop with an experimental plot combine on August 26, 1993. The crop was ready for harvest as early as August 14, but was delayed because of equipment scheduling constraints. Table 1 provides a summary of current varietal research. Overall, the highest producing variety for not only the 1993 trials, but for previous years as well has been 'L2085'. This variety is available commercially. 'Ultra', another spring lupin variety that has been grown in the low rainfall areas of the Columbia Basin has shown some potential with yields similar to or slightly less than 'L2085' in yield trials over the last several years. 'Ultra' is also available commercially. It has been noted that with the wet spring this last year, 'L2085' seemed to take more advantage of the better moisture conditions than 'Ultra' with the resulting better yields.

SEEDING RATE TRIAL

A second area of research has been focused on determining the optimal seeding rate. The traditional seeding recommendation for spring lupin has been 6 seeds per ft^2. In the 1993 plant population trials seeding rates ranged from 3 to 24 seeds per ft^2. These plots were established concurrently with the above mentioned variety trial, with planting dates, cultural practices, and harvest date the same as described previously. As noted in Table 2, seeding rates in the range of 12 to 15 seeds per ft^2 were optimal when considering seed costs and lupin yield. It should be stressed that the 1993 growing conditions were favorable for spring crops and not necessarily typical for this area. Favorable growing conditions resulted in better than anticipated yields with the higher seeding rates.

Table 1. 1993 Spring Lupin Variety Trial Yield Data.

Variety	Yield dry grain (lb/A)	Plant Ht. Harvest (in.)	Seed Pods (per plant)
L2085	1838	12.6	3.2
L1120N	1412	12.5	2.7
L2090	1615	13.2	2.8
L219N	1649	12.8	3.7
Ultra	1643	12.9	3.7

Table 2. 1993 Plant Population Yield Data for Spring Seeded White Lupin.

Seeding Rate (sds/ft^2)	Yield dry seed (lb/A)	Plant Ht. Harvest (in.)	Seed pods (per plant)
3	957	13.8	5.9
6	1622	15.1	5.1
9	1822	15.2	4.0
12	1933	16.0	3.6
15	2011	16.4	3.0
18	2020	16.3	3.0
21	1956	16.2	2.7
24	2164	16.6	2.0

FUTURE RESEARCH

Trials were begun in the fall of 1993 to look at fall planted white lupin production under the low rainfall conditions of the Columbia Basin. Previous results with small non-replicated trials have indicated a 20 to 30 percent yield increase with fall lupins compared to spring varieties. Fall planted lupin varieties of winter wheat. Current research will focus on varietal selection for yield, and earliness of maturity, as well as determining optimal seeding rates and planting dates. Further research with spring lupin is planned for 1994 to continue looking for suitable varieties for the Columbia Basin area. One of the problems that has been observed is an incidence of root and pod disease problems with currently available spring varieties. There are at this time no registered fungicides to control these disease problems. Since lupin is considered a minor crop, registration of fungicides for this crop will be difficult for the near future. The most promising opportunity for controlling these disease problems is with resistant varieties. Work in this area is being conducted in cooperation with Resource Seeds Inc. based in Gilroy, California. This company is developing new lupin varieties for the western United States and will be supplying varieties for screening. Work will also be continue on determining optimal seeding rates for the dryland areas of north central Oregon.

GREEN PEA VARIETAL DIFFERENCES IN SOIL ANCHORING ABILITY AT HARVEST MATURITY

Dale E.Wilkins and Tom Darnell

INTRODUCTION

Green peas (*Pisum sativum* L.) for processing as an edible vegetable are combine harvested. These combines utilize either a pickup or pod stripper attachment to gather peas that are shelled and separated by the combine. A newly available pod stripper type combine can eliminate the need for pea swathing and increase combine capacity by reducing the amount of plant material passing through the combine. Plant stems remain anchored to the soil and do not pass through the combine. Some varieties are more difficult to harvest with a pod stripper than other varieties. Plants that are poorly anchored to the soil are easily pulled loose and may become wrapped around the stripping cylinder causing delays. Plant stems that are pulled loose and run through the combine reduce machine shelling and separating efficiency. Research was conducted to evaluate varietal differences in green pea anchor strength at harvest maturity.

MATERIALS AND METHODS

Green pea variety trials were located on the Mansfield-Levine field southeast of Walla Walla, WA in the pea growing area of Walla Walla county. Forty-five varieties were evaluated in 1993. Varieties were seeded on April 17, 1993 with a precision plot drill. Rows were 7 inches apart and seeding rate was 6.3 seeds per foot of row. Five plants from each of two replications for all varieties in the Oregon State University Cooperative Extension variety trials were randomly selected at harvest maturity for anchor strength measurements.

Anchor strength and stem diameter were measured for each plant. Strength was measured with a hand-held puller coupled to an electronic notebook (Fig. 1). The puller consisted of a 75 lb capacity, model DS-75 Alphatron load cell with a handle attached to one end and a vee-notched bracket attached to the other end. Plant stems just below the first branch having a pod were inserted into the puller notch. A vertical force was applied at a uniform velocity to the plant stem through the hand puller until stem failure. The electronic notebook (Omnidata, Polycorder model 700) was programmed to record the maximum force applied to achieve stem failure. The variety, plant number, replication, and outside stem diameter were hand entered into the notebook for each plant prior to measuring anchor strength. Stem diameter was deter-

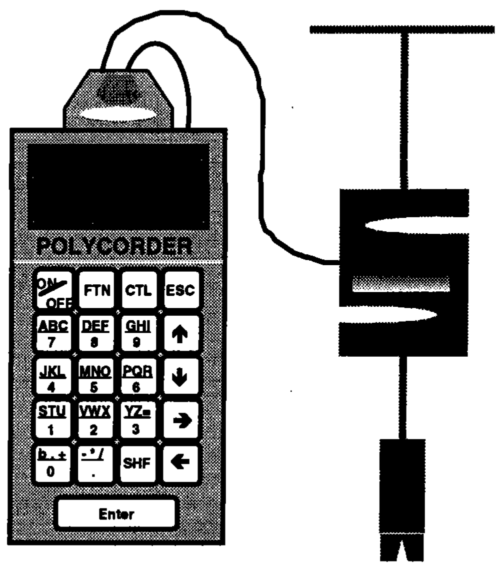

Figure 1. Hand-held pea strength measuring tool and electonic notebook.

determined by averaging three measurements made with a digital-electronic caliper. Stem diameters were measured between the nodes where the puller was located for anchor strength measurement. These diameters were measured to the nearest .01 inch. A special notation was made in the electronic notebook indicating whether the plant failed at the root system or at the stem.

Anchor strength was measured as close as possible to the date of yield measurement. Date of yield measurements were targeted to 95 tenderometer. Occasionally the stem slipped through the notch on the puller and did not provide a representative measurement. These data were not included in the analysis. For some varieties this limited the number of observations to a total of six. A total of 423 plants from the 45 varieties were used for anchor strength measurements.

RESULTS AND DISCUSSION

Table 1 shows the means of the anchor strength measurements taken in 1993. Anchor strength ranged from a high of 11.3 lbs for variety FR-516 to a low of 2.8 lbs for Stampede. Statistical analysis showed significant differences in anchor strength at the 0.01 level of probability. The least significant difference ($LSD_{0.05}$) between means was 2.9 lbs.

It was hypothesized that pea plant anchor strength was dependent on stem diameter and root strength. The latter being related to root diseases such as *Fusarium, Pythium,* and *Rhizoctonia,* which injure root tissue. Plants with weak roots would pull from the soil rather than fracture at the stem during anchor strength tests. The differences among the varieties in the percent of plants that broke at the roots was not significant at the 0.10 probability level (Table 1). Plants with large stems should provide more anchor strength than plants with small stems. Stem diameter ranged from 0.11 inches for Karisma to 0.25 inches for FR-138. The $LSD_{.05}$ for stem diameter was 0.029 inches (Table 1).

In addition to the possibility of anchor strength being related to stem diameter and root strength, it was thought that maturity at harvest and date of harvest might also influence anchor strength. Pea tenderometer values at harvest were used as a measure of harvest maturity. Linear regressions with anchor resistance as the dependent variable and percent of plants with broken roots, stem diameter, tenderometer value, and harvest date as independent variables were determined. This mathematical technique is the same as fitting straight lines to data in Figs. 2, 3, 4, and 5. Because the harvest date and the anchor strength measurements were not always done on the same day (Table 1), data were not included in tenderometer or harvest date regressions for varieties that had different dates for strength and yield measurement. If all data points fell on a straight line then the coefficient of determination would be 1.0, indicating a strong relationship between the two variables. The coefficients of determination, R^2, were all less than 0.07. This indicated almost no relationship between anchor strength and broken roots, stem diameter, tenderometer value, or harvest date.

SUMMARY

Using a simple hand puller with a load cell coupled to an electronic notebook to measure anchor strength of peas at harvest maturity worked successfully and detected significant differences in anchor strength among 45 green pea varieties. Anchor strength was not related to stem diameter, root strength, harvest date, or pea tenderometer value. The varietal differences in anchor strength may be due to genetic factors that control the amount of lignin or woody material in the stems.

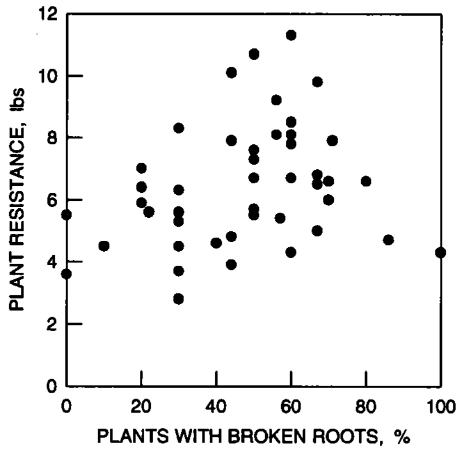

Figure 2. Effect of pea plants root failure on anchoring strength near Walla Walla, WA in 1993.

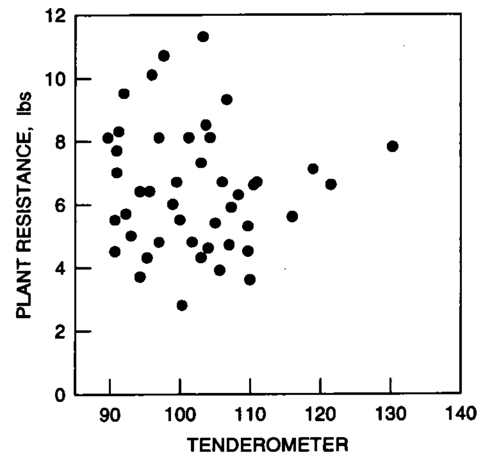

Figure 4. Effect of pea tenderometer value on plant anchoring resistance near Walla Walla, WA in 1993.

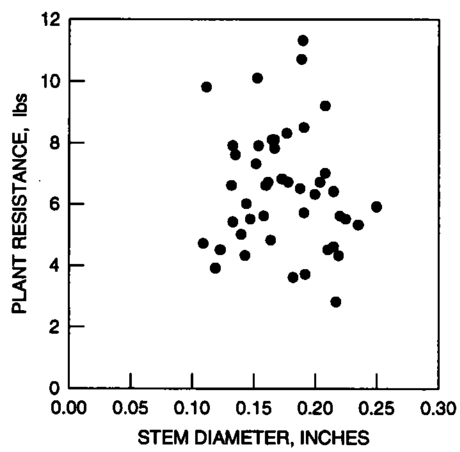

Figure 3. Influence of pea plant stem diameter on anchoring resistance near Walla Walla, WA in 1993.

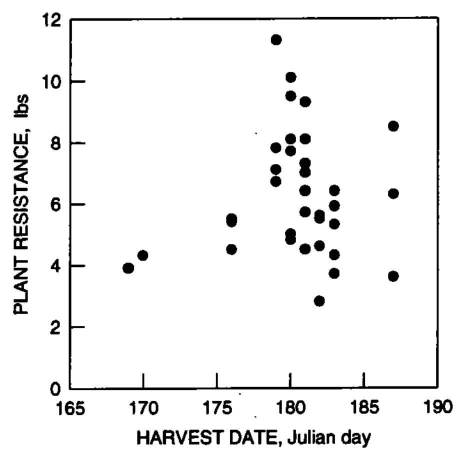

Figure 5. Effect of harvest date on anchoring resistance near Walla Walla, WA in 1993.

ACKNOWLEDGMENTS

The authors greatly appreciate the technical assistance of Craig Cameron and Bob Ayers in making field measurements and to the Blue Mountain Green Pea Industry for supporting this project.

Table 1. Effect of green pea variety on plant anchoring strength at harvest in 1993.

VARIETY NUMBER	VARIETY NAME	SAMPLE DATE	HARVEST DATE	STEM DIAMETER	ANCHOR STRENGTH	BROKEN ROOTS*
				inches	lbs	%
1	CMG-307F	6/21/93	6/19/93	0.143	4.3	100
2	NUN 1961	6/25/93	6/25/93	0.152	7.3	50
3	NUN 1040	6/18/93	6/18/93	0.147	5.5	50
4	HP-666-3-1	6/18/93	6/18/93	0.119	3.9	45
5	FR 517	6/28/93	6/28/93	0.178	6.7	50
6	FR 516	6/28/93	6/28/93	0.19	11.3	60
7	VENUS	6/25/93	6/25/93	0.157	5.4	23
8	SOLO	6/28/93	6/28/93	0.167	7.8	60
9	HP-235-1-1-3	6/28/93	6/26/93	0.167	8.1	60
10	FR 652	6/25/93	6/25/93	0.123	4.5	30
11	CMG-293F	6/28/93	6/27/93	0.204	6.7	40
12	NUN 1894	6/28/93	6/26/93	0.189	10.7	50
13	XPF 266	6/28/93	6/26/93	0.16	6.6	90
14	SPRINTER	6/29/93	6/29/93	0.153	10.1	48
15	XPF 275	6/28/93	6/28/93	0.175	7.1	68
16	XPF 274	6/28/93	6/27/93	0.165	4.7	48
17	DUAL	6/30/93	6/30/93	0.21	9.3	55
18	BOLERO	7/1/93	7/1/93	0.22	5.6	30
19	MARINER	6/28/93	6/27/93	0.177	8.3	30
20	HP-778-5-1	6/28/93	6/27/93	0.162	6.7	60
21	FR 92	6/29/93	6/29/93	0.155	8.1	45
22	FR 138	7/2/93	7/2/93	0.25	5.9	20
23	FR 563	7/2/93	7/2/93	0.235	5.3	30
24	NUN 1901	6/29/93	6/28/93	0.132	6.6	90
25	HP-928-10-6	6/29/93	6/27/93	0.144	6	70
26	ENCORE	6/29/93	6/27/93	0.106	4.8	88
27	DSP	7/1/93	7/1/93	0.225	5.5	0
28	PF 307-2-1-1	6/30/93	6/30/93	0.165	8.1	50
29	XPF 294	6/29/93	6/29/93	0.133	5	50
30	STAMPEDE	7/1/93	7/1/93	0.217	2.8	30
31	FR 667	6/29/93	6/29/93	0.134	8.1	53
32	FR 568	7/6/93	7/6/93	0.182	3.6	0
33	KARISMA	6/29/93	6/29/93	0.11	9.5	50
34	NUN9862	6/29/93	6/29/93	0.133	7.7	67
35	LASER	7/2/93	7/2/93	0.219	4.3	60
36	QUAD	6/30/93	6/30/93	0.208	7	30
37	CMG-297 AF	6/30/93	6/30/93	0.21	4.5	10
38	NUN 1889	7/6/93	7/6/93	0.2	6.3	30
39	SANCHO	6/29/93	6/29/93	0.13	4.8	55
40	POLO	7/2/93	7/2/93	0.192	3.7	30
41	FR 763	7/2/93	7/2/93	0.186	6.4	68
42	FR 772	6/30/93	6/30/93	0.215	6.4	20
43	FR 102	6/30/93	6/30/93	0.191	5.7	50
44	FR 505	7/1/93	7/1/93	0.215	4.6	50
45	PD-606-2-3-3-2	7/6/93	7/6/93	0.191	8.5	60
LSD.05	-	-	-	0.029	2.9	ns

* Broken roots = percent of plants that broke loose at the roots instead of the stem breaking when pulling force was applied to measure anchor strength.

CLUB WHEAT BREEDING PROGRAM: PROGRESS IN 1993

P.K. Zwer

Club wheat has historically been an important class of wheat in the Pacific Northwest. The club wheat variety, Omar, was grown on 75 percent of the acreage sown to wheat in 1961. Unfortunately Omar was susceptible to stripe rust, a disease that had not been prevalent in the western United States until the late 1950's. By 1966 only 8 percent of the wheat acreage remained in club production. The club acreage was replaced by the new stripe rust resistant, semidwarf common variety, Gaines. Club wheat acreage has fluctuated from 2 to 20 percent in the PNW. Although club wheat production is small in comparison to common wheat production in the PNW, club wheat represents an important component of the Western wheat class marketed to the Pacific Rim countries. The PNW and Australia are the two major club wheat growing regions in the world.

The demand for club wheat is primarily based on the exceptional milling and baking qualities inherent in this class. Flour extraction is often higher in club than soft common wheat varieties. The low protein and type of protein make club wheat suitable for cakes and cookies.

Aside from the exceptional quality factors, club wheat has offered options for growers. Club wheat varieties have historically yielded well in shallow soils and regions with minimal soil moisture. Club wheat varieties released in recent years compete with the yield of common wheat varieties. Moreover, premiums are often associated with the sale of club wheat.

The club wheat breeding program was initiated in 1988 to develop improved varieties for eastern Oregon and Washington. Research priorities identified at the onset of the program include, milling and baking quality, disease and pest resistance, agronomic characteristics, and yield.

MATERIALS AND METHODS

The club wheat breeding program is conducted at the Columbia Basin Agricultural Research Center at Pendleton and Moro, OR. Breeding populations, disease nurseries, agronomic studies, and yield trials are located at the two research stations. The crossing program is conducted in the greenhouse at the Pendleton Research Center from December to May. Research projects, such as winter hardiness evaluations and drill strip trials are conducted in cooperation with Oregon and Washington growers.

Milling and Baking Quality. The USDA-ARS Western Wheat Quality Laboratory, Pullman, WA, analyzed 532 club wheat samples harvested in 1993. The club varieties, Omar, Paha, and Tres were used as the comparison checks for the breeding material. Lines were evaluated for test weight, wheat and flour protein, grain hardness, flour yield, break flour yield, flour ash, milling score, mixograph absorption, viscosity, cookie diameter, and sponge cake volume and score. Wheat and flour protein is measured by the NIR method. Grain hardness is an evaluation to distinguish between soft (<50) and hard (>50) wheat. Flour yield is the percent by weight of total products recovered as straight-grade white flour, and break flour yield is the percent by weight of total products recovered as flour from the break rolls. Flour ash is the percent ash from a 4 g sample of wheat flour ignited and heated for 15 hours at

550 °C in a muffle furnace. Milling score is generated from an equation using flour yield, flour ash, milling time, percent long patent, and first tempering moisture. Mixograph absorption measures flour water absorption as percent by weight. Viscosity is measured by a RVT Brookfield Synchro-Lectric Viscometer using a suspension of 20 g of flour in 100 mL of water and 7 mL of 1N lactic acid. A cookie is baked and the diameter is measured for cookie diameter. Larger values indicate superior baking quality. Cake volume is measured by volume displacement of canola seeds. Sponge cake score is an additive score of texture, volume, external factors, and crumb grain. Larger values again indicate superior baking quality.

Disease and Pest Resistance. Studies of the reactions of elite club lines, varieties, and introductions to strawbreaker foot rot were done in a nursery sown at Pendleton for the last three years. The 1993 experiment was sown on 14 September 1992 to maximize autumn seedling growth. The experiment was inoculated with spores of *Pseudocercosporella herpotrichoides*, the fungus that causes strawbreaker foot rot, in January to assure uniform disease development among the 162 entries and two replicates. A disease reaction was determined from a 25 tiller per replicate assessment in June 1993. The assessment scale was based on the percent of necrosis in a culm cross section, where 0 to 2.5 had less than 50 percent (resistant class), and 2.6 to 4.0 had more than 50 percent culm necrosis (susceptible class).

Inoculum of *Puccinia striiformis*, which causes stripe rust, was increased in the growth chamber and distributed onto breeding populations in January and February. Climatic conditions favored the survival of the pathogen, resulting in the uniform infection of the F_2 populations, and F_3, F_4, F_5, and advanced head rows. F_2 plants were selected on the basis of stripe rust reaction. Notes were also taken on the reaction to stripe rust and used to advance breeding lines to the next generation.

Agronomic Characters. An emergence study with 50 entries and four replications was sown on 19 August 1993 at the Pendleton Research Center. Elite club lines, varieties, and introductions were evaluated for emergence in warm soils with 4 in seed placement. Sixty seeds were sown in a 6 ft row. The genotypes were compared using an emergence rate index. Seedlings were counted for a 4 day period with day 1 designated when the first genotype emerged. This index was calculated by multiplying the number of seedlings that emerged on day 1, 2, 3, and 4 by 4, 3, 2, and 1.

Yield. One elite, three advanced, and nine preliminary yield trials were conducted at the Pendleton and Sherman Research Stations in 1993. The yield trials were sown at Pendleton on 28, 30 September and 1 October, and at Moro on 23 and 25 September 1992. More than 600 different genotypes were evaluated in 3,000 plots. Plots measured 16 ft long by 5 ft wide with 12 in row spacings. Nitrogen rates were applied according to the soil fertility tests. Target rates were 80 and 40 lb/a nitrogen (anhydrous ammonia) at Pendleton and Moro, respectively. Hoelon was applied as a preplant herbicide to control downy brome. Spring broadleaf weed control was a mixture of Harmony, Extra and Banvel.

RESULTS AND DISCUSSION

Milling and Baking Quality. The data were received for the elite club yield trial lines grown at Pendleton and Moro. Grain protein ranges were 6.1 to 8.4 percent at the two locations. Grain hardness values ranges from 13 to 44. Eight and 12 elite club lines (same 17 entries evaluated) were equal or better than Omar and Paha for milling score (Buhler mill) at Pendleton and Moro, respectively. Nine elite club lines milled on a Quad mill had milling scores equal to or better than Omar and Paha. Fifteen and 10 elite club lines (17 genotypes evaluated) grown at Pendleton and milled on a Buhler produced cookies and sponge cake equal to or better than Omar and Paha. Only four of the same 17 genotypes performed better than the checks for cookie diameter and sponge cake volume at Moro. About eight elite lines (14 genotypes evaluated) grown at both locations and milled on a Quad mill were equal to or better than the checks for cookie diameter.

Five elite lines are being evaluated for potential variety release. Milling and baking characters from 4 years and two locations are summarized in Table 1 for these lines. The club varieties, Omar and Tres, were the two checks consistently grown in the nurseries from which data were summarized. Grain hardness is well below 50, the cut-off point for differentiating soft and hard classes. Grain protein and flour yield are also between the range of the checks. Milling score, a combination of several milling factors, was equal to or better than Omar. Cookie diameter was also superior in the elite lines to Omar and Tres. Sponge cake volume was superior in three elite lines when compared to the checks, however two lines performed significantly poorer than Omar and Tres. Three of the five elite lines have overall quality equal or better than Omar, the superior quality check.

Disease and Pest Resistance. Stripe rust and leaf rust reactions were recorded for the 32,800 single head rows. Final decisions for selection were based on the disease reactions as well as seed color, kernel plumpness and other agronomic characters.

Table 1. Milling and baking characters for promising elite club lines, 9 site/years.

Line or variety	Grain hardness	Grain protein	Flour yield	Milling score	Cookie diameter	Cake volume	Cake score
		%	%		cm	cc	
OR90138	33	7.6	74.5	86.7	9.36	1378	80
OR90155	30	7.2	73.3	86.0	9.20	1363	80
OR90168	29	7.7	72.9	86.4	9.24	1380	81
OR90171	22	7.0	73.2	86.4	9.22	1299	75
OR91005	27	7.5	72.6	87.9	9.17	1278	72
Omar	35	8.1	74.3	86.0	9.11	1351	80
Tres	30	7.0	72.8	84.7	9.11	1325	75

The strawbreaker foot rot nursery data showed that a total of 59 lines and varieties were similar to Madsen, the most resistant strawbreaker foot rot variety presently available to growers. Lines developed in France were most resistant with reactions ranging from 0.40 to 1.40. Madsen and Gene, two PNW common varieties, were also in this resistant group, with scores of 1.45 and 1.65, respectively. Among the resistant 59 lines, 43 were elite club lines. Table 2 summarizes nine of the best elite club lines and the two most resistant common and club lines as checks. The introductions from France, as well as the elite club lines with resistance are being used in the crossing program to improve strawbreaker foot rot resistance. Several elite club lines have been maintained in the yield testing program, which indicates the material has combinations of characters that may make them suitable for release. Continued evaluation is needed to provide the overall worth of the lines. Strawbreaker foot rot and stripe rust reactions are summarized in Table 3 for the five elite club lines being considered for release.

Agronomic Characters. The rate-of-emergence study identified nine introductions from Pakistan with exceptional performance when seeded deep into warm soil. The lines had emergence rate indexes (ERI) between 51 and 118. Moro, the superior check variety had an ERI of 41, whereas Daws, the poor emerging check, had an ERI of 11. The material used for introducing Russian wheat aphid resistance into the club background performed similar to Moro. One elite club line had an ERI equal to Moro. The introductions and elite club lines that performed well under test conditions in the study are being used as parents in the crossing program.

Table 2. Strawbreaker foot rot reactions for nine elite club lines in 1992-93.

Line or variety	Disease‡ reaction	Program status
	0-4	
OR910003	1.02	crossing
OR910006	0.82	yield test
OR920006	1.15	yield test
OR920007	1.15	yield test
OR920020	1.00	crossing
OR920045	1.00	yield test
OR920046	1.40	yield test
OR920049	0.95	yield test
OR920060	0.95	crossing
Madsen	1.80†	
Hyak	2.70	

† Two year average for the checks.
‡ 0 is immune and 4 is susceptible.

Emergence rate indexes averaged for 2 years are summarized in Table 3 for the five promising elite lines. Four of the five lines are superior to Tres and Hyak, the most commonly grown club varieties at this time. One line averaged poorer than the two checks. In 1993 OR91005 had an ERI of 26 in comparison to 23 and 18 for Tres and Hyak, respectively. None of the lines approach the performance of Moro. The 2 year average for the new club variety, Rohde, was 45 in comparison to 35 and 39 for Hyak and Tres, respectively.

Yield. Based on yield data, disease reactions, agronomic characters, and quality, 320 genotypes were maintained for another year of evaluation in elite and advanced club

Table 3. Disease resistance and emergence for five promising elite club lines.

Line or variety	Stripe rust[†]	Strawbreaker foot rot[‡]	Rate of emergence[‡]
		0-4	
OR90138	R	2.9	55
OR90155	R	2.8	42
OR90168	R	2.7	60
OR90171	R	2.7	53
OR91005	R	2.1	31
Omar	S	---	66
Moro	S	---	70
Hyak	MR	2.7	35
Tres	S	3.0	39
Daws	---	---	22
Madsen	---	1.8	---

[†] R = resistant, MR = moderately resistant, and S = susceptible.

[‡] 2 year average.

Table 4. Yield for five elite club lines averaged from 1990 to 1993.

Line or variety	Location	
	Moro	Pendleton
	------------- bu/a ------------	
		--
OR90138	61	71
OR90155	66	72
OR90168	66	69
OR90171	66	79
OR91005	71	86
Hyak	65	74
Tres	66	71

yield trials. Table 4 summarizes the 4 year yield averages for the five promising elite club lines being considered for release. Hyak and Tres, the two most commonly grown club varieties, were used as checks for comparison. All lines but one, OR90138, performed equal to or better than Tres. OR91005 was the highest yielding line at both locations. OR90171 was 5 bu/a higher than Hyak at Pendleton. The remaining three lines were similar to Tres. The yield advantage of Hyak and OR91005 at Pendleton may reflect the improved strawbreaker foot rot tolerance in the variety and line.

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STATE-WIDE CEREAL VARIETY TESTING PROGRAM TRIALS IN THE COLUMBIA BASIN

Pam Zwer, Dave Sutherland
Russ Karow and Helle Ruddenklau

New cereal varieties are being released by Pacific Northwest plant breeders each year. In order to provide growers in all major cereal producing regions of Oregon with local data on new and old variety performance, a state-wide cereal variety testing program was initiated in 1992-93. Funding for this program is provided by Oregon State University (OSU) Agricultural Experiment Station, Oregon Wheat Commission and Oregon Grains Commission. Clerical and office support for the effort is provide by the OSU Extension Service. Growers provide trial sites and site management for three of 11 sites. Without the support provide by these four organizations and cooperating growers, this program would not be possible.

The program is centrally coordinated by Russ Karow, OSU Extension cereals specialist, and Helle Ruddenklau, Dept. of Crop and Soil Science research assistant. The central team, with the assistance of numerous student workers, obtains, packages and distributes seed to cooperators across the state. Cooperators, like Pam Zwer and Dave Sutherland in the Columbia Basin, plant, manage, and harvest the trials. The central team then processes the harvested grain, analyzes results, and provides summary data to county extension agents, seed dealers, fieldmen, and growers across the state.

Eleven sites are included in the testing network. Winter and spring barleys, triticales, and wheats from several market classes are being tested. Height, lodging, yield, test weight, and seed size are being determined for all varieties. Heading date, disease reactions, protein content and other quality factors are determined as time and labor allow.

MATERIALS AND METHODS

Dryland plots (5 x 17 feet) in Gilliam County, Pendleton, and Moro were seeded at a rate of 20 seeds per square foot. Plots in LaGrande (5 x 17 feet) and Hermiston (5 x 20 feet) were seeded at 30 seeds per square foot. Pounds per acre seeding rates for the dryland plots varied from a low of 60 pounds per acre for Gwen barley (14,630 seeds per pound) to a high of 117 pounds per acre for W301 wheat (7,440 seeds per pound) to achieve the desired 20 seeds per square foot. All plots were seeded using a small-pot drill. Seeding and harvest dates and production practices were typical for each location. Harvested grain was cleaned with a Peltz rub-bar cleaner prior to moisture, yield, and test weight determinations. All yields are reported on a 10 percent moisture adjusted basis and in 60 pound bushels for both wheat and triticales. Wheat and triticale protein percent were determined using near infrared analysis and are reported on a 12 percent moisture basis. Protein and plump grain percent determinations have yet to be made on barleys.

RESULTS AND DISCUSSION

Yield data for winter and spring grains over all five Basin tests sites are presented in Tables 1 and 2, respectively, along with an average over nine or 10 sites in the state-wide network. Individual site data are presented in Tables 3-21.

Winter wheat and triticales Stephens, Rod, Rohde, W301, and Gene were the highest yielding varieties averaged across dryland sites (Table 1). All five, except Rohde in Gilliam County, were above the trial average at each dryland site. Rod, Stephens, and Lewjain were the highest yielding varieties at LaGrande, while Malcolm, Rod, Stephens, and Hoff were highest under irrigation at Hermiston. We have known for years that Stephens has broad adaptation. This data suggests that Rod is also widely adapted. Rod was the only variety in the state-wide network to be above the trial average at all 11 sites.

There were no differences in lodging among varieties grown at dryland sites. Average protein level at Gilliam County (Table 3) was in the "normal" range (9-10 percent; Miller et al, 1993; Rasmussen, 1990) indicating optimum nitrogen fertilization. Proteins levels at Moro (Table 5) and Pendleton (Table 7) were low, indicating a possible nitrogen shortage. Pendleton yields were lower than expected, another indicator of limited nitrogen. Protein levels at Hermiston (Table 9) and LaGrande (Table 11) were slightly high, indicating that excess nitrogen was available to the crop. There were no disease problems in any of the trials.

Look at the seed per pound information for Pendleton (Table 7). The trial average was 10,549 seeds per pound, a value typical for Pacific Northwest wheats. But note the variation. Stephens had 8,447 seeds per pound while Rely had 12,670 - a difference of more than 4,000. Seed size must be carefully considered when seeding rate decisions are being made.

Note that Celia and Whitman triticales had dryland yield levels near those of the better wheats. Their yield was 70 bushels per acre or 4,200 pounds per acre, a yield similar to that of Steptoe barley. Growers may want to consider triticale as a rotational crop if it fits into the farm program system.

Winter barleys Except for Gwen, the winter barleys were similar in yield across dryland sites (Table 1). Gwen had a lower, though not statistically different, yield. Gwen is extremely winter hardy and was intended as a low-rainfall, dryland barley; however, it actually performed better under high-rainfall and irrigated conditions this year (Table 1). Steptoe continues to do well as a fall-planted variety across environments.

Spring wheat and triticales Spring wheat performance varied significantly across dryland environments except for Wakanz and Treasure (Table 2). Wakanz had the highest wheat yield within and across drylands environments. Wakanz has performed well in past dryland tests (Zwer et al, 1991). Treasure had lower yields than Wakanz, but yielded consistently above the trial average for each dryland site (Table 2).

Note the triticale yields once again (Table 2). Victoria, a triticale released by Resource Seeds of Gilroy, CA, had a higher average yield than all wheats across dryland sites. Spring triticales were also top-yielders at Hermiston, LaGrande, and on a state-wide basis. You will note that Celia was planted in both the winter and spring trials. It is a facultative grain with a slight vernalization requirement. It has excellent winterhardiness. Celia is one of the few cereal varieties where the strong linkage between winter hardiness and vernalization requirement has been broken.

Average protein level was high at LaGrande (Table 20), low in Gilliam County (Table 13) and in the normal range at other sites. The hard wheats Klasic and WB926R showed higher protein levels than most of the other varieties at all sites, but had low protein in general. Only WB926R grown at La-

Grande (Table 20) would have met a 14 percent hard wheat protein specification.

Note once again the extreme variation in seed size. The LaGrande site had shrunken seed (see test weight and seed size, Table 20). Wakanz had over 18,000 seeds per pound!

Spring barleys There were no significant differences (at the 5 percent level) among barleys across Columbia Basin test sites (Table 2). All barleys yielded well. It was a spring barley year. On a pound per acre basis, spring barleys had a higher average yield than the spring wheats and the winter barleys except for one site. Spring barley yield exceeded the winter wheat and triticale yield at two of the five Basin sites.

Baronesse is the new "fair-haired child" of spring barleys. It has yielded well across locations, both in Oregon and Washington, and has had excellent test weights. It is slightly taller than Steptoe and has shown better lodging resistance in most, but not all, environments.

THE FUTURE

The information presented here is for only one year. Growers are encouraged to combine the data in this report with that found in previous year field day reports and Extension publications (SR 775, Winter Wheats for Oregon; Crop Science Reports on the other winter and spring grains) to make variety selection decisions. These publications are available through your local county Extension office. Carefully consider your available markets and the special needs of your production system as you make choices.

The state-wide variety testing program is in the second year of a two-year trial period. An evaluation of program success and efficiency will be made by the funding agencies after harvest 1994. Suggestions for program improvement should be directed to Russ Karow.

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Table 1. 1993 winter grain yield data for the Columbia Basin and an average for nine or 10 sites in the state-wide variety testing network.

Variety	Grain Type	Gilm	Moro	Pend	Dryland average	Herm	LaGr	10-site average
Winter wheats and triticales (60 pound bushels per acre; 10% moisture basis)								
Hyak	Club wheat	60	77	54	64	97	--	--
Rely	Club wheat	64	85	56	68	--	--	--
Rohde	Club wheat	53	86	75	71	118	74	95
Tres	Club wheat	64	75	56	65	--	93	--
Hoff	HR wheat	45	70	60	59	127	90	87
Cashup	SW wheat	--	79	62	--	111	--	--
Daws	SW wheat	63	69	49	60	118	89	89
Gene	SW Wheat	64	83	67	71	103	66	92
Hill81	SW wheat	44	73	57	58	--	98	--
Kmor	SW wheat	56	81	53	63	--	--	--
Lewjain	SW wheat	54	83	49	62	--	108	--
MacVicar	SW wheat	55	83	64	67	117	75	100
Madsen	SW wheat	52	73	66	64	118	94	98
Malcolm	SW wheat	50	70	65	62	140	88	102
Nugaines	SW wheat	--	--	--	--	--	84	--
Rod	SW wheat	72	80	67	73	129	117	108
Stephens	SW wheat	71	84	76	77	128	102	103
W301	SW wheat	66	79	69	71	122	67	98
Celia	triticale	74	67	68	70	111	88	95
Whitman	triticale	55	78	76	70	126	101	95
Trial average		59	77	63	66	119	90	97
PLSD (5%)		17	11	16	NS	21	25	10
PLSD (10%)		14	9	14	10	15	21	8
CV percent		17	8	16	11	11	17	11

Winter barleys (pounds per acre; 10% moisture basis)								9 site average
Gwen	6R F	2163	4684	3635	3494	5389	4019	4702
Hesk	6R F	3412	4726	4009	4049	3748	4041	4674
Hundred	6R F	3132	5424	4562	4373	4350	4677	4963
Kamiak	6R F	3019	5348	3955	4107	----	2859	----
Kold	6R F	2819	5543	4311	4224	3387	4568	5062
Showin	6R F	2761	5095	4207	4021	5186	3747	----
Steptoe	6R F	3628	5172	3942	4247	6331	4504	5085
Trial average		2991	5142	4089	4074	4732	4059	4897
PLSD (5%)		748	NS	NS	NS	1100	NS	NS
PLSD (10%)		612	NS	NS	447	900	NS	NS
CV percent		14	15	9	8	13	18	14

Trial averages include some data not shown.

Table 2. 1993 spring grain yield data for the Columbia Basin and an average for nine or 10 sites in the state-wide variety testing network.

Variety	Grain type	Gilm	Moro	Pend	Dryland average	Herm	LaGr	10 site average
Spring wheats and triticales (60 pound bushels per acre; 10% moisture)								
Calorwa	club wheat	42	29	33	35	65	61	51
WB926R	HR wheat	54	43	53	50	58	73	61
Klasic	HW wheat	44	24	33	34	40	75	50
Centennial	SW wheat	44	48	39	43	58	70	61
Dirkwin	SW wheat	52	46	40	46	85	61	57
ML042A	SW wheat					76		
Owens	SW wheat	52	36	50	46	76	65	62
Penawawa	SW wheat	49	40	33	41	79	64	55
Treasure	SW wheat	55	49	50	51	83	62	63
Wakanz	SW Wheat	59	62	58	60		58	
Celia	triticale	25	47	59	44	76	48	
Juan	triticale	47	53	48	49	105	74	69
RCI200	triticale			67		107		
Victoria	triticale	58	62	64	61	95	65	74
Trial average		48	45	48	47	77	65	60
PLSD (5%)		12	6	13	13	21	13	12
PLSD (10%)		10	5	11	11	18	11	10
CV percent		14	9	16	17	16	12	22

Spring barleys (pounds per acre; 10% moisture)								9 site average
Baronesse	2R F	3849	4416	--	4133	6307	5906	5534
Crest	2R M	3401	3938	--	3670	6615	5950	4988
Crystal	2R M	3752	4167	--	3960	6556	5456	5238
Columbia	6R F	--	--	--	--	5753	--	--
Gustoe	6R F	--	--	--	--	5210	--	--
Maranna	6R F	4104	4276	--	4190	7712	5866	5447
Steptoe	6R F	4527	4322	--	4425	6731	5723	5354
Colter	6R F/M	3996	3774	--	3885	6104	5441	5051
Russell	6R M	3421	3834	--	3628	5340	6375	4639
Trial average		3864	4104	--	3984	6259	5817	5179
PLSD (5%)		NS	NS	--	NS	NS	NS	542
PLSD (10%)		NS	421	--	NS	NS	NS	452
CV percent		22	7	--	6	21	13	11

Trial averages include some data not shown. Pendleton barley was lost during processing.

Table 3. 1993 state-wide variety testing program winter wheat and triticale trial on the Steve Anderson Farm, Gilliam Co.

Variety	Height	Moisture	Yield	Test wgt	kernel wgt	Seeds	Protein	Hardness
	(in)	%	(bu/a)	(lb/bu)	g/1000	per lb	%	
BZ702	29.7	9.5	57.4	61.1	49.7	9127	9.4	41
Celia	29.0	9.3	74.4	59.9	48.1	9430	9.1	67
Daws	29.0	9.5	62.8	61.9	42.6	10640	9.2	45
Gene	28.0	9.5	63.8	60.0	43.8	10363	9.7	39
Hill81	29.0	9.8	43.6	62.7	39.7	11426	10.2	34
Hoff	27.7	9.8	45.1	63.9	44.8	10118	11.4	87
Hyak	26.3	10.0	59.7	61.7	41.7	10878	9.3	43
Kmor	28.0	9.7	55.5	61.0	42.8	10598	9.1	35
Lewjain	27.7	9.4	53.5	62.8	43.0	10541	9.9	40
Madsen	27.3	9.5	51.5	62.4	43.1	10517	11.3	47
Malcolm	28.0	9.6	50.2	61.4	51.0	8894	9.1	39
MacVicar	29.3	9.6	54.8	62.4	49.5	9158	9.3	48
Rely	28.0	9.9	64.2	60.1	35.9	12635	8.6	25
Rod	29.3	9.7	72.2	60.9	45.1	10058	8.9	38
Rohde	25.7	9.6	53.4	62.3	41.3	10991	9.1	37
Stephens	25.3	9.7	70.5	61.4	49.9	9085	9.4	35
Tres	29.0	9.9	63.7	61.7	38.0	11937	8.3	41
W301	27.7	9.7	65.7	60.5	46.2	9825	8.7	39
Whitman	35.7	9.6	55.1	54.4	49.6	9140	9.6	64
Mean	28.4	9.6	58.8	61.2	44.5	10193	9.4	44
PLSD (5%)	2.0	NS	16.5	1.3	5.5	1260	1.28	14
PLSD (10%)	1.7		13.7	1.1	4.6	1049	1.1	12
CV percent	4	3	17	1	7	7	8	19

Yields adjusted to 10% moisture.
Trial managers: Pam Zwer and Dave Sutherland.
Grower Cooperator: Steve Anderson

Table 4. 1993 state-wide variety testing program winter barley trial on the Steve Anderson Farm, Gilliam Co.

Variety	Height (in)	Moisture %	Yield (lb/a)	Test wgt (lb/bu)	kernel wgt. g/1000	Seeds per lb
Gwen	18.7	9.9	2163	50.0	39.3	11542
Hesk	17.3	9.7	3412	48.1	43.0	10541
Hundred	19.3	9.9	3132	46.8	33.5	13552
Kamiak	22.0	9.8	3019	51.3	38.8	11700
Kold	19.3	9.9	2819	51.6	38.3	11853
Showin	16.3	9.9	2761	48.2	39.5	11492
Steptoe	24.7	10.0	3628	50.2	51.2	8859
Mean	19.7	9.9	2991	49.5	40.5	11200
PLSD (5%)	4.4	NS	748	1.4	3.3	912
PLSD (10%)	3.6	NS	612	1.1	2.7	746
CV percent	13	5	14	2	4	4

All are six-row feed barleys. Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland
Grower cooperator: Steve Anderson

Table 5. 1993 state-wide variety testing program winter wheat and triticale trial on the Moro Experiment Station.

Variety	Height	Lodge	Shatter	Yield	Test wgt	kernel wgt	Seeds	Protein	Hardness
	(in)	%	%	(bu/a)	(lb/bu)	g/1000	per lb	%	
BZ702	33.7	0.0	0.0	73.7	58.0	47.6	9523	7.0	31
Cashup	30.3	0.0	0.0	79.1	58.5	40.3	11247	6.7	19
Celia	35.3	0.0	0.0	67.1	57.4	40.2	11284	5.6	49
Daws	33.7	0.0	0.0	69.1	61.1	48.7	9314	7.6	31
Gene	30.0	0.0	0.0	82.5	58.4	45.0	10073	6.8	20
Hill 81	34.7	0.0	0.0	73.3	58.9	37.5	12096	7.2	32
Hoff	34.3	0.0	0.0	70.4	61.5	41.8	10859	7.0	56
Hyak	33.0	0.0	0.0	76.7	58.5	37.1	12226	6.5	23
Kmor	31.7	0.0	0.0	81.1	57.3	42.7	10630	6.0	23
Lewjain	33.3	0.0	0.0	82.9	59.5	39.2	11580	6.6	26
MacVicar	35.0	0.0	0.0	82.8	58.4	49.6	9145	6.5	21
Madsen	33.0	0.0	0.0	73.4	59.3	42.1	10782	7.7	33
Malcolm	32.3	0.0	0.0	70.4	58.7	46.3	9797	6.2	25
Rely	35.0	0.0	0.0	84.7	57.2	37.2	12184	6.0	15
Rohde	34.3	0.0	0.0	85.5	58.9	38.2	11874	6.6	26
Rod	32.7	0.0	0.0	80.4	57.1	44.6	10164	6.6	29
Stephens	33.7	0.0	0.0	84.3	54.9	47.8	9495	6.5	14
Tres	35.3	0.0	0.0	74.8	57.0	36.6	12404	6.3	14
W301	33.0	0.0	0.0	78.9	58.8	48.4	9372	7.3	30
Whitman	40.3	0.0	0.0	77.8	52.6	45.7	9932	7.3	48
Mean	33.7	–	–	77.4	58.1	42.8	10598	6.7	28
PLSD (5%)	2.4	–	–	10.8	2.2	4.1	1015	0.8	10
PLSD (10%)	2.0	–	–	9.0	1.8	3.4	846	0.7	8
CV percent	4	–	–	8	2	6	6	7	21

All yields adjusted to 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland

Table 6. 1993 state-wide variety testing program winter barley trial on the Moro Experiment Station.

Variety	Height	Moisture	Yield	Test wgt	kernel wgt	Seeds
	(in)	%	(lb/a)	(lb/bu)	g/1000	per lb
Gwen	28.7	11.0	4684	50.4	42.1	10782
Hesk	28.3	11.0	4726	47.6	44.2	10255
Hundred	26.0	10.6	5424	45.4	41.6	10912
Kamiak	32.7	10.6	5348	51.7	47.4	9576
Kold	21.7	10.9	5543	48.4	41.6	10912
Showin	32.0	11.3	5095	50.4	46.0	9867
Steptoe	30.0	11.2	5172	50.7	44.0	10316
Mean	28.5	10.9	5142	49.2	43.8	10356
PLSD (5%)	3.0	NS	NS	0.9	NS	NS
PLSD (10%)	2.5	NS	NS	0.7	NS	NS
CV percent	6	3	15	1	13	13

All are six-row feed barleys. Yields adjusted to a 10% moisture basis.
Trial Managers: Pam Zwer and Dave Sutherland

Table 7. 1993 state-wide variety testing program winter wheat and triticale trial at the Columbia Basin Ag Research Center, Pendleton.

Variety	Height (in)	Lodge %	Shatter %	Moisture %	Yield (bu/a)	Test wgt (lb/bu)	kernek wgt g/1000	Seeds per lb	Protein %	Hardness
BZ702	33.7	0.0	0.0	10.6	72.2	59.2	48.2	9411	5.5	8
Cashup	31.3	0.0	0.0	11.1	61.7	58.7	38.0	11937	5.7	11
Celia	34.3	0.0	0.0	10.3	67.8	58.6	43.6	10404	6.0	27
Daws	30.3	0.0	0.0	10.7	48.7	61.2	48.3	9391	5.5	10
Gene	29.3	0.0	0.0	10.9	67.4	59.2	38.6	11751	5.9	16
Hill 81	33.0	0.0	0.0	10.7	57.4	59.6	39.4	11513	5.8	17
Hoff	35.7	0.0	0.0	11.1	60.3	62.8	40.7	11145	5.5	10
Hyak	32.3	0.0	0.0	10.9	54.1	56.9	36.4	12462	5.7	40
Kmor	32.3	0.0	0.0	10.8	53.0	57.5	45.8	9904	6.0	27
Lewjain	32.0	0.0	0.0	10.8	48.7	59.2	38.9	11631	5.7	24
MacVicar	32.7	1.7	0.0	10.7	63.8	60.1	44.4	10216	6.4	32
Madsen	30.7	0.0	0.0	11.2	65.8	59.1	39.0	11631	6.3	12
Malcolm	33.3	0.0	0.0	10.7	64.6	60.0	47.3	9590	5.7	19
Rely	35.3	0.0	0.0	10.9	56.4	57.9	35.7	12670	5.8	20
Rod	32.3	0.0	0.0	10.6	67.1	57.7	41.3	10983	5.7	17
Rohde	35.3	0.0	0.0	10.7	74.5	60.2	45.8	9904	6.2	22
Stephens	32.3	0.0	0.0	10.9	75.6	59.0	53.7	8447	5.8	19
Tres	34.7	0.0	0.0	11.1	56.1	59.4	36.1	12565	6.3	11
W301	31.0	0.0	0.0	11.2	69.0	58.8	47.1	9631	6.1	32
Whitman	44.7	0.0	0.0	10.6	76.0	54.1	52.5	8640	6.2	34
Mean	33.3	0.0	–	10.8	62.9	59.0	43.0	10549	5.9	20
PLSD (5%)	3.7	–	–	0.4	16.4	1.0	7.0	1717	NS	NS
PLSD (10%)	3.1	–	–	0.3	13.7	0.8	5.9	1431	NS	NS
CV percent	8	–	–	2	16	1	10	9	10	72

Yields adjusted to 10% moisture level.
Trial Managers: Pam Zwer and Dave Sutherland

Table 8. 1993 state-wide variety testing program winter barley trial at the Columbia Basin Ag Reserach Center, Pendleton.

Variety	Height (in)	Lodging %	Shatter %	Moisture %	Yield (lb/a)	Test wgt (lb/bu)	kernel wgt g/1000	Seeds per lb
Gwen	39.0	0.0	1.3	12.6	3635	51.8	32.67	13884
Hesk	32.0	0.0	1.7	13.4	4009	50.0	40.63	11164
Hundred	30.3	0.0	1.3	12.5	4562	48.5	32.33	14030
Kamiak	40.3	0.0	2.0	12.8	3955	50.9	35.43	12803
Kold	31.0	0.0	1.3	12.7	4311	50.8	32.53	13944
Showin	23.7	0.0	1.3	12.3	4207	47.2	33.47	13552
Steptoe	39.7	0.0	1.7	12.5	3942	51.2	42.73	10615
Mean	33.7	0.0	1.5	12.7	4089	50.1	35.69	12706
PLSD (5%)	3.6	–	NS	NS	NS	1.0	2.8	997
PLSD (10%)	2.9	–	NS	NS	NS	0.8	2.3	815
CV percent	6	–	37	4	9	1	4	4

All are six-row feed barleys. Yields adjusted to a 10% moisture level.
Trial Managers: Pam Zwer and Dave Sutherland

Table 9. 1993 state-wide variety testing program winter wheat and triticale trial on Eastern Oregon Farms, Hermiston, OR.

Variety	Height	Yield	Test wgt	kernel wgt	Seeds	Protein	Hardness
	(in)	(bu/a)	(lb/bu)	g/1000	per lb	%	
BZ702	36	121.4	59.5	51.6	8791	10.6	53
Cashup	36	111.0	57.8	39.8	11388	11.0	44
Celia	41	110.7	56.1	48.3	9391	10.3	58
Daws	37	118.3	58.6	45.8	9904	10.0	55
Gene	33	102.7	58.5	45.0	10080	11.8	43
Hoff	42	126.9	61.6	46.4	9776	12.3	104
Hyak	37	97.3	52.5	34.3	13224	11.3	52
MacVicar	38	116.5	57.8	49.8	9108	10.7	53
Madsen	37	118.4	60.2	47.1	9631	10.6	52
Malcolm	37	139.9	57.7	49.5	9164	10.6	48
Rohde	36	118.2	58.6	36.4	12462	10.4	54
Rod	40	128.9	55.8	43.9	10333	10.2	54
Stephens	35	127.6	59.2	52.4	8656	10.4	60
W301	36	122.3	57.6	50.9	8912	11.6	57
Whitman	50	125.9	53.7	54.6	8308	10.9	63
Mean	38	119.1	57.7	46.4	9778	10.8	56.6
PLSD (5%)	2	21.0	2.0	5.2	1096	1.2	10.3
PLSD (10%)	2	17.5	1.7	4.3	911	1.0	8.6
CV percent	4	11	2	7	7	7	11

Yields adjusted to 10% moisture.

Trial managers: Mat Kolding and Helle Ruddenklau
Grower cooperator: Eastern Oregon Farming Company

Table 10. 1993 state-wide variety testing program winter barley trials on Eastern Orgeon Farms, Hermiston, OR.

Variety	Height	Yield	Test wgt	kernel wgt	Seeds
	(in)	(lb/a)	(lb/bu)	g/1000	per lb
Gwen	39	5389	49.1	35.4	12814
Hesk	38	3748	45.4	38.2	11874
Hundred	37	4350	43.4	29.8	15221
Kold	39	3387	45.5	33.1	13704
Showin	33	5186	42.7	30.9	14680
Steptoe	37	6331	46.9	47.1	9631
Mean	37	4732	45.5	35.8	12670
PLSD (5%)	5	1100	2.4	6.6	2336
PLSD (10%)	4	895	2.0	5.4	1900
CV percent	5	14	3	10	10

All are six-row feed barleys. Yields adjusted to a 10% moisture level.
Trial managers: Mat Kolding and Helle Ruddenklau

Grower cooperator: Eastern Oregon Farming Company

Table 11. 1993 State-wide variety testing program winter wheat and triticale trial on the Cuthbert Farm, LaGrande, OR.

Variety	Height	Lodging	Shatter	Yield	Test weight	kernel wgt	Protein	Hardness
	(in)	%	%	(bu/a)	(lb/bu)	g/1000	%	
BZ702	34	0	0	86.5	59.1	51.9	11.5	35.0
Celia	35	0	0	88.2	55.9	49.3	10.4	46.0
Daws	34	0	0	89.0	61.0	49.1	10.8	43.0
Gene	31	0	0	65.5	57.7	46.4	7.0	26.0
Hill81	38	0	0	97.5	60.3	44.6	9.5	27.0
Hoff	35	0	0	89.5	61.1	49.6	11.3	70.0
Lewjain	35	0	0	107.7	59.6	41.0	9.6	29.0
MacVicar	35	0	0	74.7	59.5	52.7	10.8	33.0
Madsen	35	0	0	93.9	59.4	41.5	11.0	34.0
Malcolm	35	0	0	88.0	60.2	48.9	10.4	34.0
Nugaines	32	0	0	84.1	59.6	44.3	9.8	18.0
Rod	36	0	0	116.6	59.0	51.1	9.2	31.0
Rohde	34	0	0	74.2	61.1	46.9	11.4	34.0
Stephens	33	0	0	102.4	58.4	56.0	10.8	30.0
Tres	36	0	0	93.4	60.1	42.9	10.2	34.0
W301	33	0	0	66.8	58.2	49.4	10.7	31.0
Whitman	44	0	0	101.3	54.8	55.9	10.3	50.0
Mean	35	--	--	89.5	59.1	48.3	10.6	36
PLSD (5%)	3	--	--	25.2	1.2	5.4	1.2	7.0
PLSD (10%)	2	--	--	20.9	1.0	4.5	1.0	5.8
CV percent	5	--	--	17	1	7	7	12

Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland
Grower cooperator: John Cuthbert

Table 12. 1993 state-wide variety testing program winter barley trial on the Cuthbert Farm, LaGrande, OR.

Variety	Height	Yield	Test wgt	kernel wgt	Seeds
	(in)	(lb/a)	(lb/bu)	g/1000	per lb
Gwen	29.0	4019	44.7	37.8	11990
Hesk	33.0	4041	48.5	45.4	9998
Hundred	27.0	4677	44.3	36.8	12336
Kamiak	32.0	2859	46.7	38.7	11712
Kold	32.0	4568	49.6	40.8	11109
Showin	26.0	3747	44.5	41.3	10991
Steptoe	32.0	4504	548.2	44.9	10096
Mean	30.0	4059	46.6	40.8	11112
PLSD (5%)	2.0	NS	1.9	NS	NS
PLSD (10%)	1.6	NS	1.6	NS	NS
CV percent	4	18	2	15	15

All are six-row feed barleys. Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland
Grower cooperator: John Cuthbert

Table 13. 1993 state-wide variety testing program spring wheat and triticale trial on the Clarence Bare Ranch, Gilliam Co.

Variety	Grain type	Height	Yield	Test wgt	kernel wgt	Seeds	Protein	Hardness
		(in)	(bu/a)	(lb/bu)	g/1000	per lb	%	
Calorwa	club wheat	24	42.3	60.7	34.0	13353	8.2	16
WB926R	HRS wheat	26	54.1	62.3	46.4	9770	8.1	58
Klasic	HW Wheat	19	44.2	64.2	44.9	10102	8.0	53
Centennial	SW Wheat	25	43.6	60.3	38.3	11853	7.4	12
Dirkwin	SW Wheat	29	52.3	52.8	39.1	11601	7.6	8
Owens	SW Wheat	28	52.4	59.7	37.5	12086	7.0	12
Penawawa	SW Wheat	24	48.9	61.6	39.5	11484	6.9	13
Treasure	SW Wheat	27	54.5	55.2	38.5	11782	7.5	7
Wakanz	SW Wheat	28	58.7	61.3	39.2	11571	7.1	18
Celia	triticale	33	25.1	35.2	--	--	--	--
Juan	triticale	37	47.3	35.1	--	--	--	--
Victoria	triticale	32	57.7	48.9	49.4	9177	6.9	28
Average		28	48.4	54.8	40.7	11150	7.5	23
PLSD (5%)		4	11.6	6.1	3.1	860	NS	10
PLSD (10%)		3	10	5	3	713	NS	8
CV percent		8	14	7	5	5	9	26

Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland
Grower cooperator: Clarence Bare

Table 14. 1993 state-wide variety testing program spring barley trial on the Clarence Bare Ranch, Gilliam Co.

Variety	Grain type	Height	Yield	Test wgt	kernel wgt	Seeds
		(in)	(bu/a)	(lb/bu)	g/1000	per lb
Baroness	2R F	24	3849	56.3	47.3	9596
Crest	2R M	26	3401	56.2	46.2	9825
Crystal	2R M	26	3752	54.7	49.6	9145
Maranna	6R F	24	4104	54.1	38.6	11742
Steptoe	6R F	28	4527	52.3	44.2	10262
Colter	6R F/M	29	3996	53.5	42.8	10598
Russell	6R M	29	3421	54.7	40.6	11164
Average		26	3864	54.6	44.2	10265
PLSD (5%)		3	NS	0.4	3.7	866
PLSD (10%)		2	NS	0.3	2.5	576
CV percent		7	22	4	5	5

Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland
Grower cooperator: Clarence Bare

Table 15. 1993 state-wide variety testing program spring wheat and triticale trial on the Moro Experiment Station.

Variety	Grain type	Height	Yield	Test wgt	kernel wgt	Seeds	Protein	Hardness
		(in)	(bu/a)	(lb/bu)	g/1000	per lb	%	
Calorwa	club wheat	19	29.0	61.2	38.9	11652	11.6	23
WB926R	HR wheat	23	43.2	62.6	45.8	9904	11.5	55
Klasic	HW Wheat	16	23.9	63.3	44.4	10209	13.1	63
Centennial	SW wheat	22	47.9	62.8	41.9	10826	10.0	25
Dirkwin	SW wheat	25	46.2	59.2	39.5	11484	10.0	23
Owens	SW wheat	24	35.5	61.9	34.1	13302	10.3	16
Penawawa	SW wheat	22	39.6	62.2	39.6	11463	10.7	14
Treasure	SW wheat	24	48.6	61.4	36.5	12427	10.4	17
Wakanz	SW wheat	24	61.9	62.1	38.3	11843	9.5	26
Celia	triticale	27	47.0	57.0	42.5	10680	9.5	39
Juan	triticale	30	52.5	54.6	52.2	8685	9.4	35
Victoria	triticale	26	62.4	54.8	51.9	8745	9.7	33
Average		23	44.8	60.3	42.1	10767	10.5	31
PLSD (5%)		2	6.5	1.1	4.3	1100	0.7	12
PLSD (10%)		2	5.4	0.9	3.6	910	0.6	10
CV percent		6	9	1	6	6	4	23

Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland

Table 16. 1993 state-wide variety testing program spring barley trial on the Moro Experiment Station.

Variety	Grain type	Height	Yield	Test wgt	kernel wgt	Seeds
		(in)	(bu/a)	(lb/bu)	g/1000	per lb
Baronesse	2R F	20	4416	53.4	38.7	11721
Crest	2R M	21	3938	53.0	41.2	11010
Crystal	2R M	22	4167	54.0	43.3	10476
Maranna	6R F	17	4276	51.4	33.6	13488
Steptoe	6R F	20	4322	49.8	42.9	10566
Colter	6R F/M	20	3774	50.5	36.0	12611
Russell	6R M	20	3834	54.0	37.8	11990
Average		20	4104	52.3	39.1	11607
PLSD (5%)		2	NS	1.8	4.8	1425
PLSD (10%)		2	421	1.5	3.9	1165
CV percent		6	7	2	7	7

Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland

Table 17. 1993 state-wide variety testing program spring wheat and triticale trial on the Columbia Basin Ag Research Center, Pendleton, OR.

Variety	Grain type	Height	Yield	Test wgt	kernel wgt	Seeds	Protein	Hardness
		(in)	(bu/a)	(lb/bu)	g/1000	per lb	%	
Calorwa	club wheat	23	32.5	62.0	34.6	13098	10.4	20
WB926R	HR wheat	27	53.1	63.3	49.7	9132	11.8	54
Klasic	HW Wheat	16	32.8	63.8	41.4	10949	11.5	42
Centennial	SW wheat	24	38.9	62.4	35.8	12660	8.5	17
Dirkwin	SW wheat	25	39.6	57.9	37.2	12194	9.6	23
Owens	SW wheat	27	49.7	61.7	33.7	13448	9.1	15
Penawawa	SW wheat	24	33.2	62.2	38.0	11946	9.8	9
Treasure	SW wheat	26	49.8	60.8	36.3	12486	8.6	19
Wakanz	SW wheat	26	58.2	62.9	37.2	12194	8.5	20
Celia	triticale	33	58.6	57.4	45.5	9963	9.0	48
Juan	triticale	34	48.3	54.2	48.7	9308	7.8	46
RCI2700	triticale	43	66.9	55.6	52.7	8602	7.9	37
Victoria	triticale	28	64.0	55.5	44.9	10102	8.0	39
Average		27	48.1	60.0	41.2	11004	9.3	30
PLSD (5%)		2	12.8	0.7	5.2	1395	1.4	13
PLSD (10%)		2	10.6	0.6	4.3	1156	1.1	11
CV percent		5	16	1	8	8	9	27

Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland

Table 18. 1993 state-wide variety testing program spring wheat and triticale trial on the Hermiston Experiment Station.

Variety	Grain type	Height	Yield	Test wgt	kernel wgt	Seeds	Protein	Hardness
		(in)	(bu/a)	(lb/bu)	g/1000	per lb	%	
Calorwa	club wheat	27	65.4	60.8	36.9	12440	10.2	29
WB926R	HR wheat	26	57.5	63.4	50.3	9057	12.6	77
Klasic	HW wheat	21	40.2	60.6	39.1	11620	12.1	44
Centennial	SW wheat	30	57.7	62.5	37.0	12260	9.2	28
Dirkwin	SW wheat	33	85.2	59.3	41.8	10850	9.3	27
ML042A	SW wheat	33	76.1	63.5	43.7	10450	10.1	41
Owens	SW wheat	34	75.6	62.0	39.2	11660	9.4	24
Penewawa	SW wheat	29	78.9	63.2	45.9	9914	9.5	22
Treasure	SW wheat	32	83.3	61.7	42.3	10760	8.7	35
Celia	triticale	34	75.8	58.5	47.7	9515	9.6	41
Juan	triticale	45	105.0	57.6	52.7	8613	8.8	52
RCI200	triticale	49	107.2	57.1	52.5	8659	9.2	38
Victoria	triticale	39	95.1	56.8	51.3	8877	9.3	45
Average		33	77.2	60.5	44.7	10360	9.8	39
PLSD (5%)		3	21.2	1.2	5.6	1403	0.9	10
PLSD (10%)		3	17.6	1.0	4.6	1164	0.7	8
CV percent		6	16	1	7	8	5	16

Yields adjusted to a 10% moisture level.
Trial managers: Mat Kolding and Helle Ruddenklau

Table 19. 1993 state-wide variety testing program spring barley trial on the Hermiston Experiment Station.

Variety	Grain type	Height (in)	Lodging %	Yield (lb/a)	Test wgt (lb/bu)	kernel wgt g/1000	Seeds per lb
Baronesse	2R F	30	80	6307	52.3	43.4	10450
Crest	2R M	32	57	6615	51.6	42.2	10790
Crystal	2R M	33	3	6556	53.6	52.7	8603
Columbia	6R F	27	0	5753	47.2	54.1	8399
Gustoe	6R F	23	0	5210	47.0	43.2	10510
Maranna	6R F	25	0	7712	49.6	42.5	10710
Steptoe	6R F	27	35	6731	48.7	51.1	8903
Colter	6R F/M	31	0	6104	48.3	45.4	9999
Russell	6R M	31	0	5340	48.4	45.5	9983
Average		29	19	6259	49.6	46.7	9815
PLSD (5%)		4	48	NS	1.0	3.7	830
PLSD (10%)		4	40	NS	0.8	3.1	685
CV percent		9	144	21	1	5	5

Yields adjusted to a 10% moisture level.
Trial managers: Mat Kolding and Helle Ruddenklau

Table 20. 1993 state-wide variety testing program spring wheat and triticale trial on the Cuthbert Ranch, LaGrande, OR.

Variety	Grain type	Height (in)	Yield (bu/a)	Test wgt (lb/bu)	kernel wgt g/1000	Seeds per lb	Protein %	Hardness
Calorwa	Club wheat	32	60.7	58.5	27.0	16800	12.2	4
WB926R	HR wheat	35	73.2	59.0	34.4	13198	14.4	24
Klasic	HW Wheat	25	75.3	60.6	37.4	12119	13.3	28
Centennial	SW wheat	35	69.8	59.1	27.7	16393	11.3	9
Dirkwin	SW wheat	43	61.3	50.7	26.9	16862	12.5	15
Owens	SW wheat	39	65.0	56.0	26.4	17162	12.3	4
Penawawa	SW wheat	37	63.7	57.4	27.7	16375	12.8	4
Treasure	SW wheat	37	62.3	54.4	25.1	18050	13.0	0
Wakanz	SW wheat	37	57.9	54.4	25.0	18122	12.8	6
Celia	triticale	38	47.5	47.2	34.4	13198	13.2	29
Juan	triticale	47	74.4	51.3	41.4	10957	11.8	19
Victoria	triticale	43	65.1	48.6	32.1	14118	12.8	25
Average		37	64.7	54.8	30.5	14892	12.7	14
PLSD (5%)		4	12.7	2.8	5.6	2734	1.4	17
PLSD (10%)		3	10.5	2.3	4.6	2246	1.1	14
CV percent		6	12	3	11	11	6	74

Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland
Grower cooperator: John Cuthbert

Table 21. 1993 state-wide variety testing program spring barley trial on the Cuthbert Ranch, LaGrande, OR.

Variety	Grain type	Height (in)	Lodging %	Yield (bu/a)	Test wgt (lb/bu)	kernel wgt g/1000	Seeds per lb
Baronesse	2R F	34	17	5906	51.5	41.4	10964
Crest	2R M	34	13	5950	52.0	41.2	11018
Crystal	2R M	34	30	5456	52.1	43.5	10420
Maranna	6R F	34	3	5866	52.9	48.4	9372
Steptoe	6R F	34	43	5723	50.7	43.2	10507
Colter	6R F/M	32	63	5441	51.8	45.4	9985
Russell	6R M	33	0	6375	52.6	39.5	11492
Average		34	24	5817	51.9	43.2	10495
PLSD (5%)		NS	NS	NS	NS	NS	NS
PLSD (10%)		NS	NS	NS	NS	NS	NS
CV percent		5	112	13	5	12	12

Yields adjusted to a 10% moisture level.
Trial managers: Pam Zwer and Dave Sutherland
Grower cooperator: John Cuthbert

PRECIPITATION SUMMARY - PENDLETON

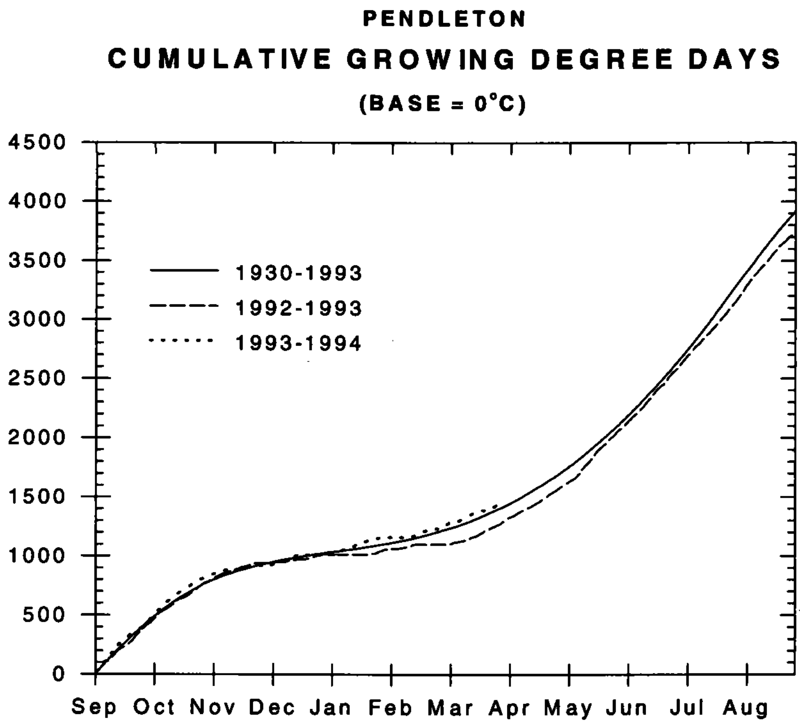
CBARC - Pendleton Station - Pendleton, Oregon
(Crop year basis, ie; September 1 through August 31 of following year)

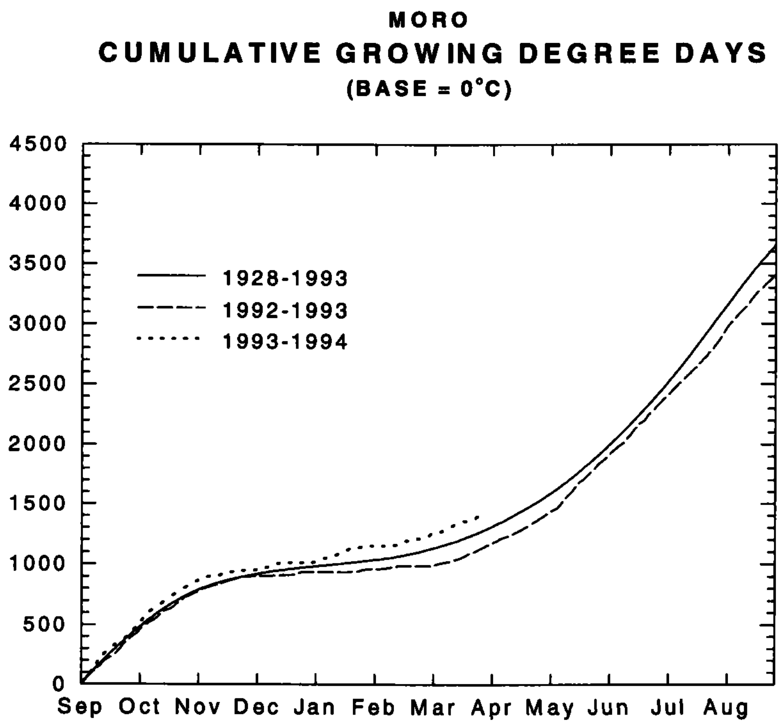
Crop Yr	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
64 Year Average	**.73**	**1.33**	**2.01**	**2.06**	**1.90**	**1.50**	**1.72**	**1.51**	**1.44**	**1.26**	**.36**	**.51**	**16.32**
1973-74	1.77	1.24	5.86	4.40	1.29	2.00	1.50	3.64	.38	.33	1.30	0	23.71
1974-75	.02	.35	1.56	1.76	3.73	1.68	.97	1.72	.68	.69	.05	1.38	14.59
1975-76	0	2.16	1.47	3.40	2.13	1.09	1.69	1.65	1.21	.58	.04	2.58	18.00
1976-77	.44	.53	.47	.59	.90	.57	1.72	.46	1.70	.31	.12	2.21	10.02
1977-78	1.54	.69	1.79	3.19	2.27	1.71	1.40	3.50	.81	1.27	.59	1.37	20.13
1978-79	1.61	0	1.68	2.28	1.31	1.54	1.74	1.82	1.15	.18	.12	2.08	15.51
1979-80	.17	2.56	2.31	1.05	2.85	1.55	2.12	1.20	2.45	1.42	.23	.18	18.09
1980-81	1.24	2.96	1.81	1.99	1.26	2.31	2.30	1.29	2.30	2.12	.40	.02	20.00
1981-82	1.51	1.62	2.41	3.27	2.61	1.86	1.99	1.54	.48	1.12	1.02	.50	19.93
1982-83	1.68	2.68	1.46	2.69	1.63	2.97	3.90	1.23	2.08	1.92	1.00	.68	23.92
1983-84	.82	.91	2.79	3.44	.99	2.56	3.23	2.37	2.11	2.05	.05	1.25	22.57
1984-85	.98	1.18	3.43	1.96	.69	1.49	1.33	.65	.89	1.42	.05	.98	15.05
1985-86	1.54	1.34	2.66	1.27	2.38	3.04	1.94	.83	1.79	.09	.61	.19	17.68
1986-87	1.87	.91	3.41	.95	2.08	1.31	1.85	.83	1.63	.62	.47	.06	15.99
1987-88	.04	0	1.44	1.61	2.60	.32	1.65	2.59	1.79	.94	0	0	12.98
1988-89	.40	.08	3.65	1.10	2.86	1.55	2.95	1.94	2.19	.33	.15	1.19	18.39
1989-90	.24	1.00	1.65	.49	1.43	.63	1.89	1.77	2.14	.70	.37	.76	13.07
1990-91	0	1.37	1.73	1.18	1.15	.86	1.71	1.01	4.73	2.22	.15	.24	16.35
1991-92	.03	.89	4.18	.97	.96	1.34	.85	1.29	.20	.90	1.74	.78	14.13
1992-93	.58	1.70	2.61	1.30	2.43	1.04	2.32	2.67	1.58	2.01	0.47	2.60	21.31
1993-94	0	.30	.49	1.91	2.38	1.67	.52						
20 Year Average	**.82**	**1.21**	**2.42**	**1.94**	**1.88**	**1.57**	**1.95**	**1.70**	**1.61**	**1.06**	**.45**	**.95**	**17.57**

PRECIPITATION SUMMARY - MORO

CBARC - Sherman Station - Moro, Oregon
(Crop year basis, ie; September 1 through August 31 of following year)

Crop Yr	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
84 Year Average	**.60**	**.91**	**1.70**	**1.65**	**1.61**	**1.16**	**.99**	**.78**	**.81**	**.69**	**.23**	**.29**	**11.42**
1973-74	.90	.85	3.70	3.99	1.29	.97	1.30	1.18	.38	.02	.41	0	14.99
1974-75	0	.37	1.02	1.39	2.01	1.47	1.25	.46	.53	.84	.40	1.26	11.00
1975-76	0	1.17	1.34	1.26	1.25	.93	.95	1.06	.14	.06	.79	1.17	10.12
1976-77	.04	.10	.43	.20	.18	.63	.50	.08	2.70	.28	.37	.90	6.41
1977-78	.88	.22	2.00	3.22	2.80	1.31	.74	1.42	.43	.44	.59	1.32	15.37
1978-79	.33	.01	.79	.69	1.59	1.54	.99	1.06	.28	.10	.07	1.05	8.50
1979-80	.53	2.59	2.23	.65	3.41	1.83	.94	.89	1.27	1.37	.16	.11	15.98
1980-81	.42	.79	1.73	2.95	1.52	1.22	.65	.41	1.06	1.15	.20	0	12.10
1981-82	.92	.82	1.99	4.73	1.10	.72	.55	1.45	.37	1.15	.21	.40	14.41
1982-83	1.42	1.96	1.08	1.89	1.40	2.43	2.74	.61	1.96	.39	.80	.60	17.28
1983-84	.52	.62	2.45	2.31	.17	1.07	2.34	1.32	.97	1.09	.17	0	13.03
1984-85	.53	.86	3.18	.41	.27	.97	.44	.14	.63	.92	.05	.14	8.54
1985-86	1.11	1.09	1.19	1.12	1.84	2.39	.98	.34	.35	.06	.54	.07	11.08
1986-87	1.52	.45	1.53	.78	1.68	1.10	1.54	.28	.99	.29	.78	.11	11.05
1987-88	.07	.01	.66	3.23	1.60	.21	1.25	2.21	.55	1.02	.04	0	10.85
1988-89	.56	.02	2.51	.22	1.33	.77	1.91	.84	.91	.08	.11	.50	9.76
1989-90	.07	.59	.96	.48	1.91	.17	.76	.79	1.36	.39	.15	1.43	9.06
1990-91	.29	1.27	.61	.74	.87	.60	1.43	.40	.77	1.27	.33	.16	8.74
1991-92	0	1.40	2.57	1.02	.47	1.64	.64	2.38	.04	.28	.81	.02	11.27
1992-93	.68	.85	1.50	1.68	1.42	1.47	1.68	1.22	1.42	.87	.39	.30	13.48
1993-94	.02	.09	.41	.68	1.40	.90	.55						
20 Year Average	**.54**	**.80**	**1.67**	**1.65**	**1.41**	**1.17**	**1.18**	**.93**	**.86**	**.60**	**.37**	**.48**	**11.65**


PENDLETON
CUMULATIVE GROWING DEGREE DAYS
(BASE = 0°C)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1930-1993
1992-1993
1993-1994
Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug


MORO
CUMULATIVE GROWING DEGREE DAYS
(BASE = 0°C)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1928-1993
1992-1993
1993-1994
Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug