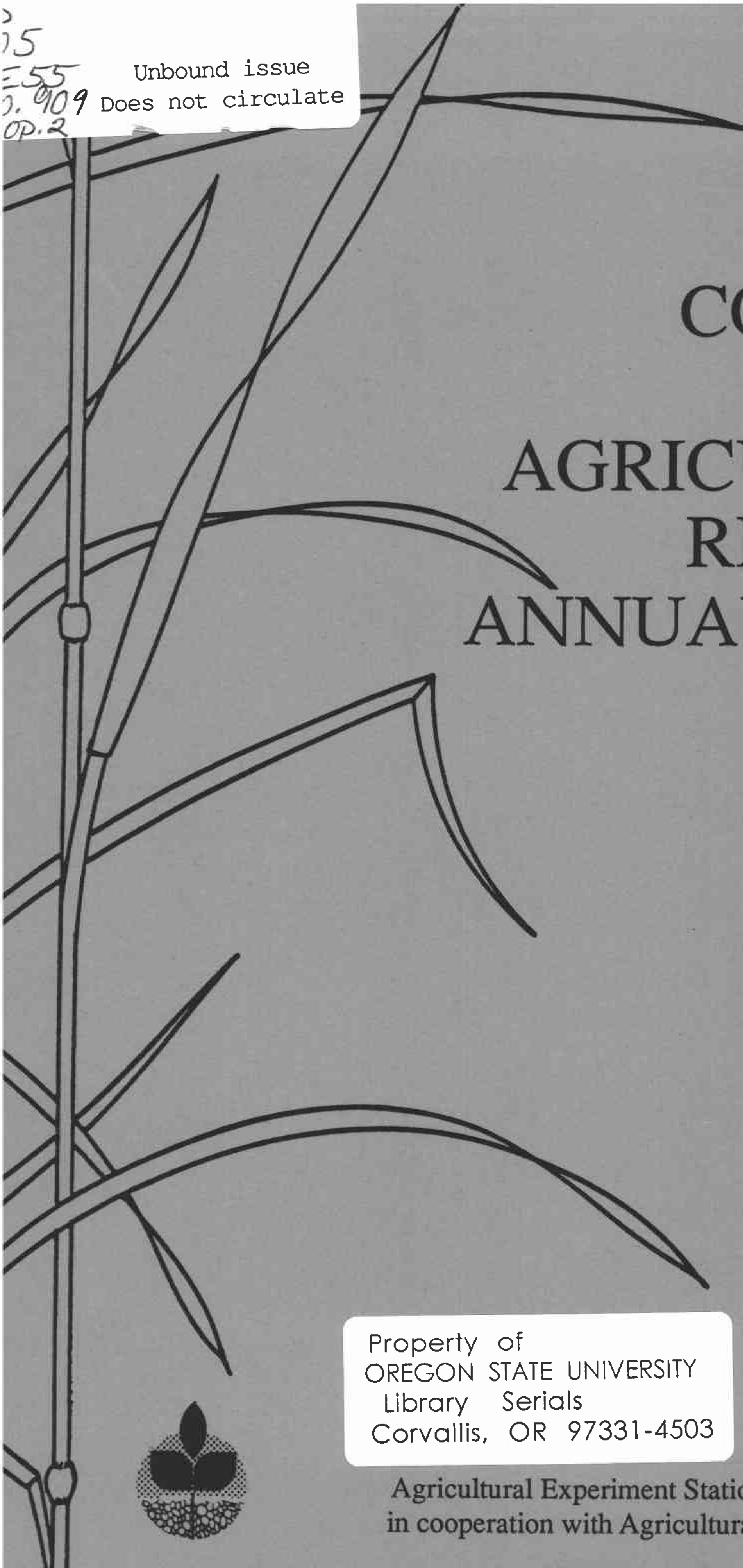

1993 COLUMBIA BASIN AGRICULTURAL RESEARCH ANNUAL REPORT

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COLUMBIA BASIN AGRICULTURAL RESEARCH

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INTRODUCTION

Staffs of the Columbia Basin Agricultural Research Center (CBARC-Oregon State University, 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, Larry Baarstad was promoted. Merit cash awards were given to Dale Wilkins and Betty Klepper in recognition of the consistently high quality of their work.

STAFF CHANGES

Staff was saddened by the death of Rodney Rolfe, who maintained the OSU weather station records and landscape at the Sherman Station. Sharon Rolfe was appointed to succeed Rodney. A family move to Condon caused Susan Gibbs to resign as Biological Research Technician in Pamela Zwer's wheat breeding program. Susan was succeeded by the appointment of Tamera Simpson, a graduate of the University of Southern California, to a temporary position in the plant breeding position. Dan McCarty also held temporary positions during 1992 and 1993 to assist in Don Wysocki's soil science program and Pamela Zwer's plant breeding program. Darrin Walenta was hired as Faculty Research Assistant in Dan Ball's weed science program after completing a B.S. degree in agriculture from Oklahoma State University. Wakar Uddin resigned as Faculty Research Assistant in Richard Smiley's plant pathology program to begin doctoral studies and serve as leader for the University of Georgia's Plant Pathology Diagnostic Laboratory. Lisa Patterson, an honors graduate from the University of Western Australia, was hired to replace Wakar.

For the USDA staff, two temporary employees, Robin Straughan and Jill Huntsman, worked for an 8-week period last summer on a special ARS program for Research Apprentices in Agriculture. Brad Nuxoll worked for 12 weeks as a USDA-ARS Summer Intern to develop a regional climatological information system. New funds were appropriated in 1992 and a permanent soil microbiology position was filled by Dr. Stephan Albrecht in November of 1992. Through the USDA postdoctoral Research Associate program, funds were made available for a two-year position in hydrology; this position was filled by Dr. Deghyo Bae in October, 1992. Additional funds for STEEP II were also received and a permanent position for a Physical Science Technician was supposed to be established to support the research program in erosion. However, a hiring freeze caused the permanent position to be cancelled and a temporary position was then filled by Craig Cameron in March. Ericka Miller joined the staff as a temporary Plant Laboratory Assistant at the end of March, 1993.

NEW PROJECTS

OSU staff continued with existing research and initiated few new projects.

Richard Smiley de-emphasized studies on Rhizoctonia root rot, physiologic leaf spot, and cereal cyst nematode. A five-year investigation of the dryland foot rot complex was initiated to determine the species of fungi involved, their geographic distribution, and the time during which infection occurs. This information will lead to development of a more accurate control strategy for a disease complex that damages many crops and is still poorly defined in Oregon. Dan Ball is expanding efforts toward the development of production systems for red lentils, a new crop for dryland regions of the Pacific Northwest, and for reduced rate herbicide practices in green peas. A regional survey is being initiated to determine the presence and distribution of herbicide resistant weeds in northeastern Oregon wheat. Pamela Zwer initiated research to assess club and common varietial and elite line differences for green cover and residue production. A program to evaluate promising elite club lines in replicated drill strips in cooperation with growers was initiated. Yield trials assessing wheat and barley varieties and elite lines were sown in Gilliam and Union Counties. The variety testing program is organized through Russ Karow; however the club wheat breeding program plans, maintains, and harvests the plots.

OSU and ARS staffs initiated cooperative studies to develop guidelines for application of methanol to increase crop productivity, increase water-use efficiency, and shorten the time for crop maturation. Several crops are being evaluated at Pendleton. The Center also coordinates winter wheat trials conducted by field crops extension agents throughout the region.

The USDA staff recently initiated erosion-related research under a postdoctoral program from the Administrator for work on hydrology. Dr. Deghyo Bae is modifying existing hydrologic model components and parameters to reflect Pacific Northwest weather and soil conditions so that these modifications can be made available for models being developed nationally by other ARS researchers. Dr. Bae is also working with Clyde Douglas and John Zuzel on a new project to define the probability of water moving below the root zone in the five dryland agroclimatic zones of the inland Pacific Northwest. Karen King, a graduate student at Washington State University at Richland, initiated research with Clyde Douglas and John Zuzel to analyze and interpret chemical data from runoff from the Kirk erosion site. Ron Rickman is beginning a new project using acoustical techniques to define surface roughness and/or macropores. Dale Wilkins, Clyde Douglas, and Paul Rasmussen have developed a new project to determine the impacts of use of stripper-header grain harvesting on residue management, moisture conservation, and erosion control. Dale Wilkins and Clyde Douglas have discovered that a gravity table can be used to separate the soft white wheat kernels in a bin of grain by protein content; they are developing further information on how the process will work on wheat from different sources and on how milling and baking properties of the separated grain compare to the original mixtures.

FACILITIES

Construction of the OSU greenhouse was completed and much progress was achieved toward completing the interior of the new headhouse (potting shed). Underground gasoline and diesel tanks were replaced with aboveground tanks at OSU facilities at Pendleton and Moro.

Residential units at both locations were improved by replacing old siding, water lines, and flooring.

The USDA shop building was upgraded with new heating and a new overhead crane. Automatic gate openers were also installed for the equipment yard. New burners were purchased for the heating system in the main office building. New cabinets have been ordered for the microbiology laboratory and for the erosion laboratory. An autoclave for the microbiology program was also purchased.

TRAINING

Gloria Eidam and Judy Elliott attended an OSU fiscal training workshop at Corvallis. Other OSU staff members participated in pesticide and first aid training to maintain their certifications.

On the USDA staff, Daryl Haasch took a week-long course in Laboratory Safety and Health Training at Albany, California. Larry Baarstad went to a Professional Development Conference in Reno, Nevada and also took a course in Legal and Ethical Issues in Business. Phil Dailey attended a Financial Management Seminar and a short-course on management. Betty Klepper took an introductory course in MS-DOS. Sharon Wart attended courses in word processing, managing projects and deadlines. Sharron Wart and Carol Brehaut attended Communication Skills for Women. Several USDA staff attended first aid, CPR, and pesticide training to maintain certifications.

VISITORS

Distinguished visitors hosted by staff at the Center included Dick Amerman, USDA National Program Staff, Beltsville, MD; Earl Rother, Public Relations Officer, Umatilla National Forest, Pendleton; Halina Siemaszko, Polish Agricultural Academy; Shigenori Morita, Tokyo, Japan; Michelle Thomlinson, Edmonton, Alberta, Canada; Gordon MacNish, Western Australia Dept. of Agriculture; Ken Stevens, Albany, CA; John Petty, Mattawa, WA; Derek Barnstable, Australia; John Van Dam, Idaho Falls, ID; Harold Collins, Hickory Corners, MI; Mike Troutman, Kennewick, WA; Heidi Dobson, Walla Walla, WA; Arthur Nonomura, Photon, Inc., Litchfield Park, AZ; Shelly Erford, Walla Walla, WA; Prasanta Kalita, Assam Province, India; Vern Stewart, Kalispell, MT; Madame Zhuli, Deputy Director, Beijing Grain Bureau; Mr. Han Yuzeng, Deputy Director, Beijing Cereal Industry Co.; Mr. Sun Cheng, Director, Beijing Sino-US Flour Mill; Ms. Zhang Li, Economic Relations & Trade Officer, Beijing Grain Bureau, Fred Schneiter, Regional Vice President, US Wheat Associates, Hong Kong; Tom Winn, Administrator, Oregon Wheat Commission; Don Phillips, University of California at Davis.

Other visitors included numerous representatives of equipment and supply companies, news media, wheat producers, extension agents, and faculty and staff from research 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: Ron Rickman, USDA-ARS, Pendleton (WEPP workshop for India), (soil and water conservation projects and practices in India), and (Using MODWHT3 to understand wheat growth), Pamela Zwer, OSU, Pendleton (root and shoot development of Russian wheat aphid-infested wheat seedlings), Clyde Douglas, USDA-ARS, Pendleton (influence of tillage and seeds on wheat emergence and development), Betty Klepper, USDA-ARS, Pendleton (role of rhizotrons in root research), Deghyo Bae, USDA-ARS, Pendleton (real-time flood forecasting for large hydrologic basins), Paul Rasmussen, USDA-ARS, (agriculture in Alaska), Dan Ball, OSU, Pendleton (jointed goatgrass distribution, biology, and control), Don Wysocki, OSU, Pendleton (update on conservation compliance), Dale Wilkins, USDA-ARS, Pendleton (seed size and density effects on seedling performance), Deghyo Bae and John Zuzel, USDA-ARS, Pendleton (research plan for the hydrology post-doctoral research program), Kathy Ward, OSU, Pendleton (seed treatment effects on sprout damaged seed), Stephan Albrecht, USDA-ARS, (global climate change), Roland Line, USDA-ARS, Pullman (computer-assisted wheat disease control), Arthur Nonomura (use of methanol to improve crop production), Jeff Jenkins, OSU, Corvallis (decision aids: using current technology), Earl Rother, U.S. Forest Service, Pendleton (NE Oregon forest health), Mike Stoltz, OSU, Pendleton (Poland today), Prasanta Kalita, Assam Province, India (WEPP hillslope erosion model), David Mulla, WSU, Pullman (nonuniform water flow in field soils), Claudio Stockle, WSU, Pullman (interfacing models to a GIS system).

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, in cooperation with the Director of the Pacific West Area, USDA-ARS. These committees provide a primary communication linkage 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.

A principal activity for the Pendleton Station Liaison Committee, led by Chairman John Rea (Touchet, WA.: 509-394-2430), involved revision of the Committee Constitution and By-Laws, for improving the focus and regional representation of the Committee. The Sherman Station Liaison Committee, led by Chairman Steve Anderson (Arlington: 503-454-2513), held several meetings as it moved forward with development of The Sherman Station Endowment Fund. This fund was established to provide supplemental financial support for agricultural research in northcentral Oregon. Ernie Moore (Moro; 503-565-3202) chaired the sub-committee responsible for establishing the endowment fund. The Committee and OSU staff at Moro, Pendleton, and Corvallis were saddened by the death of Bill Peters, an enthusiastic member of the Sherman Station Liaison Committee and The Sherman Station Endowment Fund Sub-Committee.

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 Centers during 1992-1993. The Oregon Wheat

Commission continues to provide the critical support upon which many of the Centers' projects are founded. Thanks are also given to those who donated equipment for long-term use by the Centers (Pat Davis, H and H International, Walla Walla, Kaye McAtee, Monsanto Co., Dick Skiles and Joe Temple), funds, seed, and/or chemicals (Ag Research Inc., American Cyanamid Co., Eric and Marnie Anderson, BASF Corp., Blue Mountain Seed (Walla Walla), Cargill, CIBA, E. I. du Pont de Nemours & Co., Hill Brothers Chemical Co., Hoechst-Roussel Agri-Vet Co., International Canola Co., Mid-Columbia Producers, Inc., Miles, Pendleton Grain Growers, Pendleton Flour Mills, Polysorb, Clint Reeder, Rhone-Poulenc Ag Co., Rohm and Haas, Sandoz Agro, SeedTec International, Terry S. Simpson, Smith Frozen Foods, Oregon Dept. of Agriculture, The McGregor Co., Valent Chemical Co., Wilbur-Ellis Co.), or loaned equipment or facilities (Doug Alley, John Correa, Pat Davis, Sherman County Sheriff's Dept., Frank Tubbs).

We also acknowledge those who donated labor, supplies, equipment or funding for the Pendleton Field Day: Umatilla County Ag Lender's Assoc. (U.S. Bank, Inland Empire Bank, First Interstate Bank, Farm Credit Services), Mario's Catering, Carroll Adams Tractor Co., American Cyanamid Co., BASF Corp., CIBA, E. I. du Pont de Nemours & Co., Farm Equipment Headquarters, Hoechst-Roussel Agri-Vet Co., Huntington-Price, Inland Chemical Service, Maxi-Gro Fertilizer & Chemical Co., Pendleton Flour Mills, Pendleton Grain Growers, Pioneer Implement Corp., Rohm and Haas Co., Sandoz Agro, Smith Frozen Foods, The McGregor Co., Tri-River Chemical, Valent Chemical Co. Walla Walla Farmers Co-op, Western Farm Service, Wilbur-Ellis Co., Wheatland Insurance, Pendleton Senior Center, Main Street Cowboys, Umatilla County Wheat Growers League, Frank Tubbs, and Robert Hopper. We also thank the Moro Field Day donors: Cargill Inc., Cascade Ranchers, Condon Grain Growers, Kaseberg's Wheatacres Irrigation, M & S Farm Supply, Mid-Columbia Producers, Monsanto Co. Morrow County Grain Growers (Lexington and Wasco), SeedTec International, Western Tillage Equipment Co., Mid-Columbia Bus Co., Sherman County School District, and Branding Iron Restaurant.

Cooperative research plots at the Centers were operated by Warren Kronstad, Patrick Hayes, Chris Mundt, Russ Karow, Keith Saxton, Floyd Bolton, and Brian Tuck. We also thank the SCS District Conservationists in Oregon and Washington for their assistance. Additionally, we are very thankful for the ever-present assistance from the Extension Service personnel in all counties of the region, and especially from Umatilla, Union, Sherman, Morrow, Gilliam, and Wasco Counties and from Columbia and Walla Walla Counties in Washington.

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

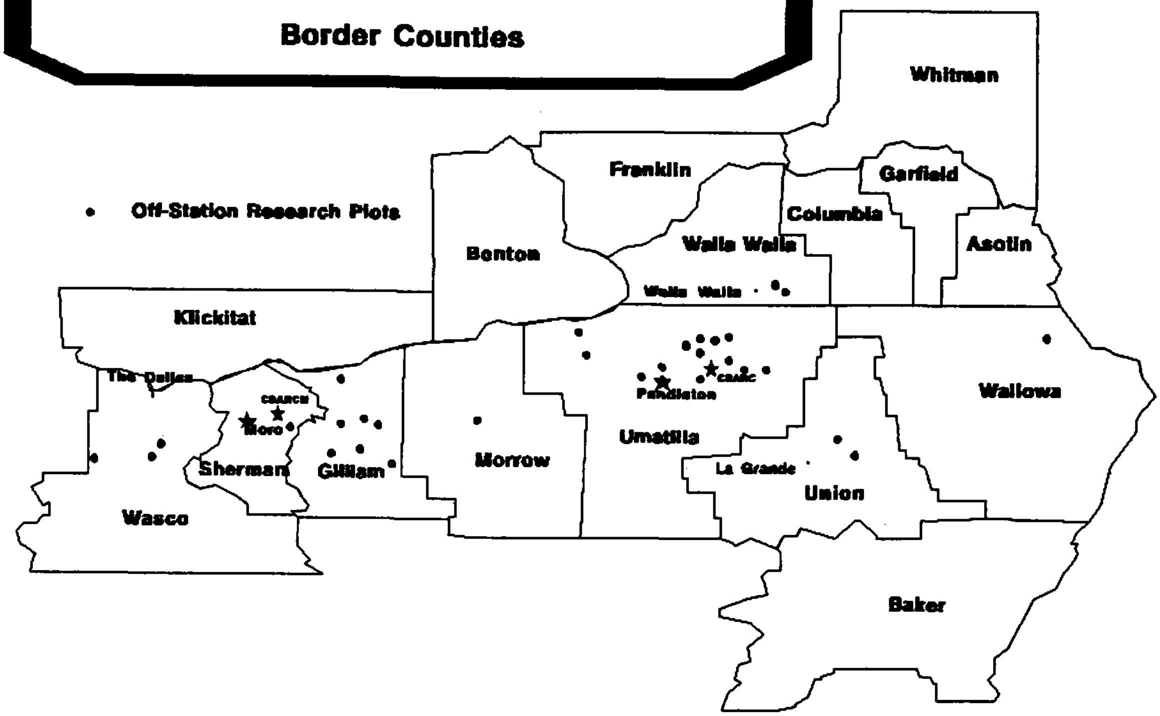
We truly appreciate the support and encouragement of growers, organizations, and businesses with a mission common to ours: to serve in the best manner possible the agricultural needs of our region. We welcome your suggestions on how we may continue to improve our attempts to reach this goal.

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

RESEARCH PLOT LOCATIONS

Eastern Oregon - Eastern Washington

Border Counties



GILLIAM, OREGON
Charlie Anderson
Steve Anderson
Clarence (Cub) Bare
Richard Harper
Vince Hill
Jordan Maley
Jack Oesterlund
Tom Rietmann
Van Rietmann
Henry Wilkins

MORROW, OREGON
Eric Anderson
Doug Drake

SHERMAN, OREGON
Don Miller
Sherman Station

UMATILLA, OREGON
Jim Duff
Berk Davis
Doug Harper
Hermiston Station
Robert Hopper
Bob Johns
George Kinder
Kay McAtee
Pendleton Station
Clint Reeder
Paul Reeder
Leon Reese
Sherman Reese

UNION, OREGON
John Cuthbert
Dale Wagoner

WALLA WALLA, WA
Donald Meiners
J. Nowogroski

WALLOWA, OREGON
Doug Wolff

WASCO, OREGON
Neil Harth
Dick Overman
Fred Schrieber

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AUTHOR AFFILIATIONS

Allmaras, R. R., Soil Scientist, USDA-ARS, Soil and Water Management Research, St. Paul, Minnesota

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

Bolton, Floyd E., Emeritus Associate Professor, Department of Crop and Soil Science, Oregon State University, Corvallis, Oregon

Churchill, Donald B., Agricultural Engineer, USDA-ARS, National Forage Seed Production Research Center, Corvallis, Oregon

Cook, Gordon, Union County Extension Agent, Oregon State University, La Grande, Oregon

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

Duff, Bart, Consulting Agricultural Economist, Pendleton, Oregon

Greenwalt, Richard N., Computer Specialist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Haasch, Daryl A., Engineering Technician, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon

Ingham, Russell, Associate Professor, Botany and Plant Pathology, Oregon State University, Corvallis, Oregon

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

Kolding, Mathias F., Senior Instructor, Hermiston Agricultural Research and Extension Center, Hermiston, Oregon

Kronstad, W. E., Distinguished Professor, Department of Crop and Soil Science, Oregon State University, Corvallis, Oregon

Love, C. S., Senior Faculty Research Assistant, Department of Crop and Soil Science, Oregon State University, Corvallis, Oregon

Metzger, R. J., Professor (courtesy), USDA-ARS, Department of Crop and Soil Science (retired), Oregon State University, Corvallis, Oregon

Nesse, Phil, Gilliam County Extension Agent, Oregon State University, Condon, Oregon

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

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

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

Rydrych, D. J., Emeritus Professor, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon

Schillinger, William F., Adams County Extension Agent, Washington State University, Ritzville, Washington

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

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

Waldman, Sue E., Mathematician, USDA-ARS, Columbia Plateau Conservation Research Center, 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

BIOLOGICAL AND ECONOMIC SUSTAINABILITY OF WHEAT/FALLOW AGRICULTURE

Paul E. Rasmussen, Richard W. Smiley, and Bart Duff

There is a growing perception among the general populace that present farming practices are neither sustainable nor environmentally sound. Sustainability is generally defined as the ability of soil to maintain crop production without degradation of the soil or contamination of the environment. Present agricultural growth is attained by steadily increasing yield through greater input of non-renewable resources. Excessive soil erosion remains an ever-present threat to continued productivity. The sustainability of Pacific Northwest wheat production systems is also related to economic viability because of strong international competition for export markets, rising production costs, and ever-increasing off-farm costs for factors such as soil erosion, fertilizers, and pesticides. There is, therefore, a strong incentive to determine if present practices are not only sustainable, but also capable of enhancing wheat production in this region.

Long-term experiments provide information about the sustainability of agricultural systems that can be obtained in no other way. Oregon State University and the USDA maintain five long-term experiments at the Columbia Basin Agricultural Research Center near Pendleton. These are among the oldest replicated research experiments in the nation. We attempted to measure trends in long-term agricultural sustainability for a wheat/fallow experiment started in 1931. The wheat/fallow system is perhaps the most sensitive of all production systems because, while it reduces the risk of crop failure resulting from inadequate soil moisture, it is subject to rapid soil organic matter loss during the non-productive part of the rotation.

HISTORY OF THE RESIDUE MANAGEMENT EXPERIMENT

This study was initiated at the Research Center in 1931 to evaluate the long-term effects of fertilizer amendments and residue management on grain yield and soil quality in a wheat/fallow production system. The experiment has two identical series offset by one year so one is in crop while the other is in fallow. The soil is a Walla Walla silt loam. This trial has been conducted relatively unaltered since inception, with changes introduced only to ensure relevance with modern agriculture. Long-term supporting data from the Center's variety breeding trials are also available to evaluate yield improvements over time.

We selected four treatments in the residue management experiment to investigate sustainability (Table 1). Winter wheat stubble is left undisturbed over winter, except for the fall-burn treatment. The organic amendment (barnyard manure) is applied to the manure treatment in the spring. The entire experiment is moldboard plowed in April and smoothed with a field cultivator and harrow. The fallow is rodweeded three to four times annually. Inorganic-N fertilizer is applied to the 80-N treatment as granular material broadcast just prior to planting. Grain yield is determined by combine harvesting a portion of each plot.

Two major changes in management have occurred since 1931. The initial experiment utilized a medium-tall soft white winter wheat variety (Rex M-1) and a low

Table 1. Residue management and inorganic-N fertilizer applied to the residue management experiment between 1932 and 1992.

Treatments		Straw Management†		N Fertilizer	
No.	Name	1931-66	1967-92	1931-66	1967-92
				pounds/acre	
6	Fall burn	FB	FB	0	0
0	Zero-N	UB	UB	0	0
5	80-N	SD	UB	30	80
8	Manure‡	UB	UB	0	0

† FB = Fall burn, UB = Unburned, SD = Spring disked.

‡ Manure applied at 20 tons/acre/crop (moist weight), except for 1943-1947. Average N input from manure is 100 pounds/acre.

Table 2. Average grain yield for five time periods between 1932 and 1986.

Treatment		Period				
No.	Designation	1932-41	1942-51	1952-66	1967-76	1977-86
		- - - - - Grain yield, bushels/acre/crop - - - - -				
6	Fall-burn	39.1	39.6	31.1	44.4	41.8
0	Zero-N	38.1	40.2	32.6	46.2	45.1
5	80-N	42.0	45.9	41.0	67.6	75.3
8	Manure	48.0	54.0	50.1	72.0	79.0

Table 3. Soil organic matter and nitrogen in the top foot of soil in the residue management plots on six dates.

	Year Sampled					
Treatment	1931	1941	1951	1964	1976	1986
	- - - - - - - - - - - - Organic matter, tons/acre - - - - - - - - - - - -					
Fall-burn	37.5	35.8	32.5	32.7	30.8	28.5
Zero-N	38.7	37.9	34.6	33.9	32.7	30.5
80-N	37.5	37.4	35.6	34.0	33.6	32.3
Manure	37.4	39.2	40.9	38.0	39.1	38.6
	- - - - - - - - - - - - Nitrogen, pounds/acre - - - - - - - - - - -					
Fall-burn	3310	3180	2930	2820	2700	2550
Zero-N	3420	3380	3130	3060	2940	2850
80-N	3310	3320	3210	3090	3050	2990
Manure	3330	3480	3690	3640	3730	3750

rate of N application (30 lb/acre). The experiment was revised in 1967 to change the wheat type from a medium-tall to a semi-dwarf variety, and to increase the N application rate from 30 to 80 lb/acre. Wheat cultivars since 1967 include Nugaines (1967-1973), Hyslop (1974-1978), and Stephens (1979-1992).

Soil samples to a depth of two feet were taken in 1931, 1941, 1951, 1964, 1976, and 1986. Total N and organic C (a measure of organic matter) were determined for the 0-12 and 12-24 inch increments. Since less than 1 percent of the total N was inorganic, all N in soil is essentially organic-N.

WHEAT YIELD AND SOIL CHEMICAL PROPERTIES

Wheat yield in the variety trials at the Center has risen steadily since 1932 at a linear rate of 0.77 bushels/acre/year (Figure 1). About 0.67 bushel of the increase has been due to development of improved N-efficient, disease-resistant varieties and the remainder to improved crop management. In the residue management experiment, the manure treatment has consistently produced grain yields equal to or above those in the variety trials. Grain yield for the manure treatment has risen steadily from 48 bushels/acre in the 1930's to nearly 80 in the 1980's (Table 2). The low fertility treatments (fall-burn, zero-N) originally yielded about 80 percent of the manure treatment, but this percentage has fallen progressively over time to about 50 percent%. The 80-N treatment currently yields about 95 percent of the manure treatment, but a direct comparison is not possible since manure supplies more N (99 vs 80 lb/acre) and also other elements (P, S, K, Zn, etc.). Fall burning originally tended to increase grain yield over zero-N, but the effect was short-lived. By the 1950's, yields were similar, and in recent years the fall-burn treatment has yielded less.

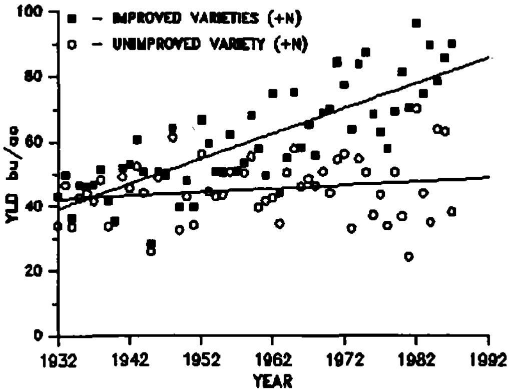

Fig 1. The effect of varietal improvement on winter wheat grain yield, 1932-1992. Pendleton Agric. Res. Ctr.

There was a substantial increase in grain yield in 1967 with the change from a medium-tall to a semi-dwarf wheat variety. Wheat yield in the zero-N treatment increased about 40 percent, even though there was little change in available N supply. This was due to both higher transport efficiency of N from vegetative to reproductive tissue and to lower protein content in the grain of semi-dwarf wheat.

With the exception of the manure treatment, soil organic matter and N declined with time for all treatments (Table 3). Organic matter in the top foot of soil averaged 37.8 tons/acre in 1931, but ranged from 28.5 to 38.6 in 1986. The manure treatment had the highest amount in 1986. The N content of the top foot of soil averaged 3,340 lbs/acre in 1931, but ranged from 2,550 to 3,750 in 1986. Again, the manure treatment had the highest amount. The organic matter decline with time was linear for each treatment, and the rate of decline related to the amount of organic residue being returned to the soil. None of the treatments presently produce enough straw residue to stop the decline in soil organic matter.

ECONOMIC ANALYSIS

We developed an index of input costs and output prices between 1931 and 1992 for each treatment based on USDA estimates of prices paid by farmers. Because the cost of experimental trials are higher than actual farm costs, we used the operational and fixed costs for a representative 2,500 acre farm in the Columbia Plateau (Table 4). Cultural operations and costs were assumed identical for each treatment. Thus, treatment costs are distinguished only by differences in the cost of fertilizer and residue inputs, the cost of yield-dependent operations such as harvesting and hauling, and external costs resulting from erosion. Individual treatment costs were multiplied by the input cost index to generate annual cost estimates for each treatment. We tested the validity of these estimates by comparing the calculated indexed costs against a limited survey of actual production costs for the years 1974-1988. Cost estimates based on the national index of prices paid by farmers closely approximated wheat/fallow production costs reported by the survey.

Farm-level wheat prices in Oregon were variable throughout the experiment (Figure 2a), with a long-term upward trend. However, both wheat price and yield were much less stable than input costs. The introduction of government programs in the 1950's stabilized prices somewhat, but this was disrupted in the late 1970's by the energy crisis and the grain embargo against the Soviet Union.

Dividing the index of wheat prices by the index of prices paid for production inputs produces a parity price ratio. There has been a decline in the parity price ratio for dryland wheat farmers since the mid-1950's (Figure 2b). Wheat prices have increased only slightly since 1970, while input costs have risen steadily since the 1950's. A fall in the parity price ratio does not imply long-term negative returns to farmers, provided yields are increasing or unit costs are declining.

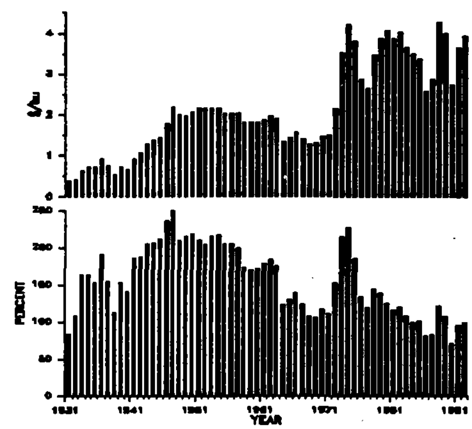

Fig 2. Wheat price (2A) and parity price ratio (2B), 1931-1992 (1992 = 100).

ANALYSIS OF SUSTAINABILITY

Crop yield over time reflects only one of the system's outputs, and is, therefore, inadequate as a measure of sustainability. Even measures of soil organic matter, water quality, soil structure, and other features are inadequate to measure sustainability because there is no clear definition of what is "healthy" (capable of maintaining production without degrading the environment).

Calculating the sustainability of cropping systems requires estimates of income and production costs, and a measure of external costs such as erosion and pollution. External costs (on- and off-

Table 4. Production costs for alternative treatments in crop residue management trials ($ ha^{-1})[a].

	Treatment				
	0	---- 5[a] ----		6	8
Item	1931-92	1931-66	1967-92	1931-92	1931-92
I. Input costs ($/acre):					
seed	7.08	7.08	7.08	7.08	7.08
fertilizer:					
inorganic-N		7.58	20.08		
organic					50.00
herbicides	6.40	6.40	6.40	6.40	6.40
machinery:					
fixed	48.58	48.58	48.58	48.58	48.58
operating	33.20	33.20	33.20	33.20	33.20
crop insurance	2.61	2.61	2.61	2.61	2.61
operating capital (interest)	7.36	8.27	9.77	7.36	13.36
conservation	0.30	0.30	0.30	0.30	0.30
labor	11.77	11.77	11.77	11.77	11.77
total for inputs	117.30	125.80	139.79	117.30	173.30
II. Yield dependent costs:					
marketing & handling ($/bushel)					
field transport	0.20				
storage	0.11				
elevator handling	0.12				
assessment	0.02				
Total	0.45				
III. Land use:					
.35 (share) x wheat price x yield					
IV. Externalities:					
erosion ($/bushel)	0.07				
pesticides					

[a] Fertilizer application rate for treatment 5 was increased in 1967 with introduction of semi-dwarf varieties.

farm costs to society) resulting from soil erosion, and pesticide and fertilizer use are part of the true cost of farming. The analysis of sustainability is achieved using an index called Total Social Factor Productivity (TSFP). External costs due to on- and off-site effects resulting from pesticides and erosion are included in the calculation of TSFP.

Off-site costs associated with fertilizers include regulatory costs, health effects of nitrates in drinking water, and environmental effects of fertilizer use. Little evidence is available indicating the extent of nitrate movement into ground and surface water in dryland wheat areas, and its potential cost. Nitrate in water from a shallow (280 ft) but not a deep (400 ft) well at the Research Center currently exceeds the EPA's maximum allowable concentration of 10 ppm. The source(s) and historical trends for nitrates in this well are not known, but an off-site source is most likely.

There are numerous ways in which pesticides can enter non-target portions of the environment. Both costs and benefits are associated with this externality. Costs include regulatory and monitoring costs, health effects on humans, and environmental effects such as reduced efficiency of natural enemies of pests, secondary pest outbreaks, pest resistance, crop and tree loss, and poisonings of fish, wildlife, bees, and domestic animals. Positive effects of pesticide use include reduced cost of weed management in noncrop areas, lower highway maintenance (weeds clog culverts and contribute to roadbed deterioration), and less expense for controlling human allergies from windborne pollen, contamination of feed and food by mycotoxins produced by fungi, or introduction of weeds, diseases, and pests into previously uninfested areas. As with fertilizers, it is difficult to assign values to external costs for pesticides. No pesticides have been detected in well water at the Research Center. In the absence of further evidence, we simply flagged external pesticide costs at $1.00/acre.

Soil erosion losses for each treatment were calculated using the Revised Universal Soil Loss Equation (RUSLE) model. Because the experiment is located on gentle sloping topography, calculated erosion losses are quite low and not representative of losses that occur on steeper slopes throughout the area. Soil losses were calculated at 0.2 to 1.5 tons/acre/year. In contrast, erosion rates of 2-14 tons/acre/year are estimated on sloping land in the Columbia Plateau. Crop productivity losses for erosion rates of 5, 10, and 15 tons/acre were estimated using equations developed by Walker and Young (1986) for similar conditions in eastern Washington. The effect of continued soil erosion on sustainability was then computed.

DEFINING SUSTAINABILITY

To define long-term environmental trends, we need to determine *biological sustainability*. To find out if systems are financially sound, we have to determine *economic sustainability*. We can achieve both by controlling TFSP over time. In this report, biological sustainability was estimated by holding input/output price indexes constant at 1992 levels. This eliminated price fluctuations and confined change to factors that affected productivity. Economic sustainability was estimated by allowing input and output prices to vary. Economic sustainability is thus a composite of both biological change and income/cost considerations. Long-term biological sustainability by itself is not a sufficient condition for economic sustainability. Conversely, economic sustainability is neither necessary nor sufficient for biological sustainability. The critical identifier of sustainability in this analysis is the slope of the trend line rather than a specific number. A sustainable system must have a positive slope to the trend line over time. To estimate the effect of variety improvement on sustainability, data were divided into two periods for analysis: 1931-1966, when a single wheat variety was grown, and 1967-92, when improved semi-dwarf wheats were grown.

CHANGES IN SUSTAINABILITY IN WHEAT/FALLOW SYSTEMS

Trends in both biological and economic sustainability are illustrated in Figure 3 for the 80-N treatment. Biological sustainability (constant price) declined moderately during the 1931-1966 period. This is generally due to declining yield associated with decreasing organic matter in soil. The trend for the 1967-1992 period, after introduction of semi-dwarf varieties, was positive. Improved yield due to varietal selection was able to offset the yield decline brought about by deterioration of the soil resource base.

Economic sustainability (indexed price) shows much greater yearly variability than does biological sustainability. There was a slight trend towards increased economic sustainability for the 1931-1966 period, but a pronounced decline for the 1967-1992 period. Economic sustainability declined despite improved biological sustainability through improved wheat varieties. A pronounced decline in the parity price ratio during this period overshadowed any increase in productivity.

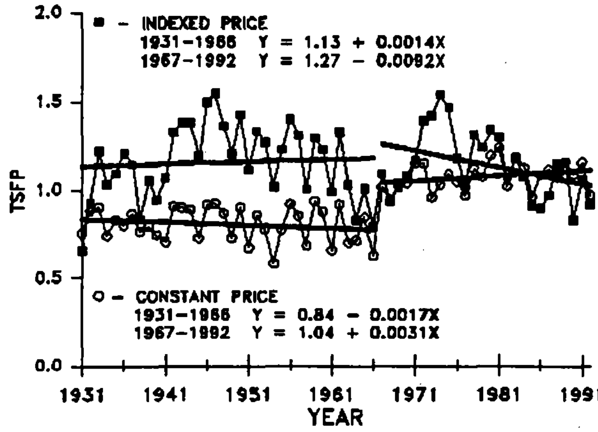

Fig 3. Trends in biological sustainability (constant price) and economic sustainability (indexed price) for the 80-N treatment over two time periods, 1931-66 (no variety improvement) and 1967-92 (variety improvement). Sustainability derived from Total Social Factor Productivity (TSFP) data.

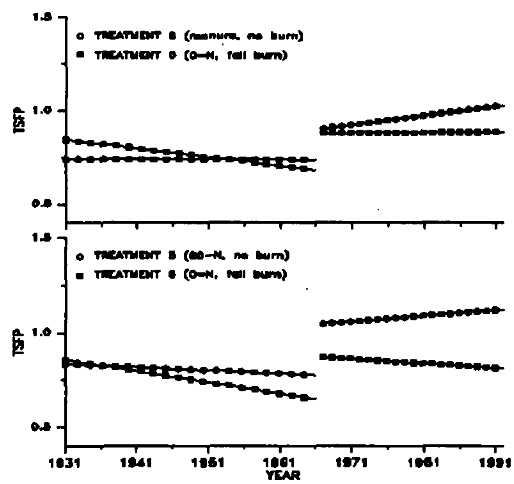

Fig 4. Summary of trends in biological sustainability for four treatments (Manure, Zero-N, 80-N, and Fall-burn) over two time periods, 1931-66 (no variety improvement) and 1967-92 (variety improvement).

A summary of the biological sustainability of the four treatments that encompass most of the effects of residue management is shown in Figure 4. Without the benefit of continuing development of intensively managed N-responsive varieties, three of the four treatments exhibited negative biological sustainability in the 1931-1966 period. These treatments (fall-burn, zero-N, and 80-N) show declining levels of soil organic matter from 1931 to 1987. Degradation in the soil resource base was sufficient to reduce sustainability. The decline was greatest in the stubble burn treatment where crop residues were burned and no supplemental N added. Crop residues are required to replenish the organic matter base in semi-arid regions, and any removal of this resource accentuates the decline in sustainability. Removal of residues for fuel or livestock feed should produce the same effect or greater effect than burning. The 80-N treatment, which most closely approximates current farm practices, had a lower rate of organic matter decline than the zero-N or fall-burn treatments, primarily because residue production was higher and less organic matter was lost.

Adoption of semi-dwarf varieties improved the biological sustainability of all treatments, but had the greatest effect in the 80-N treatment. With improved technology, only the zero-N and fall-burn treatments continued to decline during the 1967-1992 period. The manure treatment has the most favorable sustainability, reflecting adequate nutrient supply and no loss of the soil N resource base. The yield-augmenting effect of improved technology does mask some of the decline in soil organic matter. Because of the long-term decline in the parity price ratio, only two of the treatments show economic sustainability prior to 1967, and none afterward. Economic sustainability increased moderately in the manure treatment during the early period, but declined in the second, reflecting the overriding impact of the falling output/input price ratio.

We were particularly concerned about the effects of erosion on sustainability since this experiment is located on nearly-level land and has a very low rate of soil loss. Organic matter loss without erosion is due to biological oxidation of existing organic matter. It occurs in a wheat/fallow rotation because no residue is produced during the fallow year, but soil biological activity continues. Soil organic matter loss through biological oxidation is essentially independent of soil erosion loss.

The biological oxidation loss of organic matter for the zero-N treatment over 56 years was equivalent to an erosion rate of 6.8 tons/acre/year. Calculated average soil loss using RUSLE was less than 1 ton/acre/year. Thus, if soils are eroding at the presently acceptable T value (5 tons/acre/year), the actual decline in soil quality is equivalent to an erosion rate of nearly 12 tons/acre/year. Similarly, a 2T loss equates to a productivity loss of 17 tons/acre rather than 10.

The predicted effects of 5, 10, and 15 ton/acre/year erosion rates on biological and economic sustainability are shown in Figure 5. The major effect of erosion is to drop profitability substantially due to higher off-site erosion costs and to progressively lower wheat yield on eroded soil. There is also increasing reduction in long-term economical sustainability. And the decline will become progressively more severe when topsoil is nearly depleted.

To examine the sensitivity of biological sustainability to economic conditions, the price of wheat was varied from $2.50/bushel to $5.50 for the 80-N treatment (Figure 6). Price shifts the trend line up or down (affects profitability), but changes the slope of the line (affects sustainability) very little. Systems that are not profitable can not maintain sustainability indefinitely, however.

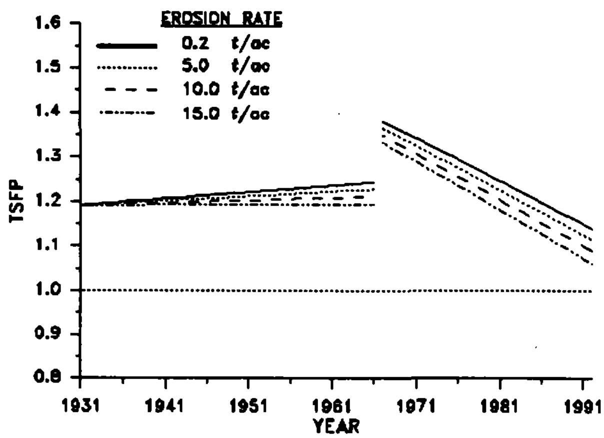

Fig 5. Predicted effect of soil erosion on economic sustainability over two time periods, 1931-66 (no variety improvement) and 1967-92 (variety improvement). Data for 80-N treatment.

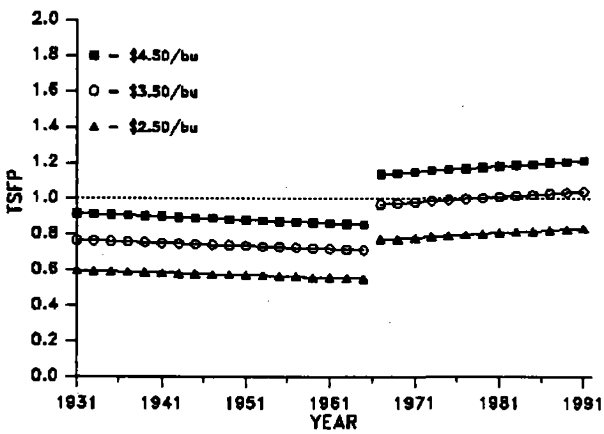

Fig 6. Sensitivity of biological sustainability to change in wheat price for two time periods, 1931-66 (no variety improvement) and 1967-92 (variety improvement). Data for 80-N treatment.

IMPLICATIONS FOR WHEAT/FALLOW SYSTEMS

Without the benefit of technological improvement, biological sustainability declined when the soil resource base declined. With technological improvement, biological sustainability rose substantially. High-input treatments show a positive trend over time, whereas low-input treatments show a negative trend. Without sufficient fertility to increase yield, soil organic matter declined. This indicates that the soil resource base affects long-term sustainability. With high-N input, biological sustainability was profitable and the long-term trend positive. When soil erosion is factored in, sustainability and profitability decline significantly. Both biological and economic sustainability are reduced even when soil erosion occurs at the presently acceptable T value of 5 tons/acre/year.

Factoring economics into biological sustainability affects long-term trends significantly. Early trends (1931-1966) were generally positive due to increasing yield and parity price ratio. Later trends (1967-1992) were generally profitable (>1) but the trend was negative for all wheat/fallow practices. Costs are continuing to rise while wheat prices remain static. While the high input systems are still profitable (TSFP>1), the trend line is distinctly negative. If this trend continues, most systems will lose profitability by the year 2000.

SUMMARY

Biological sustainability is difficult to maintain in a wheat/fallow system. Continuing development of higher-yielding varieties are helpful to increase biological sustainability in the semi-arid Pacific Northwest. Return of adequate crop residue to the soil must be stressed because of the profound effect of residue on organic matter retention and long-term biological sustainability. Present residue inputs in a semi-arid wheat/fallow system are not sufficient to maintain soil organic levels with conventional tillage. Minimum tillage systems must be perfected that yield well. Another possibility is the diversion of wheat/fallow systems to perennial grass periodically (perhaps for 5-10 of every 40 years) to maintain the soil resource base. Strong emphasis should also be placed on adequate erosion control, since any soil loss increases organic matter loss and decreases sustainability. Moderate erosion coupled with oxidation loss produced neutral biological and negative economic sustainability.

All present management practices show negative trends in economic sustainability, mainly due to increasing production costs but static wheat price. This suggests that strong efforts must be made to either strengthen the price of wheat or to intensify research to develop alternative crops to cereals. Crops with improved profitability will be difficult to develop because growing-season precipitation is inadequate for producing most warm-season crops.

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TECHNIQUE FOR PROTEIN SEPARATION OF SOFT WHITE WINTER WHEAT

D.E. Wilkins, C.L. Douglas, Jr., and D.B. Churchill

Soft white wheat grown in the Pacific Northwest is marketed to Pacific Rim countries for making pocket breads, cakes, pastries, cookies and crackers. Wheat with protein content below 10.5 percent is desired for these uses because it makes the highest quality products. Premiums have been paid by certain Pacific Rim countries for shipments of soft white wheat with low protein. Some of the Pacific Northwest soft white wheat is marketed to Middle East countries where high protein wheat is desired for nutrient value. Protein content of soft white wheat produced in the Pacific Northwest may range from 7 percent for club wheats (Zwer et al., 1992) to 14 percent for some common soft white wheats (Zwer et al., 1991). Soil depth, field aspect, weather and fertility practices influence grain protein content. Producers could provide a consistent high quality product and benefit from premium prices if a technique for separating soft white wheat by protein content was available.

A gravity table was used by Wilkins et al. (1992) to separate soft white wheat into categories of low and high density. Wilkins and Douglas observed the gravity table makes seed separation according to density. Light seeds were high in protein and dense seeds were relatively low in protein. This research was undertaken to determine if gravity tables could be used to separate soft white wheat based on protein content.

MATERIALS AND METHODS

Seven lots of soft white wheat (6 winter, 1 spring) were obtained for testing. These wheats were selected to represent different agronomic zones and different cultural practices including dryland and irrigated production. They ranged in production location from central Oregon to southern Idaho (Table 1) and represented Agronomic zones 2, 3, 5 and 6 (Douglas et al., 1990). Prior to gravity table separation, lots 1 and 2 had been processed for seeding and milling, respectively. Approximately 10 and 17 percent small and broken kernels and chaff had been removed by sieving.

Each seed lot was separated with a Boerner divider into four equal portions of approximately 5 lb each. One portion was kept as original material and the other three were designated as replicates 1, 2, and 3. Lot 4 had only enough seed for two replications. From each replicate, about 1/3 lb seed was kept non-separated and the remainder was separated with the gravity table.

A Sutton, Steele and Steele Inc. model V-135 laboratory gravity table with a perforated copper deck was used to separate the seeds. Gravity tables have a perforated oscillating metal deck that slopes both laterally and longitudinally (Harmond et al., 1968). Seed is uniformly metered onto the deck. Air is forced through the deck to stratify seeds into layers of different densities. The oscillating motion of the deck moves seeds longitudinally and laterally. As seeds progress longitudinally along the deck, dense seeds move laterally up the incline and light seeds travel down the deck. Seeds were separated into nine fractions as they were discharged over the edge of the two-ft-long deck. The first fraction, starting with the low end, where light seeds were discharged, was 6 in wide. The next seven fractions were 2 in wide and the last fraction was 4 in. wide.

Distribution of seeds discharged along the edge of the deck can be changed by adjusting deck incline angle, oscillation frequency, air flow rate, feed rate, and deck material. Initial adjustments to the gravity table were made based on Lot 7. Adjustments were made to obtain a uniform flow of seed over the discharge edge. Settings then remained constant for all other seed lots. Feed rate was approximately 2 lb/min and oscillation frequency was 550 cycles/min.

Approximately 2 oz of seed from each separated fraction were ground, dried at 140°F and analyzed for nitrogen content with a LECO model CHN-600 carbon-hydrogen-nitrogen analyzer. Percent protein was determined on oven dry samples, by multiplying percent nitrogen by 5.7. All values were then adjusted to 12% moisture content. Linear least squares regression equations for grain protein percent as a function of gravity table discharge position were determined for each seed lot.

RESULTS AND DISCUSSION

The linear relationships between gravity table discharge position and grain protein content can be seen in Figure 1 for irrigated and Figure 2 for dryland soft white wheat. Position zero represents the extreme low side of the gravity table and contains the light material. Position 24-inches is the top side of the gravity table and contains the most dense material.

Slopes of the change of protein content between gravity table position (slopes of the lines in Figures 1 and 2) ranged from 0.0 to 0.33 percent protein per position (Table 2). A steeper slope such as that for lot 6 was possible because of the large range of protein content for kernels within that lot. A zero slope such as that for lot 1 means there was too small a range in protein content for the gravity table to segregate it.

Lot 3, an irrigated spring wheat, had a relatively low protein range resulting in a small but significant difference in protein with discharge position (Figure 1). There was a significant decrease in grain protein content as location of discharged grain increased from 0 to 24 in (from light grain to dense grain). This is similar to results reported by Tkachuk et al. (1990) for Canada Western Red Spring wheat. They found only a small separation of protein content for fractions of wheat separated with a gravity table. In general, the range of protein content within lots produced with irrigation was less (smaller negative slopes in Table 2) than lots produced without irrigation (dryland). This is probably due to portions of dryland fields running short of water during grain filling, resulting in some small pinched kernels. Pinched, poorly-filled kernels are low in carbohydrates and relatively higher in protein than plump kernels. Irrigated fields are not likely to have water stress and therefore would have few pinched kernels.

The gravity table can be used to separate lots of soft white winter wheat into fractions with different protein contents (Figures 1 and 2). The coefficient of determination, a measure of the tendency for one quantity to vary with another, ranged from 0.74 to 0.96 (Table 2). This indicates that from 86 to 98 percent of the variation in protein content in the nine sections can be accounted for by a linear function of gravity table discharge position. Part of the deviation from linearity is due to the extreme positions. Positions 0 to 6 in and 20 to 24 in have higher protein content than is predicted by a linear relationship.

Table 1. Characteristics of wheat samples.

Lot number	Agronomic zone	Variety	Production	
			Location	System
1	6	Madsen winter	Ione, Oregon	irrigated
2	6	Stephens winter	Mattawa, Washington	irrigated
3	6	Penewawa spring	Burley, Idaho	irrigated
4	5	Stephens winter	Pendleton, Oregon	dryland
5	3	Stephens winter	Helix, Oregon	dryland
6	5	Stephens winter	Arlington, Oregon	dryland
7	2	Stephens winter	Cove, Oregon	dryland

Table 2. Regression parameters for soft white wheat grain protein content as a linear function of gravity table discharge position.

Lot number	Slope[1/]	Coefficient of determination	F test significance[2/]
1	0.00	.01	NS
2	-0.15	.93	***
3	-0.05	.74	***
4	-0.20	.92	***
5	-0.14	.88	***
6	-0.33	.88	***
7	-0.14	.96	***

[1/] Slope is the value of coefficient b in the regression equation $y = a + bx$ where y is grain protein %, "a" and "b" are constants and x is discharge position on gravity table.

[2/] F test was calculated as the mean square due to regression divided by the mean square due to deviation from regression. NS means not significant at the 0.10 level, *** means significant at the 0.01 level.

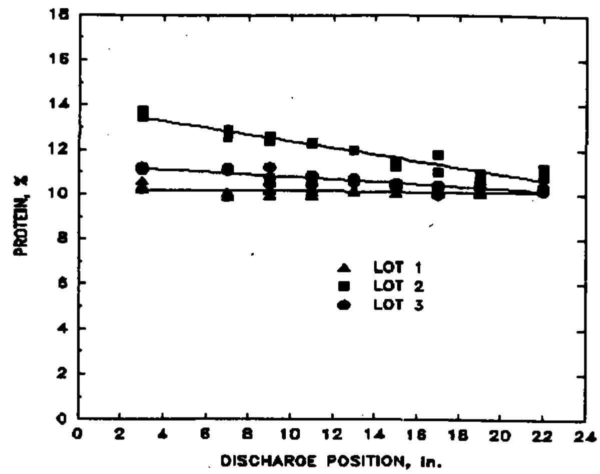

Fig. 1 Grain protein content as a function of gravity table discharge position for irrigated soft white wheat.

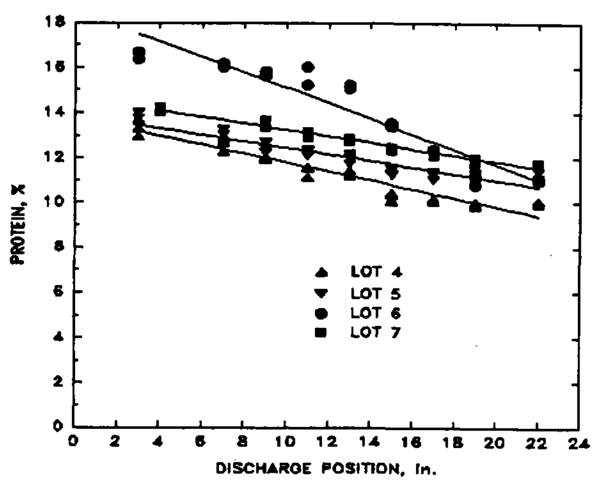

Fig. 2 Grain protein content as a function of gravity table discharge position for dryland soft white wheat.

Dexter et al. (1991) found that gravity tables could be used to separate Canada Western Amber Durum wheat into fractions with varying quality. Least dense fractions contained kernels that were most severely sprouted, broken, and damaged. Denser fractions had lower protein content. However, high protein content is desirable in durum wheat unlike the soft white wheat used for making pound cakes, cookies, and crackers. Therefore, the method had no importance to the durum wheat industry. In the soft white wheat industry, the method holds promise for improving grain quality for those marketing outlets that desire a low-protein wheat.

CONCLUSIONS

Gravity tables may provide a commercial method for separating soft white wheat into fractions with different protein contents. This method could be used to separate low protein soft white wheat from lots that have a large range of kernel protein content, but an average protein content greater than the premium threshold.

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PHYSIOLOGIC LEAF SPOT OF WHEAT

Richard Smiley

A disease called physiologic leaf spot (sometimes called "no-name" disease) occurs on wheat in the inland Pacific Northwest. This disease is similar in appearance to tan spot and Septoria leaf blotch. However, tan spot apparently does not occur in Oregon, Washington, and northern Idaho, and Septoria leaf blotch occurs but causes little damage to dryland wheat in the drier production areas. Septoria leaf blotch is often severe in western Oregon and Washington, and may damage irrigated wheat in the Columbia Basin.

Physiologic leaf spot was particularly severe in some fields during 1990, when as much as 60 percent of the flag leaf area on affected plants was killed, and lower leaves on these plants died prematurely. In 1989 and 1990 as many as 10,000 acres of wheat were treated with fungicides because physiologic leaf spot was mistakenly identified as either tan spot or Septoria leaf blotch.

Essentially nothing is known about the effect of physiologic leaf spot on either grain yield or quality, nor is there much information on the interaction of crop management practices and the severity of the symptoms.

Objectives of this investigation were to describe symptoms of physiologic leaf spot and determine if: 1) a microorganism causes the disease, 2) fungicides reduce disease severity or increase grain yield, 3) wheat varieties differ in susceptibility, 4) tillage and fertilizer systems affect disease severity, and 5) yields are affected.

METHODS AND RESULTS

Nearly 30 experiments on physiologic leaf spot were conducted in northcentral and northeastern Oregon, and southcentral Washington from 1989 to 1992. Most experiments were winter wheat/summer fallow rotations on Walla Walla, Ritzville, or Palouse silt loams. Primary tillage was with either a moldboard or chisel plow.

<u>Symptoms</u>: Leaf spot symptoms included lesions that varied in color, size, and shape. Initial symptoms were small (1-3 mm diameter; 25 mm = 1 inch), oval, dark-brown spots or small necrotic (dead) lesions. These spots or lesions sometimes expanded into spots with light-tan centers and/or narrow (<2 mm wide) yellow (chlorotic) halos. As leaf spots enlarged up to 5 x 10 mm they either remained oval or became irregularly shaped, with a light- or dark-brown center, and often with a narrow, chlorotic halo. Fungal fruiting structures such as pycnidia or perithecia, or bacterial exudates, were not present.

Leaf spot typically became evident on the oldest leaves of susceptible varieties during mid-spring (March). On some cultivars, in some fields, and during some growing seasons the leaf spot did not advance from older into younger leaves. If leaf spot moved into the upper plant canopy the field appeared to be drought stressed. Affected areas of the field became dull and had a brownish tint. This occurred during early to mid-spring, when soils were not dry.

<u>Search for the Cause</u>: Samples of affected leaves were collected from several hundred experimental plots and commercial fields in Oregon and Washington during 1990, 1991, and 1992. Isolations of fungi and bacteria were attempted from several

thousand leaf spots and many common fungi and bacteria were isolated. However, *Septoria* (leaf blotch), *Pyrenophora* (tan spot), *Pseudomonas* (leaf blight), and *Xanthomonas* (black chaff), or other notable wheat pathogens were not detected. Electron microscopy was used to determine if a mycoplasma or virus was present. Biochemical analysis was used to determine whether bacteria or fungi had been present in affected tissue even though they could not be detected by standard laboratory procedures. There was no indication that any of these microbial agents were associated with physiologic leaf spot.

Attempts to Transmit the Disease: Fungi and bacteria from leaf spots were inoculated into susceptible cultivars of wheat in a controlled-environment chamber, a greenhouse, and a field. Inoculation procedures included spraying, injecting, or rubbing spore and mycelial suspensions onto symptomless wheat leaves. Plants were subjected to various stress or non-stress conditions (drought, frost, dew, etc.) before or after inoculations. We were not able to cause this disease to occur on healthy plants.

Fungicides: Fungi from leaf spots were evaluated in the laboratory. Most were very sensitive to Prochloraz, Rubigan, and Tilt, and less sensitive to Benlate and Bravo. Replicated fungicide tests were conducted on commercial fields of Stephens wheat near Pendleton and Helix during 1990 and 1991. Fungicides included Benlate, Bravo, Dithane M-45, Tilt and TopCop (a fungicide/bactericide). Only one application was made, when the flag leaf was emerging. Leaf spot was not present on the uppermost three leaves when plants were treated. Leaf spot severity (percent necrotic area on each leaf of 100 mainstems/plot) ratings were made after head emergence. Grain yields were measured with a plot combine.

Leaf spot on flag leaves during 1990 ranged from 10 to 60 percent necrosis at Pendleton and 0 to 40 percent necrosis at Helix. During 1991 the range of damage was 0 to 25 percent necrosis. Fungicides did not reduce leaf spot or increase grain yields.

Two to five fungicide applications, from December to May, were made on additional replicated plots of Stephens wheat near Helix during 1991 and 1992. During 1991, leaf spot on the second leaf below the flag (F-2) was reduced by multiple applications of Benlate, Dithane, Tilt, and TopCop. No pesticide reduced disease incidence on the third leaf below the flag (F-3). Benomyl was the only fungicide that improved yield, but this was not correlated with a reduction in leaf spot severity. No fungicide reduced leaf spot or increased grain yield during 1992 (Table 1).

Foliar Nutrients: Nutrients were applied to replicated plots of Stephens wheat near Helix during 1991 and 1992. Application rates and times are listed in Table 2. Treatments included Foliar 158 (mostly urea + calcium chloride; 15 percent N, 8 percent Ca, 14 percent Cl; Hill Brothers Chemical Co.) or urea plus Micro-Mix Foli-Gro (micronutrients; with 0.5 percent magnesium, 1.0 percent manganese, 1.5 percent zinc, 1.0 percent iron, 0.25 percent copper, 0.025 percent boron, and 0.0025 percent molybdenum; Wilbur-Ellis), each with or without Benlate or Tilt as a tank mix. Leaf spot was never present on the upper three leaves when applications were made (including May). Leaf spot ratings (0-10 scale; 10 = severe) were made after head emergence in June. Grain yields were measured with a plot combine during July.

Table 1. Incidence and severity of physiologic leaf spot on main stem leaves, and grain yield, for winter wheat plants treated one or more times with foliar-applied fungicides.

	Rate	Application Dates: 1991-1992						Necrotic area (%)				Yield
Treatment	(per acre)	Dec	Jan	Feb	Mar	Apr	May	F[1]	F-1	F-2	F-3	(bu/ac)
Control	---							0	2	12	26	71
Benlate	2 lb	X						0	1	5	20	86
"	"		X					0	1	5	20	73
"	"	X	X				X	0	1	7	23	82
Bravo	2 pint	X	X				X	1	2	10	35	77
"	"		X		X			0	1	7	22	75
Dithane M-45	2 lb	X		X			X	0	1	7	16	72
"	"			X		X		0	1	6	22	77
Tilt	4 fl oz	X						0	1	8	26	70
"	"			X				0	1	7	23	79
"	"	X		X			X	1	1	6	25	79
TopCop	2 quart	X	X				X	0	1	10	23	74
"	"			X	X	X		0	1	5	16	78
"	"	X	X	X	X	X		0	1	5	15	74
LSD (P=0.05)								ns	ns	5	ns	10

[1]Flag leaf (F), and first (F-1), second (F-2), and third (F-3) leaves below the flag leaf.

Leaf spot did not occur on most flag leaves during 1991 (Table 2). On May 15 plants treated two or five times with Foliar 158 were taller (2-4 inches), greener, and more dense than plants in the control. Disease was uniformly severe in all treatments on June 5, indicating that Foliar 158 had delayed the rate of disease progress but did not affect the ultimate severity. Two or five applications of Foliar 158 reduced disease severity, increased grain yield, but did not affect test weight (58 lb/bu) or protein (7.5-8.6%). In contrast, a single application on May 6 did not reduce leaf spot severity or increase grain yield.

Disease severity during 1992 was more pronounced than in 1991. Leaf spot was reduced and grain yield was increased by one or two applications of Foliar 158 (Table 2). There was no effect on test weight or protein (12.4-12.9 percent). Benlate or Tilt added to Foliar 158 did not improve disease control or grain yield, compared to Foliar 158 alone.

Application of urea plus micronutrients during February and April reduced severity of leaf spot but did not increase grain yield (Table 2). Addition of Benlate or Tilt to the urea plus micronutrient mixture did not improve disease control or yield.

<u>Damage to Grain Yields</u>: The relationship between leaf spot severity and grain yield was evaluated on Stephens wheat in three experiments during 1991 and 1992. Data from fungicide trials during 1991 revealed a correlation between grain yield and leaf spot severity on the F-2 leaf. The regression equation predicted an 0.6 bu/acre reduction for each percent of dead leaf area on the F-2 leaf at the time when sampling occurred on May 15. This corresponded to a 10 percent reduction in yield on a field averaging 71 bu/acre. At

Table 2. Influence of foliar nutrient applications on severity of physiologic leaf spot and grain yield.

Table 2. Influence of foliar nutrient applications on severity of physiologic leaf spot and grain yield.

	Application Dates					Necrotic area (%)[2]				Yield
Treatment[1]	Dec	Feb	Mar	Apr	May	F[3]	F-1	F-2	F-3	(lb/ac)
1991										
control						0	2	12	26	71
F158	X	X	X	X	X	0	1	4	9	81
F158	X	X				1	0	3	8	81
F158					X	1	2	10	24	76
LSD (P=0.05)						ns	1	6	13	8
1992										
control						10	19	S[4]	S	79
F158		X		X		3	9	S	S	87
F158			X			3	10	S	S	87
F158 + Benlate		X		X[5]		4	11	S	S	87
F158 + Tilt		X		X[5]		3	9	S	S	87
UFG	X	X				8	16	S	S	80
UFG		X		X		7	14	S	S	82
UFG + Benlate		X				10	21	S	S	80
UFG + Benlate		X		X[5]		6	15	S	S	80
UFG + Tilt		X				7	16	S	S	82
LSD (P=0.05)						2	5	-	-	5

[1]F158 = Foliar 158 (Hill Brothers Chemical Co.) at 5 gal/ac (8.0, 4.4, and 7.6 lb/ac for nitrogen, calcium, and chloride, respectively); UFG = urea (8 lb N/ac) plus Micro-Mix Foli-Gro (Wilbur-Ellis) at 3 pt/ac (0.5% magnesium, 1.0% manganese, 1.5% zinc, 1.0% iron, 0.25% copper, 0.025% boron, and 0.0025% molybdenum); Benlate (DuPont) at 2 lb/ac; and Tilt (Ciba-Geigy) at 4 fl oz/ac.

[2]Leaf spot severity ratings were on May 15, 1991 and June 2, 1992.

[3]Flag leaf (F), and first (F-1), second (F-2), and third (F-3) leaves below the flag leaf.

[4]S = Many or most leaves had died prematurely.

[5]Fungicide was applied during the first application of nutrients but not during the second application.

the time of evaluation on May 15 leaf spot was mostly absent on the flag leaf (F), less than 2 percent on the next lower leaf (F-1), and intermediate (5-12 percent) on the F-2 leaf. The F-3 leaf was severely affected (15-35 percent necrosis) and becoming chlorotic, and the F-4 leaf was fully chlorotic and often dead. Yield loss predictions were most precise when based on damage to a leaf with an intermediate level of damage.

Disease was more severe in 1992 than in 1991. Regressions predicted yield losses of 0.8 and 0.5 bu/acre for each percent of dead leaf area on F and F-1 leaves, respectively. Necrotic leaf area in the control treatment was 10 and 19 percent for the F and F-1 leaves, respectively, on 2 June. The grain yield was 79 bu/acre. Yield losses of 10 and 11 percent were predicted, which was similar to losses predicted during 1991. Regression analysis in the foliar nutrient experiment during 1992 also indicated that this leaf spot suppressed yields by about 10 percent.

Table 3. Physiologic leaf spot ratings[1] on winter wheat varieties at five eastern Oregon locations.

Cultivar	Market Class[2]	1990 Helix	1991 Helix	1991 Athena	1991 Heppner	1992 Moro	1992 Pendleton	Mean
Buchanon	HR	-	1.0	1.7	0.3	1.7	2.0	1.3
Tres	CL	1.3	2.0	0.7	1.0	1.3	3.0	1.6
Dusty	SW	1.3	1.3	3.3	0.7	-	-	1.7
Moro	CL	1.0	-	-	-	2.3	2.3	1.9
Ute	HR	-	1.6	2.3	0.7	3.0	3.3	2.2
Hyak	CL	2.7	2.0	3.3	2.3	0.7	3.0	2.3
Cashup	SW	2.0	2.7	2.7	0.7	2.7	3.7	2.4
Andrews	HR	1.7	2.0	4.7	1.0	2.7	2.7	2.5
OR 855 (Rohde)	CL	2.3	3.7	3.3	1.7	2.0	3.7	2.8
Wanser	HR	1.7	3.0	5.3	1.7	1.7	3.7	2.9
Daws	SW	3.3	3.7	3.3	3.0	2.0	2.7	3.0
Basin	SW	4.0	3.7	4.3	2.0	2.0	3.7	3.3
Hill 81	SW	3.7	4.0	2.0	2.3	3.3	5.0	3.4
Eltan	SW	-	4.3	3.0	3.3	3.0	3.7	3.5
Gene	SW	3.3	3.7	3.3	4.7	3.0	3.0	3.5
Oveson	SW	3.7	3.7	3.3	3.0	3.7	4.3	3.6
Yamhill	SW	-	5.0	3.3	3.7	2.7	3.7	3.7
Madsen	SW	4.3	4.0	5.7	3.3	2.0	4.0	3.9
Lewjain	SW	5.0	4.3	3.7	2.7	2.7	5.0	3.9
Malcolm	SW	3.3	4.0	4.7	3.3	3.3	5.0	3.9
Batum	HR	3.3	5.0	4.0	4.0	-	-	4.1
Kmor	SW	-	4.3	5.3	2.7	4.0	4.3	4.1
MacVicar	SW	4.0	3.7	3.3	3.0	4.7	6.0	4.1
Hoff	HR	4.0	4.7	4.0	3.0	3.3	5.7	4.1
Stephens	SW	5.7	5.0	5.3	3.7	5.3	6.7	5.3
LSD (P=0.05)		1.4	1.6	1.5	1.4	1.9	1.4	0.9

[1]Scale of 0-10, 0 = none, 10 = sever.

[2]HR = hard red winter wheat, SW = soft white winter wheat (common head type), CL = soft white winter wheat (club head type).

Wheat Cultivars: Leaf spot was evaluated in winter wheat nurseries during 1990 (two sites), 1991 (four sites), and 1992 (two sites). Nurseries were planted near Pendleton, Athena, Helix, Lexington, Heppner, and Moro. The replicated nurseries each contained 28 wheat and two triticale varieties. During 1990 and 1992 a leaf spot rating scale of 0 (no damage) to 10 (severe damage) was used to describe disease severity on the entire mainstem. Percentages of leaf spot on each leaf was determined during 1991.

Leaf spot did not occur at Lexington during 1991 and was very minor at Pendleton during 1990. In the latter test Stephens had a leaf spot rating of 3.7 and all other entries rated 0 to 1.7. Data for the other six nurseries are reported in Table 3. Club wheats were among the varieties least susceptible to physiologic leaf spot. Susceptibility among common-type soft white winter wheats and hard red winter wheats was variable. Stephens was the most susceptible variety. Two triticale varieties (Whitman and Flora) were essentially immune, with leaf spot ratings of 0 to 0.5 in the seven nurseries.

Nitrogen Rate: Malcolm wheat was planted near Pendleton in replicated plots treated with 0, 50, 100, or 150 lb N/acre. Nitrogen was applied as Uran 2 inches below the seed at planting. Wheat was seeded at 10-inch row spacing with a modified John Deere HZ drill. Planting was in early September, but drought delayed emergence until early November. Leaf spot severity on April 1 was reduced by increasing rates of nitrogen. Disease ratings (scale of 0-10) were 7.8, 3.3, 2.5, and 1.3 (lsd = 3.7) for rates of 0, 50, 100, and 150 lb N/acre.

Surface Residues: Four winter wheat varieties and three levels of wheat stubble residue on the soil surface at seeding time were examined in a replicated factorial design. Varieties were Daws, Hyak, Moro, and Stephens. Residue levels of 49, 39, and 17 percent surface cover were achieved by chisel plow, off-set disk, or moldboard plow, respectively. Nitrogen (80 lb N/acre) was injected as anhydrous ammonia into the fallow, and wheat was planted in 12-inch rows in October, using a plot drill with double-disk openers. Leaf spot was evaluated on April 21.

Varieties and residue levels each had significant effects on leaf spot (Table 4). Leaf spot on Stephens was more severe with high than with low levels of residue. Leaf spot on the more resistant varieties Daws, Moro, and Hyak, was not affected by residue.

Planting Date: Stephens wheat was planted at 15-day intervals on six planting dates from September 1 to November 15 at Pendleton during 1991. Leaf spot was assessed during April 1992, when most plants were in the boot stage. Percent necrotic leaf area was evaluated individually on F, F-1, F-2, and F-3 leaves on May 6 and June 4. On May 6 the heads were emerging from plants seeded during September. On June 4 all plants were in the soft-dough to milk stages.

Leaf spot severity on April 21 declined with successive planting dates (Table 5). By May 6, the influence of planting date was still present for the F-1 and F-2, but was disappearing on the F-3 leaves. On June 4, the influence of planting date on disease severity was becoming obscure for all except the November plantings.

Crop Residue Management: Observations of plants were made on the

Table 4. Influence of crop residue level on severity of physiologic leaf spot on four varieties of winter wheat during 1992.

Residue on soil surface	Stephens	Daws	Moro	Hyak
17%	2.1	1.9	0.8	0.4
39%	4.0	1.8	1.0	0.5
49%	3.6	1.6	0.6	0.3
LSD (P=0.05)	0.9	ns	ns	ns

Table 5. Influence of planting date on physiologic leaf spot severity (0 = none, 10 = severe) on Stephens wheat.

Planting date (1991)	Assessment date (1992 and leaf or leaves[1]									
	6 Apr	21 Apr	6 May				4 Jun			
	(all leaves)		F	F-1	F-2	F-3	F	F-1	F-2	F-3
1 Sep	8.3	7.6	0.3	5.6	7.5	7.9	3.2	7.1	S[2]	S
15 Sep	8.4	5.5	0	3.7	6.9	8.1	3.4	7.2	8.5	S
1 Oct	5.3	5.3	0	3.1	5.3	7.7	2.9	6.8	7.1	S
15 Oct	4.6	4.7	0	1.5	5.2	7.4	3.1	6.2	7.3	S
1 Nov	2.5	3.4	0	0.2	0.4	5.4	2.1	3.1	4.9	6.7
15 Nov	1.3	1.7	0	0	0.5	3.2	0.2	2.5	3.4	6.9
LSD (P=0.05)	1.4	1.2	ns	1.9	0.8	1.3	1.5	2.1	1.8	-

[1]Flag leaf (F), and first (F-1), second (F-2), and third (F-3) leaf below the flag leaf.

[2]S=Many or most leaves had senesced prematurely.

Table 6. Influence of crop residue management and rate and source of nitrogen on physiologic leaf spot ratings[1].

Nitrogen rate (kg N/ha)	Nitrogen source	Stubble burned[2]		Stubble incorporated[2]	
		1991	1992	1991	1992
0	ammonium nitrate	2.3	5.5	2.2	4.5
40	ammonium nitrate	4.3	6.0	4.4	5.0
80	ammonium nitrate	3.8	4.0	3.8	3.5
30	pea vines	-	-	2.9	4.5
100	cow manure	-	-	3.1	3.5

[1]Leaf spot ratings (0 = none, 10 = sever) are described intext.

[2]Disease severity ratings differed significantly (LSD = 0.4) during 1991 but not during 1992.

long-term management plots at the Columbia Basin Agricultural Research Center to observe patterns of disease with respect to management history. The wheat-fallow rotation experiment with crop residue treatments was established in 1931. Treatments include application of ammonium nitrate at 0, 40, or 80 lb N/acre, with stubble either retained or burned during the spring (6 treatments), no added N and stubble burned during autumn, and addition of cow manure (10 tons per crop) or pea vines (1 ton per crop) in the spring. All plots are plowed in the spring and planted to Stephens in the autumn.

The source of nitrogen had no effect on leaf spot response during 1991 or 1992 (Table 6). Severity of disease was highest at intermediate levels of nitrogen fertility during 1991, and at lowest levels of nitrogen during 1992.

At comparable rates of nitrogen there was no difference among leaf spot ratings when wheat stubble was burned or incorporated into soil with a moldboard plow. Burning the stubble during the autumn or spring was equivalent. These observations are contrary to the response of Stephens in the surface residue study.

Tillage x Nitrogen Interactions: This wheat-fallow rotation was established in 1940 at the Columbia Basin Agricultural Research Center. The experiment contains three tillage treatments and six levels of nitrogen. Tillage treatments are moldboard plow, disk, subsurface sweeps, which leave 5, 40, and 65 percent surface residue, respectively. Uran is applied at rates of 0, 40, 80, 120, and 160 lb N/acre.

Leaf spot was most severe in the moldboard plow treatment (Table 7). The response to tillage was most apparent at intermediate rates (40 and 80 lb N/acre) of nitrogen. Leaf spot was more severe at 40 lb N/acre than at lower or higher rates for all three tillage systems. The effects of tillage on leaf spot severity in this experiment were opposite those observed for Stephens in the surface residue experiment.

Table 7. Influence of tillage implement, nitrogen rate, and their interactions[1] on physiologic leaf spot ratings[2] during 1991.

Nitrogen	Tillage			
(lb N/ac)	Plow	Disk	Sweep	Mean
0	3.0	2.7	3.0	2.9
40	4.7	3.3	3.3	3.8
80	3.3	3.0	2.3	2.9
120	2.7	2.3	2.7	2.6
160	2.3	1.7	1.3	1.8
Mean	3.2	2.6	2.5	-

[1]Analysis of variance indicated that least significant differences were 0.5 for nitrogen variables and 0.4 for tillage treatments.

[2]Leaf spot ratings (0 = none, 10 = severe) are described in text.

Annual Winter Wheat and Wheat/Pea Rotation: The annual wheat experiment began in 1931 at the Columbia Basin Agricultural Research Center. Ammonium nitrate and ammonium phosphate sulfate (80 lb N/acre) are broadcast before the plot is plowed and planted to Stephens.

Winter wheat/pea rotations under four tillage systems were initiated in 1963. Each year four replicates of each tillage treatment are planted to dry seed peas and four to Stephens wheat. The treatments are: 1) rototill in autumn before planting spring peas and Noble sweep and chisel plow in autumn before planting wheat, 2) moldboard plow in autumn before peas and Noble sweep before wheat, 3) moldboard plow in spring before peas and Noble sweep and moldboard plow in autumn before wheat, and 4) conduct no tillage before planting peas and Noble sweep before planting wheat.

Leaf spot severity did not differ among tillage treatments in the wheat/pea rotation. Disease severity ratings on April 3, 1992 were 0.5 for all treatments. Ratings in the annual winter wheat averaged 7.1. Ratings of 3.5 were present in a comparable treatment (80 lb N/acre) of the nearby wheat/fallow rotation. Later in the growing season the ratings became more uniform; leaf spot ratings on June 5 were 4.6, 7.3, and 5.1 in the wheat/pea, annual wheat, and wheat/fallow plots, respectively.

DISCUSSION

There was no evidence that a microbial agent caused physiologic leaf spot. The cause of the disease remains unknown, and the reason for the increase in severity during recent years also remains unknown. This trend does not appear to be related to changes in dominance of wheat varieties, tillage procedures, crop rotations, or fertilizer application rates or procedures. It is unlikely that the prolonged drought is directly responsible for the increase in leaf spot because this disease also occurs on irrigated wheat. If the cause is of genetic origin (e.g., a physiologic dysfunction) there must be a strong environmental effect governing expression of symptoms.

This research provided the first evidence that physiologic leaf spot can reduce grain yield by 10 percent and is not controlled by fungicides. Moreover, this is the first report of crop management procedures for reducing damage to winter wheat by physiologic leaf spot. Leaf spot incidence and severity were reduced by variety selection, delaying the planting date, increasing the rate of nitrogen fertilizer, applying a Foliar 158 to foliage, and reducing the frequency of wheat in the crop sequence. These control measures are likely to result in a yield response during years when this disease becomes severe.

Management practices that had no apparent affect on leaf spot severity included different application timings or sources of nitrogen, or burning the stubble of previous wheat crops. Tillage practices that left different amounts of straw residue on or near the soil surface provided inconclusive results.

Winter wheat varieties varied in susceptibility to physiologic leaf spot and were relatively consistent in response over seasons and locations. Heritability studies are needed to determine if higher levels of resistance to physiologic leaf spot can be selected. This has apparently been accomplished in Canada.

Physiologic leaf spot is difficult to distinguish from tan spot or Septoria leaf blotch. It is therefore important to identify crop management practices that minimize the risk of making an error in disease identification. All three diseases are minimized by crop rotation, resistant varieties, and delayed seeding. Tan spot and Septoria leaf blotch, but not physiologic leaf spot, can also be controlled with fungicides, destroying (burning or burial) residues of infected wheat stubble, reducing the rate of nitrogen fertilizer, and avoiding dense seedling canopies.

Application of Foliar 158 suppressed physiologic leaf spot, prolonged juvenility of leaves, and increased grain yield during 1991 and 1992. Urea plus a mixture of micronutrients provided an intermediate level of disease control but no increase in grain yield. We have not yet determined whether there is some unique property of the Foliar 158 formulation, or whether physiologic leaf spot and yield responded to the calcium chloride. This is being investigated.

Calcium protects roots from effects of low pH, toxic ions, salinity, and ion imbalance. Calcium reduces cellular membrane damage and leakiness. Calcium deficiency has been associated with reduced cold hardiness, increased risk of magnesium toxicity, and reduced growth of meristematic tissues. Calcium improves plant resistance to diseases caused by soilborne plant pathogens but there is little evidence it has an important role in foliar diseases. Although soil acidification is occurring throughout the Pacific Northwest there is no evidence that calcium concentrations have already gone below a critical level for wheat growth and metabolism.

Chloride is necessary for photosynthesis and osmotic relations in leaves. Chloride deficiency causes wilting, chlorosis, and reduced leaf growth. Application of chloride salts to soil or foliage can suppress rust and Septoria leaf blotch of wheat, and can increase yield, even when soil and tissue tests did not indicate that chloride was in low supply. Chloride application to wheat in the Netherlands caused flag leaves to remain green for a longer period, and grain yield to increase. Research in Montana indicated that chloride affected the rate of spikelet formation and maturation, and volume and weight of kernels. The relationship between chloride, crop yield, and diseases is not understood. It is also unclear whether the response of physiologic leaf spot to application of Foliar 158 is dependent on the chloride or some other component of this product.

Four management strategies may prove beneficial on fields where physiologic leaf spot has damaged wheat during recent years. Select a wheat variety resistant to this disease. Plant as late as possible, without compromising yield by planting too late for your region. Rotate crops wherever possible. Applications of Foliar 158 have been cost effective in experimental plots conducted thus far. However, the application had to be made before symptoms of physiologic leaf spot became fully apparent. Application of Foliar 158 , or equivalent, in May, after the disease became well established in the upper plant canopy, was not effective.

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WHEAT PRODUCTION IN SOIL INFESTED WITH CEREAL CYST NEMATODE AND FUNGAL PATHOGENS

Richard Smiley, Russell Ingham, and Gordon Cook

Cereal cyst nematode (CNN) (*Heterodera avenae*) infests agricultural soils throughout the world. The nematode is spread when contaminated soil moves on or in vehicles, equipment, plants, shoes, animals, dust, water, or other means. CCN was first reported in the United States (in western Oregon) during 1974. Since 1983 CCN has been identified in a small number of fields in all major wheat production areas of the Pacific Northwest (PNW). Infested areas include, but may not be limited to, the following counties: Union, Morrow, Washington, and Umatilla in Oregon; Whitman County in Washington; and Caribou, Fremont, Jefferson, Madison, and Teton Counties in Idaho. Hosts of CCN in the PNW include wheat, barley, oats, corn, and grass seed crops. These crops are valued at $1.2 billion annually, and are produced on 70 million acres. A survey of fields in the Grande Ronde Valley during 1987 indicated that 67 percent of the fields surveyed were infested with CCN.

Management strategies for CCN have not been developed in semi-arid regions of the PNW. Yields of winter and spring wheat in eastern Oregon have been improved from 0 to 29 percent with one application of Temik, but this is not a registered use. No local information was available regarding management practices involving resistant varieties, crop rotations, or tillage.

Crop rotations are particularly useful for reducing damage caused by CCN in other regions. In eastern Canada, three-year rotations including one or two years of winter wheat and soybean, corn, barley, and/or alfalfa produced wheat yields 20 percent higher than annual winter wheat in plots managed with moldboard plowing, minimum tillage, or no tillage. It was not known whether crop rotations would reduce CCN damage in eastern Oregon. Amplifying this uncertainty are the complex root diseases resulting from combined actions of CCN and pathogenic fungi that have been described, and the suite of pathogens in eastern Oregon which differs from areas where rotations have been studied in other parts of the world. Root and crown diseases in the PNW include Cephalosporium stripe, common root rot, strawbreaker foot rot, Pythium root rot, Rhizoctonia root rot, and take-all. Effects of CCN and Rhizoctonia root rot on wheat in Australia were less damaging individually than when combined. Another study revealed that Rhizoctonia root rot and take-all both reduced formation of CCN cysts by rotting the roots and competing for root sites, causing the CCN population to decline.

The primary objective of this research was to examine winter wheat growth, diseases, CCN damage, and yield in various crop sequences. Other objectives were to determine effects of tillage and grass weeds on damage from CCN.

METHODS

The study was conducted on the John Cuthbert farm five miles northeast of La Grande. The field had been managed as a winter wheat/summer fallow rotation for six years. The area has 20 inches annual precipitation, and a deep, poorly drained Conley silty clay loam. Eleven treatments (Table 1) were established on 16 x 100 ft

Table 1. Crop sequences and yield of winter wheat in soil infested with cereal cyst nematode and fungal pathogens.

	Crop sequence[1] and year					Wheat yield (bu/ac)					
Treatment	1988	1989	1990	1991	1992	1988	1989	1990	1991	1992[2]	5-yr sum
1	W	W	W	W	W	117	55	77	49	66	364
2	W	W	W	W	W	129	105	63	43	61	401
3	W	F	W	F	W	129		98		97	324
4	F	W	F	F	W		122			104	226
5	F	W	B	F	W		130			94	224
6	W	P	W	P	W	128		106		93	327
7	W	W	P	P	W	118	59			94	271
8	R	W	F	R	W		123			101	224
9	W	A[3]	A	A	W	123				94	217
10	W	A[3]	A	A	W	126				81	207
11	G	G	G	G	W					97	97
Least significant difference (0.05)						ns	18	9	ns	8	--

[1]W = Stephens winter wheat, B = Steptoe spring barley, F = summer fallow, P = Moranda or Columbia spring pea, R = Tobin spring rape, A = Blazer alfalfa, G = Baron Kentucky bluegrass. Years refer to year of harvest. Tillage was performed on all treatments except #2, using a moldboard plow, disk, and spring-tooth harrow. Summer fallow was maintained with a rod weeder. Treatment #2 was not tilled, and stubble was removed by burning.

[2]Yields in 1992 are means of Temik treated (mean yield of 89.9 bu/ac) and untreated (mean yield of 88.8 bu/ac) wheat, which did not differ significantly.

[3]Alfalfa was grown under two weed management regimes. Treatment #9 was continually rogued to eliminate grass weeds and volunteer cereals. Treatment #10 was moderately contaminated by volunteer wheat, downy brome, and wild oats.

plots replicated four times. The experimental area was sprinkler irrigated to meet requirements of a perennial bluegrass seed crop grown on the surrounding field from 1988 to 1992.

1987-1988: In September 1987, wheat stubble from a commercial crop was incorporated into the soil by moldboard plow and disk. Ammonium nitrate was broadcast and incorporated with a harrow. In October wheat was planted into treatments 1-3, 6-7, and 9-10 (see Table 1), using a John Deere HZ drill. Uran was banded 2 inches below the seed at planting.

In the spring, Bronate was applied to wheat, and plots not planted to wheat (treatments 4-5, 8, and 11) were tilled with a rod-weeder. Rapeseed was planted into treatment 8. Bluegrass seed was broadcast on treatment 11. Rape was mowed as necessary to avoid harvesting. Summer fallow was rod-weeded three times. Wheat was harvested in August.

1988-1989: All treatments except no-till wheat (treatment 2) and the bluegrass were plowed and disked in September. Residue was burned from the no-till wheat. The entire plot was fertilized by broadcasting ammonium nitrate, and extra N was applied to no-till plots to compensate for burning the residue. Fertilizer was incorporated to 1-inch depth with a skew treader on all plots. Wheat and Austrian winter peas (treatment 6) were planted in early October.

Treatments 9 and 10 were harrowed and alfalfa was planted in March 1989. Long periods of water-saturated soil caused poor survival of winter peas and emergence of alfalfa. Treatments 6, 9, and 10 were harrowed and reseeded in May. Treatment 6 was treated with Treflan and Sencor before planting to Moranda dry pea. Wheat was treated with Bronate, and the summer fallow was harrowed and rod-weeded. Bluegrass was treated with Buctril. Peas were mowed in July to prevent seed maturation. Wheat was harvested in July. Manual weeding of "weed-free" alfalfa (treatment 9) was performed repeatedly during the summer and autumn of 1989.

<u>1989-1990</u>: Alfalfa and bluegrass were mowed in September. All plots to be fallowed or planted to wheat (except no-till), barley, or pea were plowed and disked, and bluegrass and no-till wheat plots were burned. The entire experimental area was fertilized with ammonium nitrate. Roundup was applied to treatment 2 (no-till wheat). Treatments 4-5 and 7-8 (for spring crops or summer fallow) were rod-weeded. Wheat was planted in late September.

"Weed-free" alfalfa was manually rogued as needed during the season. In March all plots for summer fallow or spring crops were harrowed, and wheat plots were treated with Bronate. Tilled plots were harrowed again in May, and summer fallow (treatment 4 and 8) was rod-weeded. Pea plots (treatment 7) were treated with Treflan, harrowed, planted to Columbia green pea, and treated with Sencor. MCPP was applied to bluegrass. Barley was planted in treatment 5. The summer fallow was disked and rod-weeded, Bronate was applied to barley, Thistrol was applied to peas, and Di-Syston was applied to wheat and barley. Fallow was rod-weeded and alfalfa and bluegrass were mowed as needed through the summer. Peas were mowed, and wheat was harvested in August.

<u>1990-1991</u>: No-till wheat stubble was burned in September. In October all treatments except alfalfa and bluegrass were treated with Roundup, and all plots except alfalfa, bluegrass, and no-till wheat were plowed and disked. All plots except the fallow (treatments 3-5) were fertilized with ammonium nitrate. All plots, including the no-till wheat plots, were tilled shallowly with a skew treader, and wheat was planted. The summer fallow was rod-weeded and "weed-free" alfalfa was rogued as needed through the season.

In April, wheat was treated with Bronate. Landmaster and Bronate were applied to fallow, pea, and rape treatments in June. Bluegrass was also treated with Buctril. In June, rape and Columbia pea were planted, and alfalfa and bluegrass were mowed. Summer fallow was rod-weeded three times during the summer. Thiodan was applied to peas in July, and wheat was harvested in August.

<u>1991-1992</u>: In September, soil samples were collected from all 44 plots (4 replicates of 11 treatments) to analyze the residual nitrogen in each plot. Alfalfa, rape, bluegrass, and peas were mowed and stubble of no-till wheat was burned. All treatments except no-till wheat were plowed, and all treatments were disked twice (only to 2-in depth on no-till wheat plots). Each of the 44 plots was fertilized individually with ammonium nitrate. Rates ranged from 0 to 110 lb N/acre, based on soil test results plus estimates of N to be released during mineralization of straw. A uniform target rate for each plot was 150 lb

total N/acre. Hoelon was applied and incorporated with a skew treader. All plots were rod-weeded and planted to wheat in early October. Wheat was planted with a Great Plains double-disk no-till drill with 10-in row spacings. The planting direction was crosswise to the length of each 16 x 100 ft plot. Temik 15G (3.6 lb a.i./acre) was banded with the wheat seed on half the entire block, providing 88 rotation x Temik plots of 16 x 50 ft (11 rotation treatments; 4 replicates; +/- Temik). Roundup was applied as a pre-emergence spray.

In March, Harmony Extra and Lexone were applied to control downy brome, foxtail, pigweed, tumble mustard, and volunteer peas. Temik (2.5 lb a.i./acre) was re-applied as a broadcast to the previously Temik-treated portion of the block. Wheat was harvested in August. All grain from the Temik-treated area was destroyed after harvest.

Every year: Wheat plants were collected one to three times every year for quantitative evaluations of growth, development, all diseases, and damage from CCN. Non-hosts of CCN (alfalfa, pea, and rape) and bluegrass were not monitored for diseases, growth, or yield. Soil samples were collected each year to extract and count cysts and larvae of CCN in each of the 44 plots (88 plots in 1992).

CCN damage to roots was rated on a scale of 0 to 5; 0=no damage, and 5=roots very knotted and shortened, and shoots stunted by 50 percent. Strawbreaker foot rot was quantified as the percentage of tillers containing lesions that penetrated into the culm beneath the leaf sheath. Common root rot was quantified as percentage of subcrown internodes affected by characteristic dark lesions. Take-all was rated as the percentage of roots affected by characteristic blackening of the root cortex or vascular system. Pythium root rot was quantified as percentage of roots with light-brown, water-soaked lesions. Rhizoctonia root rot was identified by brown lesions that often severed the root in a characteristic "spear point". Rhizoctonia root rot was evaluated separately for the seminal (0-5 scale) and crown (0-4 scale) roots; 0=no disease in each scale.

Plant growth and development were measured on plants evaluated for diseases. Measurements included development stage (Haun system), plant height, tillers per plant, oven dry weight of shoots, and number of roots intersecting horizontal planes 1- or 2-in below the seed. Percentages of plants with the coleoptilar tiller (T_0) and tillers from axils of first (T_1), second (T_2), or higher numbered leaves were also quantified. Grain yields and test weights were measured by threshing 5 x 100 ft strips from each plot. Two 5 x 50 ft strips were harvested from 88 plots in 1992.

RESULTS

1987-1988. As expected for the first year, no treatment differences were measured for foliar growth or development, or root numbers, during the spring and summer. Incidence and severity of damage from CCN, take-all, Rhizoctonia root rot, Pythium root rot, and common root rot were minimal. Grain yields also did not differ (Table 1).

1988-1989. Damage ratings for CCN were significantly higher in the three second-season crops of annual wheat (1.7-1.8) than in wheat following fallow (1.1) and rape (0.9). Damage to bluegrass roots was minimal (0.3). Rhizoctonia root rot was moderate (indices of 2.5-3.1) on seminal roots of the second consecutive crops of wheat, intermediate on wheat following rape (2.1), and least on wheat following fallow (1.0). Rhizoctonia root rot damage to crown roots was low to moderate (0.8-1.2) in all treatments. Take-all, Pythium root rot, and common root rot were minimal and did not differ among treatments. Yield of wheat following wheat in tilled soil was 55-62 percent less than wheat following fallow or rape (Table 1). In contrast, yield of wheat following wheat in non-tilled soil was only 14-21 percent less than for wheat following fallow or rape. Wheat in no-till yielded more than wheat in tilled soil.

__1989-1990__. CCN damage ratings to seedlings in November were higher for annual wheat (1.0) than wheat following fallow or peas (0.2-0.3). Pythium root rot was also higher on annual wheat (1-3 percent roots) than wheat in rotations (trace). In contrast, Rhizoctonia root rot ratings on seminal roots were higher in the rotations (1.8-1.9) than in annual wheat (1.1-1.4). Plants were 1 inch taller in rotations than in annual wheat, and were phenologically more developed in rotations (Haun 3.2-3.3) than in annual wheat (Haun 2.6-3.0). Plants had higher percentages of tillers in rotation treatments than in annual wheat treatments; respectively, 3-28 percent vs 0-1 percent for T_0, 77-92 percent vs 6-34 percent for T_1, and 16-17 percent vs 0 percent for T_2.

Incidence and severity ratings for diseases in April 1990 did not differ significantly among treatments. Diseases present in minor amounts included Rhizoctonia root rot, Pythium root rot, common root rot, and take-all. CCN damage ratings were 0.7-0.8 for annual wheat and 0.1 for wheat following fallow or peas. Rhizoctonia root rot and Pythium root rot each became less damaging as take-all and CCN became more damaging.

Grain yields were significantly lower in annual wheat than in wheat-fallow or wheat-pea rotations. In contrast to yields in 1989, wheat in tilled soil yielded more than in no-till during 1990. Yield of wheat was directly correlated with numbers of roots on plants during the spring, and was negatively correlated with CCN populations in soil before wheat was planted (Fig. 1), and with CCN damage ratings during the spring. Backwards multiple regression analysis indicated that the strongest determinant of yield was combined damage from CCN and take-all. Rotation effects on yield of spring barley could not be compared because barley was present in only one treatment (5,249 lb/acre).

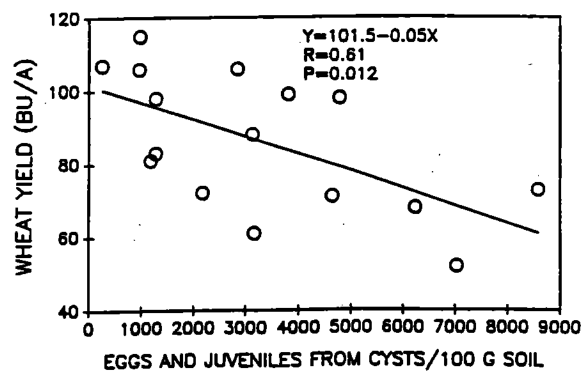

Figure 1. Relationship of pre-plant nematode populations (August, 1989) to yield of winter wheat in 1990.

__1990-1991__. None of the disease parameters differed among the two annual wheat treatments during March. However, wheat in tilled soil was 1 inch taller than in non-tilled soil, and was phenologically more advanced (Haun 3.5 vs 3.2). Numbers of roots did not differ among treatments.

In May the damage from CCN was very light on seminal roots (ratings 0.1-0.2), and moderately severe on crown roots; 3.6 in tilled and 2.3 in untilled soil. In contrast, Rhizoctonia root rot of seminal roots was more severe in non-tilled (1.3) than tilled (0.4) soil, and was not present on crown roots. Pythium root rot also affected more roots in non-tilled (12 percent) than tilled (5 percent) soil. Take-all (2 percent roots), strawbreaker foot rot (23-25 percent plants), and common root rot (41-46 percent plants) did not differ among treatments.

Numbers of roots below the seed revealed that plants in tilled soil had 20 percent more roots than plants in non-tilled soil. There was a corresponding difference in plant height; 14 inches in tilled soil and 9 inches in non-tilled soil. Tillering was variable for plants in tilled and non-tilled soils; 18 vs 31 percent for T_0, 90 vs 85 percent for T_1, 73 vs 53 percent for T_2, 21 vs 0 percent for T_3, and 6 vs 0 percent for T_4. Grain yields did not differ among treatments.

<u>1991-1992</u>. Temik banded with the wheat seed did not reduce numbers of CCN-affected plants or root damage severity ratings in March 1992. The nematicide also did not affect the incidence or severity of Rhizoctonia root rot, Pythium root rot, or take-all. However, when re-applied as a surface broadcast during March, Temik significantly reduced the CCN damage assessed during May. The beneficial effect of Temik was least apparent in treatments where hosts of CCN had not been present for two or more years. Percentages of plants affected by fungal diseases were higher in Temik-treated than untreated soil. Compared to untreated soil, Rhizoctonia root rot in the Temik treatment was increased by 75 percent and 31 percent on crown and seminal roots, respectively, and Pythium root rot and take-all were increased by 23 percent and 10 percent, respectively.

Root damage from CCN was low during early spring (March) and in Temik-treated soil during late spring (May). Damage ratings were high in untreated annual wheat during late spring, and were intermediate in the wheat/fallow, wheat/pea, and wheat/barley/fallow rotations. Damage ratings were lowest in treatments where hosts had not been present for two or more years. Incidence or severity of CCN damage did not differ among tillage treatments for annual wheat. Grass weeds in alfalfa led to an increase in CCN damage to the following wheat crop.

Rotations did not have a significant effect on incidence or severity of Rhizoctonia root rot or take-all during early spring. Pythium root rot was most frequent and damaging in wheat/pea rotations or wheat following two years of fallow, and least frequent and damaging following bluegrass or annual wheat in tilled soil. Common root rot occurred on 10-30 percent plants in all treatments except annual no-till wheat (2 percent) and both treatments containing alfalfa (2-6 percent).

As plants matured into the late spring most of the earlier patterns were maintained. Take-all became more important (15-20 percent plants) in annual no-till wheat and in wheat following weedy alfalfa than in other treatments (0-5 percent plants). Fewer plants were diagnosed with common root rot during late spring than early spring, which may have been an artifact caused when symptoms became obscured by prolific root growth. Although treatment differences for strawbreaker foot rot became significant (23-67 percent plants) during late spring no patterns relative to crop sequences were apparent.

Nearly all growth and development parameters examined were affected by crop sequences. Fewest roots occurred in annual wheat, wheat following bluegrass, and wheat in rotation with barley and fallow. Plant height, development, and tillering were also less for annual wheat and wheat following bluegrass than for other treatments.

Wheat in all rotations yielded more than wheat produced annually (Table 1). Grain yield was not improved by application of Temik. Tilling or not tilling soil prior to planting annual wheat also had no effect on yield. Yield of wheat following three years of alfalfa was higher when alfalfa was weed-free rather than contaminated by grasses. Wheat following fallow, peas, rape, or bluegrass provided the highest yields. Yield was negatively correlated with percentage of plants affected by CCN and take-all, and positively correlated with all plant growth parameters. Backwards multiple regression analysis indicated that the strongest determinant of yield was combined damage from CCN and take-all. Numbers of roots 1 inch below the seed during seedling growth and number of tillers on mature plants were the most important plant growth and development parameters affecting yield. Numbers of roots were negatively correlated with combined damage from CCN and Pythium root rot. Numbers of tillers were negatively correlated with combined damage from CCN and take-all.

Total wheat production for the five-year period was also calculated (Table 1). Yield was higher in no-till than tilled annual wheat, but only because the yield of tilled wheat declined one year earlier than in the no-till. Yields of wheat for the wheat/fallow and wheat/pea rotations were nearly the same as for annual wheat. Depending on pea prices and costs of production, the wheat/pea rotation is likely to have been the most profitable of these crop sequences. Likewise, comparable amounts of wheat were produced by two crops of wheat in the following sequences: wheat/2-yr fallow/wheat, wheat/barley/fallow/wheat, wheat/fallow/rape/wheat, and wheat/3-yr alfalfa/wheat. Sequences with barley, rape, or alfalfa were likely the most profitable, compared to the double fallow.

DISCUSSION

Crop rotations of any type, including summer fallow, provided higher yields than annual winter wheat. Rotations that could generate additional income from other crops would have produced the highest profitability as well as the highest level of plant health. Barley and Kentucky bluegrass did not seem to aggravate the amount of damage caused by CCN. In an earlier test, also located in the Grande Ronde Valley, Temik did not affect yields of winter or spring barley, but improved yield of winter and spring wheat by 25-29 percent. It appears that barley and bluegrass may be poor hosts for the biotype (race) of CCN present in the valley. Evaluations of CCN populations in all treatments (in progress) may clarify this observation.

Temik did not increase yield of winter wheat during 1992. Temik reduced the amount of CCN damage, but there was an increase in damage from Rhizoctonia root rot, Pythium root rot, and take-all. The net effect was simply to trade damage from one pathogen to others, resulting in equivalent grain yield.

Wheat yields in CCN-infested soil in Australia have been improved by direct drilling (no-till) compared to seedbed tillage. In our study there was no consistent effect of tillage for annual wheat, although the yield decline with re-cropping occurred one year earlier with tillage than with no tillage. However, our study did not allow for a second observation of these tillage effects during continuous cropping. Nevertheless, the difference between our observation and that in Australia appears to depend on the complexity of the disease situation present in each field. As in the Australian study, damage from CCN was lower with no-till than with tillage. However, in our study the opposite was true for Pythium and Rhizoctonia root rots during 1991, and take-all and Pythium root rot during 1992. As exemplified by the Temik treatment during 1992, a trading of damage caused by various pathogens in a root disease complex caused yields to be comparable in the tilled and untilled annual wheat.

Alfalfa with grass weeds perpetuated the potential for damage by CCN, whereas weed-free alfalfa allowed production of a healthier wheat crop during 1992. However, the 13 bushel advantage for wheat during 1992 may not have been sufficient to offset the multiple herbicide applications required to maintain weed-free alfalfa for three years.

Wheat yields during 1990 and 1992 were most highly correlated (negatively) with damage caused by CCN and take-all. When faced with the challenge of two or more major root pathogens in the same field, the best way to increase yield is to rotate crops. This reduces the survival of most pathogens that attack wheat. Additionally, other control strategies should also be used in an integrated approach to further reduce the potential damage from one or more pathogens. For instance, it is possible to develop wheat varieties that are resistant to CCN, and seed treatments or biological agents may be developed.

Results of this study suggest that CCN is likely to cause significant damage to wheat only when continuous annual wheat is produced. This practice is neither recommended nor common in the PNW. As such, CCN is likely to be most important in irrigated fields and areas that receive enough rainfall for annual wheat to be produced. Spring wheat can be damaged even more than winter wheat, and must also be considered in the crop rotation sequence.

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LONG-TERM INFLUENCE OF TILLAGE METHOD ON SURFACE SOIL NUTRIENT DISTRIBUTION

William F. Schillinger
and Floyd E. Bolton

Soil organic matter (OM) in surface soils is of fundamental importance in maintaining soil productivity. Method of tillage has a significant impact on the OM level in the surface soil. Organic nitrogen (N) containing compounds, the product of microbial decomposition of crop residue, account for over 90 percent of the N in most agricultural soils (Haynes, 1986). During decomposition, some of the carbon (C) and N is immobilized into microbial tissue, and part is microbially converted into resistant humic substances, which constitute the bulk of soil OM. Tillage accelerates net mineralization of soil organic N by increasing soil porosity and aeration, and exposing surface residue to the soil microbial biomass. In contrast, no-tillage results in the accumulation of OM in the surface soil.

The long-term tillage effects on OM in a wheat-fallow cropping system have been measured at Pendleton. After 45 years of continuous management, the soil OM content in the surface 3 inches under stubble mulch tillage (either disk or sweeps) was 2.8 percent compared to 2.1 percent with moldboard plowing (Rasmussen et al. 1989). Little information is available on the effects of no-tillage management on maintenance of OM in wheat-fallow production systems in the Pacific Northwest.

MATERIALS AND METHODS

Data reported in this study were obtained from soil samples taken from the long-term tillage plots at the Sherman Experiment Station at Moro, OR. The tillage treatments, established in 1981, were: 1) moldboard plow tillage in late March to create a bare soil surface, followed by 3 to 4 rodweedings; 2) sweep plow tillage in late March to create a stubble mulch with approximately 70 percent of the residue remaining on the soil surface, followed by 3 to 4 rodweedings, and; 3) no-tillage, where weeds were controlled with herbicides and the soil was disturbed only at planting. Twelve soil samples were taken from the surface 1 ft from each of the fallowed treatments one day before seeding on October 7, 1989. The 12 samples were divided into 0 to 3, 3 to 6, and 6 to 12 inch increments. One composite sample for each treatment from each sampling depth was then made. Samples were air-dried and subsequently analyzed by the Oregon State University Soil Testing Lab in Corvallis.

RESULTS AND DISCUSSION

After eight years of continuous management, the no-tillage treatment had higher levels of surface soil extractable phosphorous (P), mineralizable N, exchangeable potassium (K), and OM than the other tillage treatments (Figure 1). Accumulation of OM on the soil surface would likely account for differences in extractable soil nutrients between no-tillage and the other treatments. With no-tillage, much of the P and K brought up by the roots and recycled into crop residue tends to become concentrated in the soil surface. In general, no-tillage resulted in increased nutrient concentrations in the surface 3 inches and a rapid decrease with depth. Long-term moldboard plow and stubble mulch tillage systems resulted in more homogeneous fertility in the surface 1 ft of soil. These findings are consistent with those found in the literature (Eckert, 1985; Follett and Peterson, 1988). There were no differences among treatments in surface soil pH (not shown). These data suggest that changes in soil surface nutrient status can be expected with no-tillage management in a wheat-fallow cropping system in the Pacific Northwest.

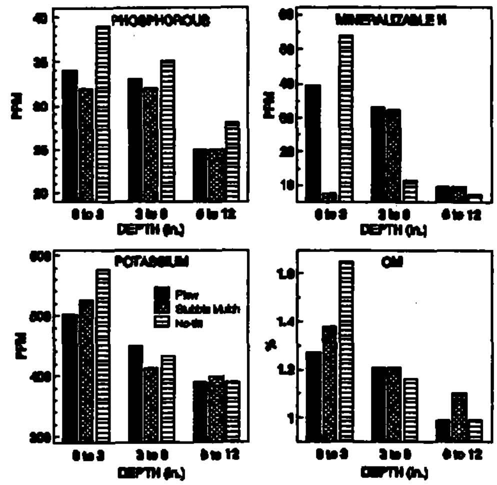

Fig. 1 Extractable P, mineralizable N, exchangeable K, and organic matter in the surface soil as affected by tillage method. Data are from the long term tillage plots at Moro, OR.

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YIELD COMPONENTS AND CROP CHARACTERISTICS OF NO-TILLAGE WINTER WHEAT GROWN IN A WHEAT-FALLOW ROTATION

William F. Schillinger
and Floyd E. Bolton

No-tillage winter wheat (*Triticum aestivum* L.) grown under a wheat-fallow rotation has consistently produced lower grain yields than conventionally tilled soils in a long-term tillage trial at Moro, OR (Table 1). In a 4-year study conducted near Pendleton, OR, Oveson and Appleby (1971) reported that grain yields from no-tillage plots were significantly reduced compared to yields from tilled plots. The objective of this study was to determine factors responsible for differences in wheat growth and yield in north-central Oregon as affected by moldboard plow tillage, stubble mulch tillage, and no-tillage.

MATERIALS AND METHODS

Data were collected during the 1990-91 crop season from the long-term tillage trial at Oregon State University's Sherman Experiment Station at Moro, OR. Fallow management treatments were: 1) moldboard plow tillage in late March to create a bare soil surface, followed by 3 to 4 rodweedings; 2) sweep plow tillage in late March to create a stubble mulch with approximately 70 percent of the residue remaining on the soil surface, followed by 3 to 4 rodweedings, and; 3) no-tillage, where weeds were controlled with herbicides and the soil was disturbed only at planting. Average annual precipitation at this site is 11.4 inches. Each treatment was replicated four times in randomized block design with individual plots measuring 135 ft x 8 ft.

On 19 September 1990, 70 lb/acre nitrogen (N), as Solution 32, mixed with 0.5 lb/acre atrazine herbicide for downy brome control was surface applied to all treatments. Winter wheat (Malcolm) was seeded in 16-inch rows at 50 lb/acre on 20 September 1990. The conventional tillage and stubble mulch systems were seeded with a John Deere HZ deep furrow drill, and the no-tillage system was seeded with a strip-till drill. Soil water to a depth of 5 ft was measured at time of planting, and at Feekes Growth Stages (FGS) 4 (lengthening of leaf sheath); 5 (leaf sheaths strongly erected); 7 (second node visible); 10 (boot); 10.5 (flowering), and; 11.4 (ripe for cutting). Three access tubes were installed in each plot where soil volumetric water content of the 2 to 5 ft depth was measured in 1 ft increments with a neutron probe. Volumetric water content of the surface 1 ft was measured gravimetrically in two 6-inch core samples.

Plant samples from randomly selected 3 ft row sections were collected from each treatment at FGS 4, 5, 7, 10, 10.5, and 11.4 for above-ground dry matter and plant N uptake determination. Whole plant samples were oven dried at 60°C for 48 hours, weighed, and then ground to pass through a 0.02 inch mesh screen. A LECO CHN-600 carbon-hydrogen-nitrogen analyzer was used for determination of total N (percent). Early spring soil temperature was measured by inserting thermistors 2 inches below the furrow of all tillage treatments at FGS 4. Soil temperature was recorded daily at 3:00 PM as it was assumed that this time would approximate daily maximum air temperature. Other climatic data were acquired from the records of a standard U.S. Weather Bureau shelter located less than 1 mile from the experimental site.

RESULTS AND DISCUSSION

Early Development

Total soil water as well as seedzone water at time of planting was greatest in the stubble mulch treatment, followed by the plow and no-tillage treatments, respectively (Figure 1). Germination and stand establishment were greatest in the plow treatment, followed by stubble mulch and no-tillage. This is reflected by highly significant differences in plant density among treatments measured at FGS 2 (Table 2). Greater quantities of surface residue in the no-tillage treatment and, to a lesser extent, in the stubble mulch treatment, likely contributed to reduced germination and stand establishment because of poorer seed-soil contact and less uniform seedbed conditions compared to plow tillage.

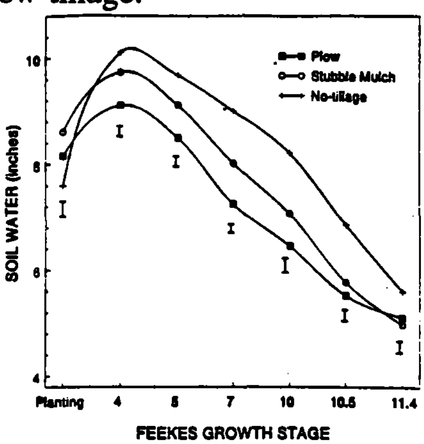

Fig. 1. Water in 5 feet of soil as affected by tillage system during the 1990-91 growing season at Moro, Oregon. Vertical bars represent LSD 0.05 differences among treatments at each Feekes Growth Stage.

Spring Development

During the 5 week period in the early spring when plants were in FGS 4 to FGS 7, maximum soil temperature 2 inches below the furrow in the no-tillage treatment averaged about 3°C and 2.5°C cooler than in the plow and stubble mulch treatments, respectively (Figure 2). Because of poor plant stands, no-tillage had significantly more surface soil water than the other treatments between FGS 4 and FGS 7 (data not shown). As the energy required to warm a wet soil is much greater than that for warming a dryer soil, it seems likely that the effects of surface residue and water combined to keep no-tillage soil temperatures cooler than the other treatments. This effect would be especially notable during early spring following winter precipitation, and when there is limited canopy.

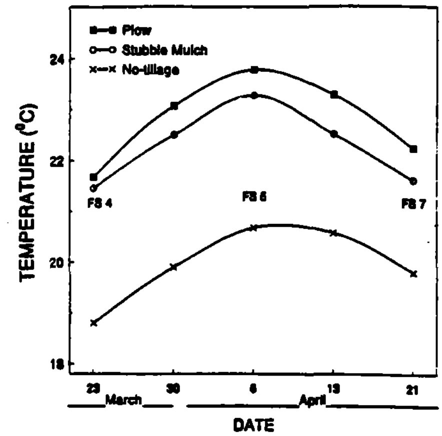

Fig. 2. Maximum 2 inch soil temperature in early spring as affected by tillage system. Each data point represents average temperature for one week in ;1990-91 at Moro, Oregon.

Between FGS 4 and FGS 10, a general linear decrease in soil water among treatments was measured (Figure 1) which corresponded to a rapid accumulation of dry matter (Figure 3). Plant N uptake was essentially completed in the plow and stubble mulch treatments by FGS 7, whereas in the no-tillage treatment plant N uptake continued until FGS 10 (Figure 4). At flowering (FGS 10.5), visual signs of water stress (flag leaf rolling) were pronounced in the plow treatment, and apparent to a lesser degree in the stubble mulch treatment. Little water stress was observed in no-tillage plots. This corresponds to significantly higher soil water content in no-tillage plots compared to the other treatments at FGS 10.5 (Fig.

1). Water deficit at flowering may severely reduce net photosynthesis in the flag leaf and spike of wheat, and significantly reduce grain weight per spike (Wardlaw, 1971).

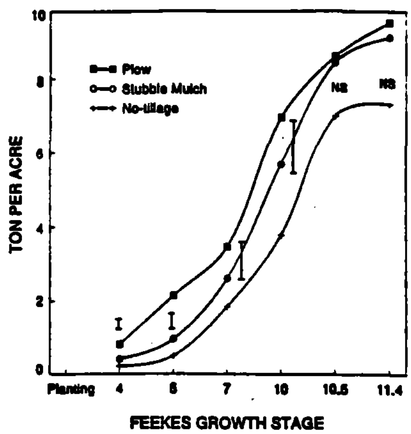

Fig. 3. Dry matter production as affected by tillage system in 1990-91 at Moro, Oregon. Vertical bars represent LSD 0.05 differences among treatments at each Feekes Growth Stage.

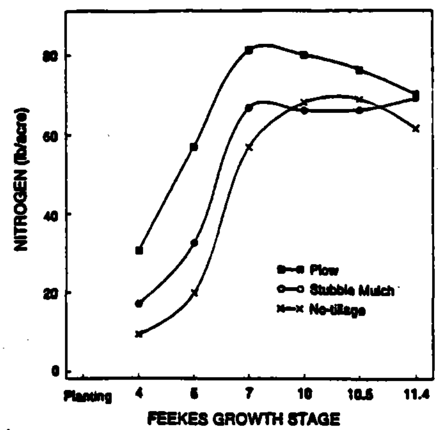

Fig. 4. Plant nitrogen uptake in 1990-91 at Moro, Oregon as affected by tillage system at several wheat growth stages.

Yield Components and Crop Characteristics

The no-tillage treatment produced the fewest spikes per unit area, which resulted in reduced grain yield compared to the plow and stubble mulch treatments (Table 2). Grain protein in the no-tillage treatment was significantly higher than in the other treatments because more soil N was present than needed for growth (Table 2).

Excessive vegetative development in the plow treatment led to more rapid depletion of soil water, and plants were unable to form satisfactory spikes or to fill grain adequately, compared to the stubble mulch treatment. This is evidenced by greater dry matter production and reduced kernels per spike, grain weight, and grain yield compared to stubble mulching (Table 2). Coefficients of determination for regression models describing the relationship of yield components and crop characteristics to grain yield are shown in Table 3. Spikes per ft of row (r^2 = .61) was the yield component most closely correlated with grain yield. High positive correlations have consistently been obtained showing wheat grain yield dependent primarily on number of spikes per unit area (Langer, 1980). Dry matter production (r^2 = .58) and plant stand establishment (r^2 = .38) were the measured crop characteristics most closely associated with grain yield. This emphasizes the importance of stand establishment and successful early tiller production on grain yield under dryland conditions.

Table 3. Coefficients of determination for regression models to describe the relationship of yield components and crop characteristics to grain yield in 1991 at Moro, Oregon.

Variable	r^2	P-Value
Dry matter	.58	.004
1000 grain weight	.08	.356
Spikes per ft of row	.61	.003
Kernels per spike	.13	.250
Plant stand at FGS 2	.38	.031

Table 1. Grain yield (Bu/A) for Stephens (1986-88) and Malcolm (1989-91) winter wheat grown under three tillage treatments at Moro, OR.

Tillage †	1986	1987	1988	1989	1990	1991
Plow	63.4	65.6	69.8	60.4	40.4	47.4
Stubble mulch	57.4	58.1	61.9	56.8	42.7	51.0
No-tillage	51.7	42.7	54.7	53.2	36.9	23.7
LSD 0.05	NS	8.5	5.5	6.7	NS	16.5

† Atrazine 0.5 lb/acre surface applied to all treatments at time of planting for control of downy brome.

Table 2. Yield components and crop characteristics of Malcolm winter wheat grown under three tillage systems in 1990-91 at Moro, Oregon.

	Tillage Method				
Component/characteristic	Plow	SM	NT	Sig	LSD
Grain yield (bu/acre)	47.4	51.0	23.7	*	16.5
Kernels per spike	23.5	26.2	22.9	NS	
1000 grain wt. (g)	40.9	42.6	40.0	NS	
Grain protein (%)	9.4	9.3	12.0	**	0.27
Spikes per ft/row	41.1	39.4	23.0	*	12.8
Total DM (lb/acre)	9964	9572	7315	NS	
Plant height (inches)	31.7	32.3	31.9	NS	
Plants ft/row at FGS 2	4.48	3.66	1.98	**	0.70
Tillers per plant	5.70	5.25	8.25	**	1.26

NS = not significant
** = significant at 1% level
* = significant at 5% level

CONCLUSIONS

No-tillage winter wheat has produced lower grain yields than winter wheat grown in either plow or stubble mulch tillage plots for six consecutive years at Moro. The main limitations to no-tillage soil management compared to other tillage treatments during the 1990-91 season were: 1) diminished seedzone water at time of planting that resulted in reduced germination and stand establishment; 2) cooler spring soil temperatures that slowed crop development and dry matter accumulation, and; 3) production of fewer spikes per unit area.

No-tillage management is optimum for soil erosion control, and is being accepted as an alternative system of crop production in many parts of the world. Grain yield reductions associated with no-tillage, however, may limit its potential for the wheat-fallow cropping system in the Pacific Northwest.

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TILLAGE, SEED SIZE, AND SEED DENSITY EFFECTS ON EARLY PLANT DEVELOPMENT AND GRAIN YIELD OF WINTER WHEAT

C. L. Douglas, Jr, D. E. Wilkins,
R. W. Smiley, and D. B. Churchill

INTRODUCTION

Cereal residues left on or near the soil surface are often blamed for poor winter wheat seedling emergence and early growth. This has been attributed to moist microenvironments with decreased soil temperatures (Barlow et al., 1977), increased disease incidence, such as take-all, Pythium root rot and Rhizoctonia root rot (Cook and Veseth, 1991), phytotoxic substances derived from plant residues (Cochran et al., 1977), "hair pinning" of residue by seeders resulting in poor seed-soil contact (Hyde et al., 1987), and slow uptake of water by seeds because of the aqueous substances from plant residues (Krogmeier and Bremner, 1989).

Mian and Nafziger (1992) found no differences in emergence or production of fertile tillers between small seeds and large seeds of soft red winter wheat. Peterson et al., (1989) found seed size had no significant influence on emergence when intact seeds of soft white winter wheat were used. Chastain and Ward (1992) found large seed emerged faster than small seeds, but there were no yield differences. However, other published reports suggest larger seeds increase yields (Bulisani and Warner, 1980; Ries and Everson, 1973)

Objectives of this study were to determine if early development and grain yield of soft white winter wheat were related to tillage and seed size, and density.

MATERIALS AND METHODS

Commercially processed Stephens winter wheat grains were subdivided with slotted sieves (Table 1) into three sizes (large, medium, small). Each size was then subdivided on a gravity table (Kamas/Westrap model LALS) at the National Forage Seed Production Research Center in Corvallis, OR., into approximately three equal portions (dense, medium, light). Seeds selected from size and density categories, large dense, large light, small dense, small light and normal mix (non-separated) were field tested.

Table 1. Minimum sieve sizes used for seed separation.

Seedsize	Minimum sieve size
	(inches)
Large	8/64 by 3/4
Medium	7/64 by 3/4
Small	5.5/64 by 3/4
Normal	Not sieved

Seed size treatments were planted in a Walla Walla silt loam soil in a split-plot experimental design with moldboard plowing and no-tillage as main plots, and seed size and density as subplots. In 1990, the plots were irrigated on Aug. 29 and Sept. 10 because the previous wheat crop had depleted the soil moisture. Tillage plots were moldboard plowed and disc harrowed on Sept. 18, 1990. In 1991, there was no pre-irrigation as plots were placed in a field that had been chemical-fallowed for one year following winter wheat. Tillage plots were moldboard plowed in Sept. 1991, and disc harrowed prior to seeding. Wheat was seeded in both 1990 and 1991 on Sept. 24, with a John Deere model HZ deep furrow drill, calibrated to plant 23 seeds per foot of row, in rows spaced 16 in. apart (17 seeds/ft^2) for each seed treatment. Starter fertilizer (12 lbs. N as Solution 32, 7.6 lbs P as Polyphosphate, and 13 lbs. S as Thiosul) was applied at seeding in the fall of 1991. Nitrogen fertilizer (80 lbs N as ammonium nitrate) was broadcast on the surface after the 5 to 6 leaf stage samples were taken in the spring in both 1991 and 1992. Soil samples were taken both years at seeding to determine gravimetric soil water content.

At the 5 to 6 leaf developmental stage, whole plants, including roots, from 3.3 ft. of row were collected, washed, total number of plants were determined, and 20 plants were randomly selected from each sample for shoot and root observations. Above ground dry weights, plant heights, and crown and seed depths were evaluated, as well as Haun value and number of tillers as described by Klepper et al. (1982). Number of seminal roots, total number of roots bisecting lines 1.2 inches and 2 inches below the seed, and number of disease-pruned roots were determined.

Thirteen ft of row from each plot were hand harvested to determine number of heads per unit area, and grain yield.

RESULTS AND DISCUSSION

In 1991, when soil moisture was adequate, there was no significant difference between plow and no-till for any measured parameter, except number of roots at the five to six leaf stage of development (Table 2). This was not true in 1992 when seed zone moisture was marginal. Even though there was less seed zone moisture in tilled plots, plants emerged faster, had more first tillers, better seminal root systems, and significantly higher grain yield (Table 2).

There were no significant differences in any measured parameters in 1991 as a result of seed size and density. In 1992, small light seed emerged faster 11 days after seeding (data not shown). Small light seed may germinate and emerge quickly because the small amount of material present would reach the threshold water content required for initiation of germination more quickly than large seed. However, there were no differences in number of plants emerged 21 days after seeding (Table 3). Even though there were no significant grain yield differences in 1992, small light seed had more seminal root axes and branches at 1.2 and 2 inches below the seed, and fewer disease pruned roots than any other treatment at the 5 to 6 leaf development stage. This may be the result of the rapid early growth in the first 11 days after seeding, which helped the root systems resist diseases.

CONCLUSIONS

Tillage, seed size, and seed density had no significant effect on early growth and development, or grain yield in 1991 when soil moisture was adequate. When soil moisture was marginal in all treatments in 1992, tillage significantly affected emergence, leaf numbers, early tiller development, number and branching of seminal roots, disease pruned roots, and grain yield. Seed size and density significantly affected only number of leaves above ground and root branching below ground. Light seed, specifically small light seed, emerged faster and had more seminal roots and greater branching of seminal roots than other seed treatments. However, there were no yield differences as a result of seed size and density.

Table 2. Tillage effects on selected plant parameters.

Year	Tillage	Emergence[1/] 21 day	Mainstem leaf	Plants with T1[2/]	Plants with T2	Roots: Seminals	Roots: 1.2"	Roots: 2"	Roots: Disease pruned roots	Yield
		Five to six leaf development stage								
		(plants/ft²)	(leaves/plant)	- - (%) - -		- - - - - - - roots/plant - - - - - - -				(bu/A)
1991	Plow	9	5.8	44	78	4.9	13.4	9.7	0.3	94
	No tillage	8	5.6	36	79	4.7	15.6	12.0	0.3	89
		NS	NS	NS	NS	NS	*	**	NS	NS
1992	Plow	7	6.1	70	96	5.3	7.1	6.7	2.7	92
	No tillage	4	5.5	48	91	5.1	3.4	3.3	3.3	82
Significance[3/]		***	***	***	NS	*	**	***	NS	**

1/ Plants emerged per sq. foot 21 days after seeding.

2/ T1 and T2 are the tillers borne on the main stem that are subtended by main stem leaves one and two respectively.

3/ For the difference between tillage means * = significant at the 10% level, ** = significant at the 5% level, *** = significant at the 1% level, and NS = not significant.

Table 3. Seed size and seed density effects on selected plant parameters.

Seed size	Emergence[1/] 21 day	Mainstem leaf	Plants with T1[2/]	Plants with T2	Roots: Seminals	Roots: 1.2"	Roots: 2"	Roots: Disease pruned roots	Yield
	Five to six leaf development stage								
	(plants/ft²)	(leaves/plant)	- - (%) - -		- - - - - - - roots/plant - - - - - - -				(bu/A)
Large dense	6	6.0 a[3/]	50	84	5.3	4.3 b	4.4 b	3.3 a	87
Large light	6	5.9 ab	46	84	5.2	4.5 b	5.1 b	3.3 a	88
Small dense	4	5.7 bc	32	82	5.1	4.0 b	3.4 b	3.1 a	84
Small light	6	5.8 abc	42	89	5.1	8.1 a	7.1 a	2.3 b	90
Normal	5	5.7 c	43	86	5.2	5.3 b	5.0 b	3.1 a	87
Significance[4/]	NS	**	NS	NS	NS	***	***	***	NS

1/ Plants emerged per sq. foot 21 days after seeding.

2/ T1 and T2 are the tillers borne on the main stem that are subtended by main stem leaves one and two respectively.

3/ Means within a column followed by the same letter are not significantly different as determined by Duncan's Multiple Range Test (P = 0.05).

4/ For the difference between seed size means ** = significant at the 5% level, *** = significant at the 1% level, and NS = not significant.

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ANNUAL SPRING BARLEY IN HIGH- AND LOW-RESIDUE TILLAGE SYSTEMS

Richard Smiley and Dale Wilkins

Annual spring barley may reduce soil erosion on highly erodible fields without significantly compromising the income from traditional winter wheat/summer fallow rotations (Young and van Kooten, 1989). During the first one or two years of annual cropping, barley yields are typically comparable for conventional tillage (autumn or spring plow with spring disking), minimum tillage (autumn chisel with a spring disking), and no-tillage (direct drilling in standing or flailed stubble) systems (Reinertsen et al., 1983). Unfortunately recropped spring barley yields tend to decline after two or more years due to damage from root diseases. Yield decline is more pronounced in fields that are most protected from erosion with high amounts of surface residue.

Rhizoctonia root rot, common root rot, and take-all are of particular importance on annual barley in regions with low rainfall (9 to 15 inches annual precipitation). Rhizoctonia root rot is notable for causing the greatest root damage in the absence of tillage (Pumphrey et al., 1987; Weller et al., 1986). However, it has been our experience with winter wheat that yield is not always directly related to the severity of Rhizoctonia root rot. Highest wheat yields have been measured with some crop management systems that also had the most severe root rot.

The objective of this study was to determine the effects of tillage history on root diseases, crop growth and development, and grain yield during four years of annual spring barley production at two locations. A full-length technical version of this work is being published (Smiley and Wilkins, 1993).

METHODS

Plots were located on two farms in Umatilla County. The Wolfe farm has a 30-inch deep Condon silt loam in a 12-inch/year precipitation zone eight miles southwest of Pendleton. The field had been used for no-till annual spring or winter barley for four years before our experiment began. The Thompson farm had a deep (>5 feet) Walla Walla silt loam in a 14-inch/year precipitation zone 15 miles north of Pendleton. The field had a long history of wheat/fallow rotation, using a chisel plow for primary tillage.

An experiment was designed in 1987 to respond to needs created by the United States Food Security Act of 1985. The USDA-Soil Conservation Service needed information on frequency of plowing required to suppress Rhizoctonia root rot in otherwise no-till management systems. Annual spring barley was used to answer this question because barley is more susceptible than wheat to Rhizoctonia root rot.

Randomized complete blocks (32 x 150 ft) with four replicates were established. Treatments included four years of no-till, four years of conventional tillage, and plowing one, two, three, or one and two years before a final crop of barley was produced without tillage during 1990 (see Table 1).

Plowing was done in the autumn and disking was done immediately before planting, in March. Roundup was applied two to 15 days before planting Steptoe barley in mid-March. Planting was done

Table 1. Influence of tillage history on yields of annual spring barley from 1987 to 1990 on two farms in eastern Oregon, and on severity of Rhizoctonia root rot during 1990.

Tillage System[†]				Grain Yield (bu/ac)					Root Rot
1987	1988	1989	1990	1987	1988	1989	1990	4-yr mean	Ratings[§]
Wolfe farm									
T	T	T	T	19.4	14.1	17.9	15.5	16.7	2.3
T	NT	NT	NT	16.5	24.9	30.4	18.6	22.6	4.2
NT	T	NT	NT	40.5	16.5	24.0	12.9	23.5	3.4
NT	NT	T	NT	35.9	32.7	21.1	17.6	26.8	3.2
NT	T	T	NT	40.2	15.2	24.5	21.1	25.0	2.6
NT	NT	NT	NT	43.9	31.4	41.6	20.8	34.4	3.8
lsd (0.05)				4.6	3.3	5.4	ns	ns	0.7
Ratio[‡] NT/T				2.2	2.0	1.5	1.2	1.7	--
Thompson farm									
T	T	T	T	57.0	40.2	44.9	42.2	46.1	1.7
T	NT	NT	NT	57.1	21.4	20.5	51.4	37.6	4.2
NT	T	NT	NT	62.5	40.0	20.9	48.2	42.9	4.1
NT	NT	T	NT	58.8	24.0	45.9	40.5	42.3	3.1
NT	T	T	NT	65.9	36.6	45.0	43.8	47.8	2.5
NT	NT	NT	NT	62.0	27.8	22.6	50.7	40.8	4.5
lsd (0.05)				ns	8.0	6.6	8.1	ns	1.3
Ratio[‡] NT/T				1.1	0.6	0.5	1.1	0.8	--

[†]T = tilled with moldboard plow in autumn and disk in spring; NT = skew tread soil to 1-inch depth in autumn to break stubble and encourage germination of weed seed and volunteer barley.

[‡]Ratio of yield average for all non-tilled plots to all tilled plots; considering tillage for current year only.

[§]Rhizoctonia root rot was rated on a scale of 0 to 5; 0=no disease and 5=severe root rot. Most roots were badly rotted at ratings of 4 and 5.

with a John Deere model HZ drill equipped with Wilkins slit openers. Row spacing was 16 inches, with liquid Uran (urea-ammonium nitrate; at 50 lb N/acre) plus Thiosol (10 lb S/acre) placed two inches below the seed. A rain gauge and thermograph were used to monitor precipitation and temperature at each site. Soil samples at one-foot increments from the surface to basalt were collected immediately after planting for determination of soil water.

The entire plot area was treated annually, during May, with Bronate to control broadleaf weeds. Benlate PNW was applied during May 1989 to suppress a severe epidemic of scald. Di-Syston was applied by air during May 1989 to suppress damage from the Russian wheat aphid.

Seedlings were removed from each plot for growth and disease assessments during mid-spring. Growth parameters included plant height, shoot weight, main-stem leaf number, tillers per plant, and numbers of seminal and coronal root axes crossing a plane one inch below the seed. Disease assessments included Rhizoctonia root rot, take-all, common root rot, and Pythium root rot. Percentages of stunted plants were measured after head emergence, and a plot combine was used to measure grain yield.

RESULTS

Rhizoctonia root rot was always more severe when barley was produced without tillage than with tillage. Rhizoctonia root rot was most severe in treatments with two or more years of continuous no-till, least severe where soil was plowed every year, and intermediate where soil was plowed one year prior to the no-till spring barley crop. Root rot was less when soil was plowed during two consecutive years rather than only one year before a no-till crop. Pythium root rot and common root rot affected more plants in continuously plowed soil than in no-till soil at the Wolfe farm. Common root rot was essentially absent at the Thompson farm, and the incidence of Pythium root rot did not appear to be affected by tillage treatments. Take-all was most severe in the continuously plowed treatment at the Wolfe farm, but did not occur in the same treatment at the Thompson farm. Overall, the barley plants in the continuously plowed treatment at the Wolfe farm had a broader and more severe root disease complex than plants produced without tillage. Differences were reversed at the Thompson farm.

Shoot weight and height, plant growth stage, tiller development, and numbers of roots were not affected by tillage treatments at the Wolfe farm, but all were strongly increased by tillage, compared to no tillage, at the Thompson farm. Stunting of plants in the mature crop was more severe with no-till than with tillage at both sites. No-till barley usually matured two to three weeks later than barley produced with conventional tillage.

Grain yields for barley were nearly always higher in no-till than tilled plots at the Wolfe farm (Table 1). The yield in the continuous no-till plot always exceeded that in the continuously tilled plot. These relationships also occurred during two of four years at the Thompson farm. The four-year mean grain yields for these experiments did not differ significantly, but there appeared to be a yield advantage for the no-till treatment at the Wolfe farm. Yields of no-till barley at both locations increased with cumulative number of years in no-till (Fig. 1).

The Thompson farm had more precipitation than the Wolfe farm during 1987 (2.7 inches), 1988 (1.5 inches), and 1990 (1.5 inches). The Wolfe farm had 2 inches more precipitation than the Thompson farm during 1989, which was the wettest year at both farms.

Quantity of water in the soil profile when each treatment was planted had no consistent relationship with grain yield at either experimental site during three years of evaluation. There was no significant difference in amount of stored water between tilled and non-tilled treatments during 1988, 1989, and 1990 at the Wolfe farm, but non-tilled treatments at the Thompson farm had more stored water in 1989 and 1990. Yields per unit of stored water in tilled plots were higher at the Thompson farm than at the Wolfe farm, but were comparable in no-till plots at both locations.

Growing degree days did not differ between farms, and was not correlated with disease severity or yield parameters.

DISCUSSION

Rhizoctonia root rot was always more severe in barley grown without tillage than with tillage, but grain yield was not related to the severity of this disease. Take-all, Pythium root rot, and common root rot were each relatively minor in all six tillage systems, but each disease was more prevalent in tilled than non-tilled soil at the Wolfe site, where tillage clearly suppressed yield of annual spring barley. The combined root disease complex in tilled soil appears to have had a more negative impact on yield than the singular effect of Rhizoctonia root rot in non-tilled soil.

Other management practices for our experiment were also partially responsible for the absence of a direct association between grain yield and Rhizoctonia root rot. Disking soil shortly before planting sometimes caused a larger loss of soil water from tilled than non-tilled soil. At the Thompson farm more stored water was measured in non-tilled than tilled plots during 1989 and 1990, but not 1988. It is of interest that 1988 was the year in which grain yields in tilled plots were almost double the yields in the non-tilled soil at the Thompson site. Increased amounts of stored water in the non-tilled soil during 1989 and 1990 appeared to have compensated for the higher damage by Rhizoctonia root rot in that treatment.

Roundup was used to kill volunteer barley and weeds before planting. The herbicide was applied two or 16 days before planting during 1989 or 1990, respectively. In other experiments (Smiley et al., 1992) root rot of barley was dramatically increased when Roundup was applied to Rhizoctonia-infected volunteer plants several days before planting. Disease severity decreased as the timing was increased between herbicide application and planting barley. This process was named the green-bridge relationship. The timing interval affected the efficiency by which the pathogen moved from roots of dying plants to roots of newly emerging plants. The green bridge was not caused by herbicide residue or phytotoxicity to the barley crop. We also reported that the green-bridge effect could be reduced or eliminated at some sites by tilling soil after applying Roundup, but before planting spring barley. It is probable, therefore, that disking soils shortly before planting created off-setting effects on barley growth and productivity. Disking negated the herbicide-related increase in root rot but also reduced the amount of soil water available for seed germination and seedling establishment.

Rhizoctonia root rot typically delays the maturation of plants. In this experiment spring barley produced without tillage matured two to three weeks later than that in tilled soil. Delayed maturation places the crop at a distinct disadvantage by increasing the time period for susceptibility to further damage from rain, hail, wind shatter, and insects. Since barley typically matures several weeks earlier than wheat, delayed maturation may also cause conflicts for the set-up and use of combines on farms that produce both spring barley and winter wheat.

Grain yields at the Wolfe farm were nearly always higher in the non-tilled soil than in the tilled soil. The yield advantage in non-tilled (NT) over tilled (T) soil at the Wolfe farm declined steadily during the four years of this study (NT/T ratios of 2.2, 2.0, 1.5, and then 1.2). This trend appears to be an artifact rather than a true decrease in productivity of continuous no-till barley. The yield of barley was always highest in plots that had the largest number of consecutive no-till crops (Figure 1). NT/T ratios therefore appear to represent a trend specific to the drought years in which this study was conducted. Seasonal influences could include quantity of available soil water, influence of pre-plant tillage on seedbed moisture, root diseases, seasonal temperature and precipitation, fertilizer application rates, and other factors.

Another five-year (1987-1991) comparison of annual spring barley in non-tilled or stubble-mulched (chisel plow and rodweeder) soils at Moro (11-inch precipitation zone) resulted in no significant differences between yields in any of the five years. Five-year cumulative yields at Moro were 9,932 and 9,566 lb/acre for stubble mulch and no-till, respectively. Our finding that spring barley yielded more grain in non-tilled than in tilled soil in six of eight location-years indicates that annual production of spring barley in high-residue tillage systems is possible in the 10- to 16-inch/year precipitation zone of eastern Oregon. Although high-residue tillage systems often have higher levels of Rhizoctonia root rot, aesthetically displeasing irregularities in crop

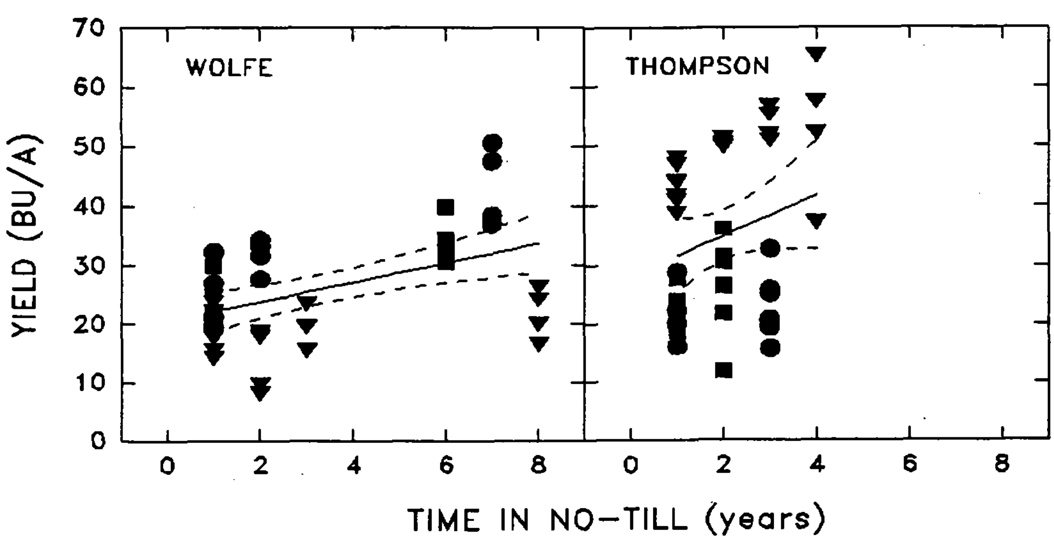

Figure 1. Relationships between grain yields and number of years of continuous no-till management at the Wolfe and Thompson farms; 1988 (■), 1989 (●), 1990 (▾). Dashed lines indicate 95% confidence limits

appearance, and a delay in crop maturation, we conclude that annual spring barley production systems are likely to be more affected by weed management than by disease.

ACKNOWLEDGEMENTS

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SOIL PROPERTIES, WATER CONSERVATION AND YIELDS OF WINTER WHEAT AFTER SUBSOIL SOIL TILLAGE

Don Wysocki, Phil Nesse, and Sandra Ott

This is a preliminary report of subsoil tillage experiments established in the autumn of 1990 and 1991. The first season harvest data was obtained in the summer of 1992 and additional results will be collected in the summer of 1993. Plot results from subsoil tillage done in the autumn of 1990 and cropped 1991-92 are reported here.

INTRODUCTION

Subsoiling is a practice that has recently received increased interest from dryland producers in semiarid Oregon. This practice entails deep tillage of standing wheat stubble using a parabolic-shank subsoiler, with shank spacing ranging from 20 to 60 inches. In dryland conditions under wheat-fallow rotation, subsoiling is done in the early fall on the contour to depths of 12 to 18 inches. Producers perceive three immediate benefits from subsoiling: 1) increased water conservation; 2) reduced erosion and runoff; and 3) disruption of compact or cemented soil layers caused by tillage. The purpose of performing tillage in early fall is to create channels open to the surface, which collect runoff over winter, and to maximize soil shattering because of dry conditions. Subsoiling a dry, silt loam soil to a depth of 16 inches at 30-inch spacing costs approximately $10.00 to $12.00/acre. This is an expensive practice that must be sustained by increased wheat yields. Wheat crops often appear more vigorous and healthy on subsoiled fields and increased yields have been observed in some years and situations. Crop response to subsoiling has been attributed to greater stored water and better soil root exploration. However this has not been substantiated and additional factors are probably involved.

The continued use of subsoiling and its widespread acceptance as an agronomic and soil and water conserving practice is dependent upon its cost effectiveness. This project was initiated to answers several questions: 1) What effect does subsoiling have on water storage and erosion? 2) What effects does subsoiling have on soil properties and how long do they last? 3) What is the best shank spacing for subsoiling? and 4) What effect does subsoil have on plant growth and yield? Answers to these questions will allow producers to assess the value of subsoiling in their operations over a large area of semiarid Oregon.

METHODS

Subsoil tillage plots were established in dry soil after harvest in standing wheat stubble at six sites, three sites each year in 1990 and 1991. Sites tilled in 1990 were located on the Osterlund, Maley, and Harper farms in Gilliam County, Oregon. The Osterlund and Maley sites are situated on Condon and Valby silt loams, 12 to 20 percent slopes, Agronomic zone 4 (Douglas et al. 1990), and the Harper site is located on Ritzville silt loam, 7 to 12 percent slopes, Agronomic zone 5 (Douglas et al. 1990). These sites represent typical landscape positions and dominant soils of semiarid Oregon and Washington. The tillage implement was a custom-built, V-tool bar subsoiler with five parabolic shanks on 48-inch spacing. Tillage treatments were: 1) no subsoil tillage (control); 2) 24-inch shank spacing (two tillage passes displaced 24 inches); 3) 48-inch shank spacing (all shanks attached); and 4) 96-

inch shank spacing (2nd and 4th shanks removed). The experimental design was a complete randomized block with each site being a replication. Nominal plot size is 80 x 100 ft placed on the contour. Tillage depth and speed were 16 inches and 4 mi/hr respectively. During tillage, nylon baler twine was buried in the shank grooves. This was accomplished by 1) attaching a ball of twine to the implement, 2) welding a chain link behind the shank tip, 3) looping the end of the twine through the link, and 4) anchoring the end in the soil, thus feeding twine into the shank groove during tillage.

During April and May of 1991 soil bulk density, soil water content, soil impedance and shank groove macroporosity data were obtained from sites tilled in autumn of 1990. This was after primary tillage and the first rod weeding. Soil samples and impedance measurements were taken at 0, 6, 12, 24, and 48-inch intervals perpendicular from the tillage groove, using the nylon baler twine as the zero reference. Bulk density and water content samples were taken in 3-inch intervals from a depth of 3 to 18 inches. The 0 to 3 inch increment was not used because of its loose fluffy condition after rodweeding. Soil below 18 inches was sampled for water content at 12-inch intervals to a depth of 72 inches, or root-restricting layer, whichever was less. Soil impedance values were recorded using a Bush recording penetrometer at 1.5-inch intervals to a depth of 24 inches. Intact bulk soil volumes were taken by driving 8-inch square x 12-inch deep sheet metal frames into the soil directly over the shank groove. These measurements were repeated in standing crop in May of 1992. Data were collected 6 months and 18 months after subsoil tillage.

Plant growth samples were taken in March of the crop year and at harvest. Three 1-ft sections of row were the sampling units. Plant (Haun system) stage, plants/ft of row, heads/ft of row, kernel/head and 300 seed weight were recorded. Plots were harvested using grower combines and a weigh wagon. Borders and alley ways were harvested around the plots and precise dimensions of plot areas obtained. Test weights were determined from samples removed from the weigh wagon after harvest weights were obtained.

RESULTS AND DISCUSSION

Weather has had a major affect on water storage and crop response thus far in this study. A brief explanation of precipitation since this study began is necessary to understand and interpret the results. Precipitation for the winters of 1990-1991 and 1991-1992 is shown in Table 1. These are periods during which water recharge and erosion typically occur. These two seasons had below average precipitation and frequent light rainfall as indicated by the amount received in events of < 0.2 inches. Consequently, runoff and erosion did not occur. Subsoil tillage leaves shank grooves open over the first winter to act as channels for water to infiltrate. However, the lack of runoff over winter resulted in no difference in water storage between treatments (Table 2). In addition to dry, open winters, the 1991-1992 crop year was dry during the fall and spring. This resulted in poor control of downy brome in the fall and severe drought stress in the late spring and summer. Plots did not show yield response to subsoil tillage (Table 3). Yields were reduced substantially because of droughty conditions. In addition subsoiling had no effect on plant height or head density

(Table 4). Plants may have responded to subsoiling under more favorable conditions precipitation.

The effects of subsoil tillage on soil properties could be detected six and 18 months after tillage. Cone index, a measure of the force required to penetrate the soil with a tool, was lowest six months after tillage, intermediate after 18 months, and highest when soil was not tilled (Figure 1). The soil appears to be gradually moving back to a pre-tillage condition, but has not yet reached this state after 18 months. This indicates that the effects of tillage persist for at least two seasons, and through normal summer fallow tillage operations. The advantage of subsoil tillage for water conservation or erosion control is, however, greatly diminished as soon as shank grooves are closed by subsequent tillage or siltation.

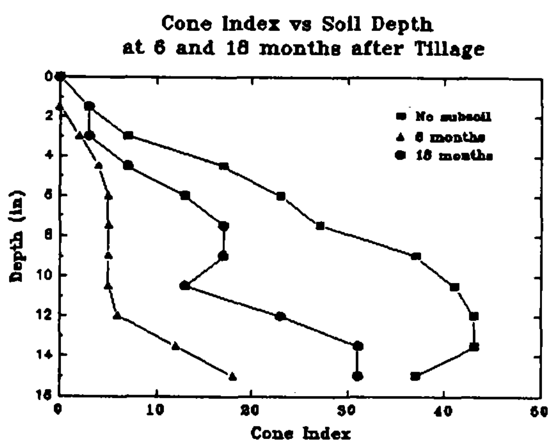

Figure 1. Effects of subsoil tillage on soil properties.

CONCLUSIONS

Although, the results of the project are preliminary, the information obtained thus far, can be summarized in the following statements.

1. Subsoiling resulted in no additional water storage following two dry, open winters.
2. Differences in soil properties can be detected at least 18 months after tillage.
3. Subsoiling did not increase yield in a dry year.

From observations in this study it appears that subsoil tillage can be utilized in two situations: 1) as a stop-gap measure to control runoff from frozen ground, or 2) as a practice to treat compact or cemented soil layers that retard or limit plant growth and/or water infiltration. In the first situation subsoil tillage should be done on the contour, so shank grooves do not concentrate water on a slope. The subsoiler can be lifted out of the ground to provide breaks in the grooves to eliminate water concentrating in the groove. Cover over the landscape does not necessarily need to be 100 percent. Tillage passes at interval should be sufficient to control runoff. In the second situation, an obvious tillage pan or other layer needs to be identified. If such a layer exists the entire field or a portion of the field effected needs to be tilled. It appears that situation 1 predominates in semiarid Oregon. Subsoil tillage can be effective at controlling runoff if done correctly. Spot treating areas would be the most economical procedure.

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Table 1. Total winter precipitation and amount received in events less that 0.2 inches, Condon, Oregon.

	Precipitation (inches)			
	1990-91		1991-92	
Month	Total	< 0.2	Total	< 0.2
September	0.03	0.03	0.00	0.00
October	1.29	0.43	0.96	0.20
November	0.91	0.36	2.43	1.24
December	1.88	0.59	0.97	0.17
January	0.76	0.19	0.50	0.27
February	0.64	0.34	1.03	0.68
March	1.27	0.66	0.78	0.52
Total	6.78	2.60	6.67	3.08

Table 2. Volumetric water content in the soil profile at each tillage site.

Subsoil Treatment	Site			Average
	Osterlund	Maley	Harper	
	-------------------------	inches	-------------------------	
Control	5.55	5.21	5.52	5.43
2' spacing	6.12	5.17	5.45	5.58
4' spacing	5.77	6.97	5.50	6.08
8' spacing	5.61	6.60	5.51	5.91

Table 3. Yields on subsoil tillage plots.

Subsoil Treatments	Site: Osterlund (Wheat)	Maley (Wheat)	Harper (Barley)	Average
	lb/acre			
Control	780	2040	1139	1319
2' spacing	900	2100	1222	1407
4' spacing	900	2220	1175	1431
8' spacing	790	2340	1323	1484

Table 4. Effect of subsoiling on plant height and head density.

Treatment	Plant height: Osterlund	Maley	Harper	Average
	inches			
No subsoil	20.3	25.3	19.9	21.8
24" spacing	19.1	25.6	20.4	21.7
48" spacing	21.8	28.3	19.9	23.3
96" spacing	19.2	25.8	18.7	21.2
	CV = 4.0%	LSD (5%) = 1.75		
	Head/foot of row			
No subsoil	24.4	23.9	18.9	22.4
24" spacing	25.7	31.1	22.4	26.4
48" spacing	23.4	35.9	18.1	25.8
96" spacing	26.8	32.2	23.0	27.3
	CV = 12.3%	LSD (5%) = 6.3		

BREEDING FOR DISEASE RESISTANCE IN WINTER WHEAT

C. S. Love, R. J. Metzger,
and W. E. Kronstad

The wheat breeding program at Oregon State University has focused on producing high-yielding winter wheats with superior end-product uses. Cultivars developed for eastern Oregon environments ideally are fall sown, with high stable yields, adequate winter hardiness, and acceptable milling and baking characteristics for specific end use products quality. In addition, resistance to strawbreaker foot rot and common bunt is desirable. In areas near Flora where snow cover persists for longer than 3 months, adapted cultivars must be resistant to dwarf bunt.

Strawbreaker foot rot is caused by *Pseudocercosporella herpotrichoides*. Infection of winter wheat occurs in late fall or early spring, as conidia on host debris are splashed by water onto seedlings. They germinate and penetrate the stem just above the soil line. The elliptical lesions or "eyespots", which are diagnostic of this disease, enlarge and penetrate the stem, weakening or eventually killing individual tillers or possibly entire plants. Delayed seeding, 3-year rotations, and reduced tillage can reduce disease.

Tolerant cultivars such as Rendezvous and Cappelle-Desprez are used widely in Europe where strawbreaker foot rot is a serious constraint to wheat production, and fungicide-resistant strains of the fungus are common. Efforts are currently underway to transfer resistance genes from these cultivars into winter wheats with acceptable agronomic characteristics. We have used Rendezvous and Cappelle-Desprez extensively in our breeding program, and are currently screening a number of segregating populations in inoculated trials in both the greenhouse and the field in Corvallis.

The 1993 foot rot screening nursery consists of 160 F_4 populations planted as six-row plots. The material was seeded at Hyslop Farm near Corvallis on September 30, 1992, about 14 days before the optimum seeding date in the Willamette Valley. Early seeding favors disease development because larger plants create higher humidity near the soil line, which increases germination of conidia and leads to higher infection levels. The individual rows were inoculated November 7, 1992 as temperatures decreased and conditions for infection became favorable. At maturity, lodging and disease development, as evidenced by lesion score, will be assessed for each head row. Lines exhibiting low disease severity will be advanced into yield trials and also tested for quality traits. These same 160 F_4 populations are also currently being screened in the greenhouse as seedlings.

Breeding efforts have also focused on developing soft white wheats with common bunt (*Tilletia caries*) and dwarf bunt (*T. controversa*) resistance. Although bunt does not, in most cases, cause major yield losses in the state, marketing considerations require that seed be free of spores. Growing resistant cultivars reduces inoculum levels in both the soil, and on the seed. Genes conferring resistance to common bunt also provide resistance to dwarf bunt, and we utilize this relationship to screen breeding material. Dwarf bunt has strict environmental requirements for infection, and "escapes" during screening are common. Since the same genes condition resistance to both diseases, we can inoculate with the less environmentally-dependent fungus *T. caries*, and use this information to predict the dwarf bunt resistance of a given line before yield trial testing in a dwarf bunt area.

The common bunt screening nurseries are planted at Corvallis and at the Columbia Basin Agricultural Research Center in Pendleton. We screen segregating populations beginning in the F_2 generation by inoculating from 250 to 500 seeds with a mixture of common bunt spores from races R-39 and R-55. The spores are suspended in a methyl cellulose solution and applied to the seed. The inoculated seed is air-dried and then space planted into deep furrows once the soil temperature reaches 10°C. Advanced breeding lines are inoculated with the common bunt races T-16, T-30, R-39, and R-43, and solid seeded in a three replicate trial in both locations. These combinations of common bunt races allow us to detect the presence of several resistance genes including Bt5, Bt8, Bt9 and Bt10. These genes have been the most effective in this region for reducing disease incidence.

Initial screening with common bunt races allows us to advance only the most resistant lines to yield testing. Experimental lines with fewer than 2 percent infected tillers in the common bunt screening trial are advanced into a non-inoculated replicated yield trial established in a dwarf bunt area near Flora. The 1993 trial, seeded September 22, 1992 consists of nine entries and six replications. This screening sequence has allowed us to identify several lines which perform well under severe dwarf bunt pressure. Two siblings, OR880494 and OR880510, ranked 1 and 3, respectively, are in the 10-entry dwarf bunt yield trial planted in 1992, and are again included in the 1993 trial. These lines show promise and will continue to be evaluated for disease resistance, yield, and quality.

The bunt resistance breeding program is currently utilizing dwarf bunt resistant parents obtained from breeding programs in Utah and Idaho, as well as lines identified in the breeding programs at Hermiston and Corvallis.

W 301, A NEW SOFT WHITE WINTER WHEAT

Mathias F. Kolding

INTRODUCTION

A new soft white winter wheat, W 301, PI 559718, *Triticum aestivum*, L., was developed as a cooperative effort between the Oregon Agricultural Experiment Station and Wulff Farms, Flora, Oregon to provide an early maturing soft white winter wheat that will survive at the elevations greater than 3,000 feet in Wallowa County.

Soft white winter varieties such as Stephens, Malcolm, and Dusty have poor winter survival rates under snow-cover near Flora, Oregon. John, Luke, Lewjain, and Madsen winter wheats survive the winters, but have weak straw and tend to lodge. They are slow to ripen, and consequently are vulnerable to late August rains that cause sprout damage.

HISTORY

W 301, PI 559718, *Triticum aestivum* L., is derived from a cross of Sm-4/Daws and Sm-11/McDermid, which were selections from Dr. Robert Metzger's common bunt project. The cross was made in 1980. The F-1 was grown in row 454 in 1981. F-3 head-rows were planted in the annual evaluation and selection trials on the Wulff Ranch near Flora. Several head-rows were harvested and bulked. Three of these bulks were planted in drill plots on the Wulff Ranch. Bulk -301 was the most favored by Kenneth and Doug Wulff. Their evaluations were based on relative earliness, plant height, lodging resistance, ease of threshing, clean grain in the truck-box, estimate of relative yield, and grain appearance.

Heads were selected from the bulk in 1985. During the ensuing years, lines were discarded for dwarf bunt susceptibility via the common smut trials. Unfortunately the lines having the best resistance did not have the desired kernel color, i.e. not pure white.

The Wulff Ranch continued evaluating the line in field plantings. (The fields in the Flora-Paradise area are bordered by trees. Soil depths range from zero to 6 feet depending on the undulation of the underlying lava flow and soil deposition.)

Field observations led to the following conclusions. W 301 is earlier maturing than Dusty, and matures a week earlier than Lewjain. W 301 yields better than Lewjain and survives like Lewjain. Head size is good. W 301 yielded 65 bushels per acre versus 50 bushels per acre for Lewjain in 1990. In 1991 W 301 yielded nearly 70 bushels per acre versus 50 to 60 bushels per acre for other fields.

Head-rows selected from plant plots were planted at the Hermiston Agricultural Research and Extension Center (HAREC) in the fall of 1990. During 1991 'off-type' head-rows were destroyed prior to anthesis. A number of head-rows were selected, threshed separately, seed type was examined, and the "keepers" planted in long four row plots at HAREC. During 1992 off-type long plots were destroyed and the remaining were threshed into indiviual sacks.

DISCUSSION

Table 1, and Table 2, summarize grain yields for the Eastern Oregon White Winter Wheat trials (EOWW). The EOWW trials are planted in diverse locations. They compare new selections from Project 0396 with recent releases from other programs.

The locations provide different times of planting and adverse soil or disease pressures. The EOWW trials are evaluated in growers' fields, so they are subjected to the whims of producers as well as nature. Entries are discarded when they fail in one of the trials, or their ranking for the year is in the bottom third to one-half of the entries tested. During the past 20-plus years, the check varieties such as Gaines, Nugaines, McDermid, Luke, Hyslop, and Yamhill were replaced by the present check varieties Stephens, Hill Malcolm, Dusty and Lewjain. The ranking system evaluates W-301's yield stability across environments and years in eastern Oregon, as well as providing reactions from growers. W 301 survived the EOWW trials, and was entered for testing in the regional trials.

Table 1 contains 1990 data as an example of one year for the EOWW trials. W-301 ranked first for grain yield. Its test weight was as good as Stephens.

Grain yields in Table 2 illustrate the confusion that can occur when accumulating data in various environments. W-301 yields ranked near the bottom in 1986, 1989, and 1991, but were on the top for 1987, 1988, and 1990.

Agronomic data from Oregon test sites and the Western Regional White Winter Wheat Nursery are summarized in Tables 3 and 4.

W-301 had the top yields at Pullman (high-fertility), Pomeroy, Ritzville, Lind-dry, Lind-irrigated, Ontario, Pendleton, Moro, Moscow, and Kalispell in 1986. It was the top yielder at Pullman-high fertility, Lind-irrigated, Hermiston, Ontario, and Moscow in 1987.

It was the top yielder at Cunningham, Hermiston, and Kalispell in 1988. In 1989 it was top at Moscow. During 1990 it was top at Yreka, Bonners Ferry, Moscow, and Lind.

W-301 did poorly at Aberdeen in 1986, 1987, 1988, 1989, and 1990. W-301 also did poorly at Pullman for the medium and check fertility in 1987, and in the strawbreaker and Benlate treatments in 1988, and at Bonners Ferry in 1988.

QUALITY

Table 5 has nutrient information concerning W-301 and several checks. Grain nutrients are similar to the check varieties. W-301 ranks highest for grain yield. Its protein is high at 12.03, but 1.80 percent less than Madsen. Data in Table 5 is from a trial where 24 entries were planted in 24 replications to evaluate variety by herbicide interactions. The trial was planted October 26. Twenty-five pounds of nitrogen were broadcast on the trial area in early March. Nitrogen in the amount of 100 ± 10 pounds was applied via the sprinkler system near late boot. The trial area had considerable winter damage so that tender lines had very low yields.

Baking and milling results of The Western Regional White Winter Wheat Nursery reported in Table 6 are averages of composite samples from each of four years. Wheat and flour protein for W-301 was lower than Stephens and Madsen, but higher than Nugaines and Hyak. Flour yield is not as high as Madsen and Hyak. Cookie diameter, cake volume, sponge cake score, and noodle weight increase are within the range of the check's.

Baking and milling results in Table 7, and the agronomic observations in Table 8 are from a club wheat trial planted in late

January 1991. Stephens and W-301 were the common wheat checks. W-301 compares very favorably with the club wheats Moro, Tres, Crew, and Hyak for quality, and ranked as the highest grain yielder in the trial.

Table 9 and Table 10 illustrate how W-301 recovered residual nitrogen where a previous crop (either onions or sugar beets) had left excess nitrogen below its effective root zone. Grain yields were about 75 to 80 percent of expected levels, partly because of poor seedling vigor from low nitrogen in the early rooting zone. Stem rust also had some yield-reducing effect, but infections were too late to cause severe yield loss. Quality evaluations were very good.

W-301 did not produce high quality grain when planted in August (Table 11). Grain from the "Late August" planting date had lower test weight, less flour yield, higher flour ash content, lower milling scores, higher flour protein content and lower mixograph absorption than the later plantings.

DISEASE

The author's interpretation is that W-301 is moderately resistant to stripe-rust and Flora area snow-molds. It is susceptible to septoria, stem rust, and leaf rust. It is not resistant to all races of common or dwarf bunt in the Flora area. It is moderately resistant to mildew and flag smut. It may have some tolerance to wheat streak mosaic virus. It is a long-term survivor of the interaction of root and foot rots with aphid-caused problems in the early planted wheat-stubble-fallow-wheat disease nursery in Hermiston.

Table 1. Eastern Oregon White Winter Wheat; summary of grain yield, rank, test-weight, date headed, plant height, and percent lodged of 6 fall planted wheats evaluated at 8 irrigated sites in 1990.

Name	Yield	Rank	Test Weight	Date Headed	Plant Height	Lodging
	(bu/ac)		(lbs/bu)	(Jan. 1)	(inches)	(%)
1 Stephens	89	5	56.9	132	35	0
2 Hill	86	6	57.6	134	38	5
3 Malcolm	91	3	56.1	132	35	10
4 Dusty	91	2	54.1	132	35	10
5 Lewjain	90	4	55.6	132	35	5
6 W-301	93	1	56.9	132	35	5

Table 2. Eastern Oregon White Winter Wheat: summary of grain yields of six fall planted white winter wheats evaluated from 1986 through 1991 at various sites throughout eastern Oregon.

Name	1986	1987	1988	1989	1990	1991	Average
	- - - - - - - - - - - - - bushels per acre - - - - - - - - - - - - -						
1 Stephens	129	126	131	81	89	91	101.5
2 Hill	131	121	130	80	86	91	99.9
3 Malcolm	126	131	137	76	91	80	100.4
4 Dusty	130	128	137	76	91	80	100.5
5 Lewjain	-	129	139	72	90	75	95.0
6 W-301	119	131	140	76	93	80	100.5
Test years	3	3	3	5	8	4	26

Lewjain = 23 test years.

Table 3. Oregon Cooperative Winter Cereal Yield Trial: grain yield, test-weight, date headed, plant height of 7 fall seeded winter cereals evaluated in trials grown in 1990 near Ontario (O) and Hermiston (H), Oregon.

	Yield			Test Weight				
Name	O	H	Average	O	H	Average	Date Headed	Plant Height
	- - - - (bu/ac) - - - -			- - - (pounds) - - -			(Jan. 1)	(inches)
1 Stephens	123	102	112	59	55	57	131	37
2 Hill 81	120	91	105	62	57	59	133	41
3 Malcolm	120	90	105	62	57	59	131	36
4 Dusty	118	98	108	59	55	57	133	36
5 Hyak	117	51	84	58	54	56	133	39
6 Madsen	130	94	112	60	55	57	133	39
7 W-301	135	103	119	59	53	56	131	38

Standard Error = 7.197

Table 4. Summary of grain yield, test weight, plant height, and date 50% headed for 1986, 1987, 1988, 1989, and 1990 excerpted from the annual reports of Western Regional Soft White Winter Wheat Nursery co-ordinated by Dr. Robert Allan, USDA-ARS Pullman, Washington.

Entry	Yield	Test Weight	Plant Height	Date Headed
	(bu/ac)	(lbs/bu)	(inches)	(Jan. 1)
Nugaines	77	60.5	31	153
Stephens	86	58.5	33	150
Madsen	88	59.3	34	154
Hyak	79	58.8	33	151
W-301	85	58.4	32	150
Number of station years	74	66	66	48

Table 5. Nutrient information* comparing Stephens, Madsen, Hyak, and W-301 planted November 1990 in OSU-AES, HAREC field N range C in a 24 replication trial.

Nutrient	Unit	Stephens	Madsen	Hyak	W-301
Grain as harvested	bu/ac	91.3	103.2	96.2	110
			Dry weight		
Grain	lbs/ac	4937	5590	5192	5917
Crude protein	percent	10.36	13.83	11.39	12.03
Crude fat	percent	1.59	1.66	1.58	1.56
Crude fiber	percent	3.80	3.17	3.20	3.52
Ash	percent	2.01	2.41	2.00	2.20
N free extract	percent	82.87	78.30	81.83	80.69
Tot. Dig. nutrients	percent	89.25	88.55	89.12	88.85
Calcium	percent	0.02	0.06	0.03	0.04
Phosphorus	percent	0.27	0.31	0.26	0.28
Sulphur	percent	0.12	0.15	0.12	0.14
Potassium	percent	0.5	0.7	0.6	0.6
Magnesium	percent	0.15	0.16	0.13	0.14
Boron	ppm	2	4	2	2
Zinc	ppm	30	33	26	30
Manganese	ppm	22	23	21	18
Copper	ppm	3	6	2	3
Iron	ppm	27	42	23	31

* Analysis performed by Agri-Check, Inc. December 11, 1991 on samples from the first replication and were grown within a 60 foot perimeter.

Table 6. Four year summary (1987 through 1990) of baking and milling results as conducted by the USDA-ARS Wheat Quality Laboratory, Pullman, Washington on composite samples from the Regional White Winter Wheat Nursery.

Entry	Test weight	Wheat protein	Hardness	Flour yield	Flour ash	Mill score	Flour protein	M absc	Mill type
Nugaines	62.3	9.2	37	69.7	0.33	80.5	8.7	54.0	3M
Stephens	60.9	10.0	32	71.6	0.39	82.4	9.1	53.4	2M
Madsen	61.5	10.1	43	72.3	0.39	83.3	9.4	52.7	2M
Hyak	60.8	9.4	49	72.8	0.37	86.1	8.8	54.2	4LM
W-301	60.5	9.6	43	71.9	0.38	83.2	8.9	53.4	2M
Test years	4	3	1	4	4	4	4	4	4

Entry	Cookie diameter corrected	Cake volume	Sponge cake score	Noodle weight increase	Noodle score	Viscosity	
Nugaines	8.79	1251	72	334	71	88	97
Stephens	8.75	1278	74	344	72	72	72
Madsen	8.61	1245	72	349	72	86	83
Hyak	8.65	1318	76	343	72	111	122
W-301	8.73	1260	72	348	72	74	78

Table 7. Baking and milling results from the USDA-ARS Wheat Quality Laboratory, Pullman, Washington of W-301 soft white winter wheat tested in 1991 at HAREC, Field N Range A, Planted January 23, 1991. in a yield estimate trial (H1045) of irrigated winter club wheats.

Entry	Test weight	Flour yield	Flour ash	Mill score	Flour protein	Hardness	TGS	Cookie diameter*
Stephens	59.9	71.2	.43	84.3	7.7	34	9	9.84
Moro	59.5	73.2	.47	84.4	7.7	36	9	9.76
Tres	59.8	73.0	.46	84.8	7.1	34	9	9.60
Crew	59.9	72.7	.46	84.4	7.7	40	8	9.31
Hyak	60.2	72.9	.45	85.3	6.9	40	8	9.30
W-301	60.3	72.2	.44	85.1	8.4	38	8	9.65

* Cookie diameter corrected to mean of nursery = 9.5.

Table 8. Agronomic observations of yield trial (H1045).

Entry	Grain Yield	Test Weight	Date 50% Headed	Plant Height	Percent Plump
	(bu/ac)	(lbs/bu)	(Jan. 1)	(inches)	(6/64)
Stephens	95	56	158	35	95
Moro	84	56	158	43	88
Tres	81	59	156	36	87
Crew	84	57	157	36	78
Hyak	87	57	158	37	85
W-301	96	59	157	35	96

Table 9. Eastern Oregon Irrigated White Winter Wheat: grain yield, date 50% headed, test weight, percent lodging, and stem rust reaction of soft white winter wheats evaluated in a 1989 trial at the Malheur Experiment Station, OSU, Ontario, Oregon.

Entry	Yield	Date	Plant Height	Test Weight	Lodging	Stem* Rust
	(bu/ac)	(Jan. 1)	(inches)	(lbs)	(%)	
Stephens	109	137	36	59.8	0	VS-30
Hill	116	139	40	60.3	0	MR-TR
Malcolm	125	137	36	59.3	0	VS-20
W-301	116	138	36	59.0	0	S-20
Dusty	114	139	34	58.3	0	VS-80
Lewjain	112	140	35	58.4	0	VS-60

* Stem-rust readings are the reaction types (R = Resistant, MR = Moderate Resistance, S = Susceptible, VS = Very Susceptible) and the percent of stem area infected.

Table 10. Eastern Oregon Irrigated Soft White Winter Wheat: 1989 milling and baking results* of three white wheats produced from residual nitrogen at the Malheur Experiment Station.

Variety	Test Weight	Flour Yield	Flour Ash	Milling Score	Flour Protein	Mixograph Absorption Corrected	Cookie Diameter Corrected
	(lbs/bu)	(%)	(%)		(%)	(%)	(cm)
Malcolm	62.3	71.6	0.42	85.3	8.9	53.4	8.90
Dusty	60.6	70.0	0.42	83.4	8.8	55.2	8.83
W-301	62.6	72.2	0.38	88.7	8.9	53.5	9.49

* Milling and baking test results were supplied by the USDA ARS, Western Wheat Quality Laboratory, Pullman, Washington.

Table 11. HAREC Date of Planting milling and baking results of white winter wheats as determined by the Western Wheat Quality Lab, Pullman, Washington.

Variety	Date Planted	Test Weight	Flour Yield	Flour Ash	Mill Score	Flour Protein	Cookie* Diameter
Tres	Late August	58.4	70.5	.52	77.6	12.0	9.14
Tres	Mid-September	59.9	72.1	.49	81.6	10.5	9.23
Tres	Early October	60.6	73.1	.46	84.8	9.8	8.86
Hill	Late August	59.6	69.8	.51	77.4	12.3	8.81
Hill	Mid-September	59.8	70.9	.48	80.6	11.4	9.43
Hill	Early October	60.6	72.2	.47	82.9	10.2	9.01
W-301	Late August	51.7	66.7	.50	74.1	11.5	9.30
W-301	Mid-September	59.5	68.4	.49	76.9	10.8	8.80
W-301	Early October	60.3	69.6	.45	81.0	10.4	9.27

* Cookie diameter corrected to mean of nursery flour protein 10.8.

CLUB WHEAT VARIETY IMPROVEMENT

Pamela K. Zwer and D.L. Sutherland

INTRODUCTION

The most striking difference between club wheat (*Triticum compactum*) and common wheat (*Triticum aestivum*) is the spike morphology. Club wheat varieties possess a laterally compressed, compact spike, usually measuring less than 6 cm in length. Common wheat spikes are approximately two times the length of club wheat spikes. Three to five seed are closely situated in the club wheat spikelet, resulting in a small, laterally compressed kernel.

Aside from spike morphology, other differences have been reported between club and common wheat. Club wheat varieties were reputed to resist drought and "grow freely on the poorer classes of soils" (Percival, 1921). Gul and Allan (1972) reported club wheat was more adapted than common wheat in the dryland areas where stand establishment was difficult.

Club wheat, a soft wheat class, has played a significant role in Pacific Northwest (PNW) wheat production for almost 100 years. The spring club wheat, Little Club, was introduced to the Pacific Coast states sometime between 1701 and 1845 by Spanish missionaries from Mexico (Clark and Bayles, 1935). Big Club, another documented introduction from Chile, occurred between 1860 and 1870. Club wheat represented one of the first wheat classes grown in the Columbia Plateau and along the foothills of the Blue Mountains in Oregon.

Club wheat production was well suited to the mild, wet winters and hot, dry summers of the PNW and California. The intermountain region of the Pacific Coast states provided an excellent environment in comparison to the Great Plains and eastern states, where summer rains often resulted in sprouting damage as well as stem rust infection, and severe winters affected plant survival. Characteristics, such as strong, stiff culms that rarely lodged and firm spikes that seldom shattered in spite of the hot, dry, windy summer weather provided club wheat varieties with superior adaptation to the environment and harvest operations when compared to common wheat.

Club wheat was widely distributed in Asiatic Russia in mixed stands with *T. aestivum* and *T. durum* (Percival, 1921). Percival collected club wheat spikes in China and Manchuria. Club wheat was commonly found mixed with *T. aestivum* in England, Germany, France, Italy, Switzerland, Spain, Portugal, and Chili at the turn of the century. Percival (1921) noted club wheat was grown as a pure stand in central Asia and the PNW. Although club wheat has not been significant in world wheat production, the class continues to be a small albeit important class of wheat in the PNW.

Oregon and Washington have historically produced significant club wheat acreage. The exceptional milling and baking qualities for pastry end-use have maintained club wheat as an important component in the western white market class exported to the Pacific rim countries. The percentages of acreage planted to club wheat were 40 per cent in 1950, 75 per cent in 1961, and 8 per cent in 1966 (Clarke and Bayles, 1933; Reitz and Hamlin, 1978). Club wheat production dropped significantly by 1965 after the introduction of high yielding, stripe rust resistant, semidwarf common wheat cultivars. The percentage of winter wheat sown as club varieties in Oregon varied between 1.7 per cent in 1987 and 6.2 per cent in 1990 (Williamson and Kriesel, 1986 to 1992). Figure 1 shows the total percentage of club varieties grown for the years 1986 to 1992. The percentage of varieties grown each year is also shown. The category "other" in 1990 to 1992 primarily reflects the use of the variety Hyak.

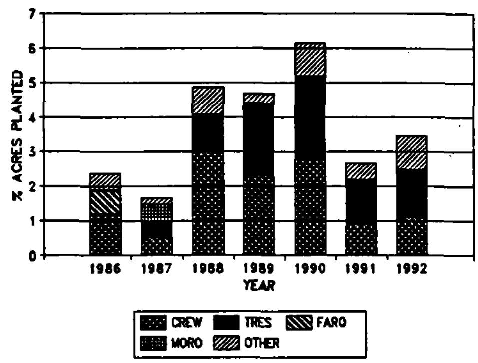

Figure 1. Percent of winter wheat acres planted to club wheat varieties, 1986-1992.

The demand for low protein club wheat continues to exceed production. Club wheat premiums were offered for 7, 7, 12, and 10 months in 1989, 1990, 1991, and 1992. Although premiums have fluctuated greatly in the four-year period, they were consistently higher in the last two years. The amount of the premiums are shown in Figures 2 and 3.

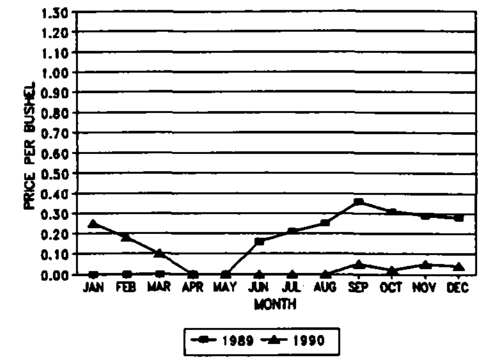

Figure 2. Premiums per bushel for club wheat, 1989 to 1990.

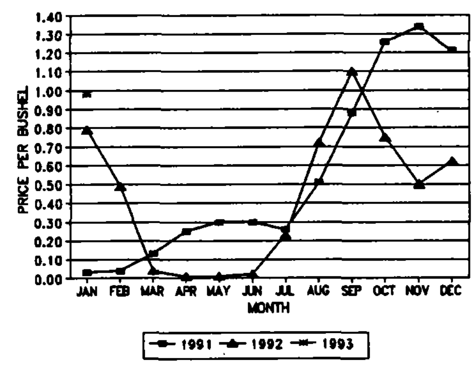

Figure 3. Premiums per bushel for club wheat, 1991 to 1993.

CLUB WHEAT BREEDING PROGRAM

The primary goal of the club wheat breeding program is to provide growers with club wheat varieties with improved disease resistance, higher yield potential in both low and high rainfall environments, and milling and baking characters inherent to this class. The breeding program encompasses several research areas that provide information used in the selection of improved varieties. The disease resistance component focuses on several diseases that cause significant yield losses in club wheat; including stripe rust, strawbreaker foot rot, and Cephalosporium stripe. Developing higher yielding club wheat varieties is the result of many factors, such as vigorous emergence and stand establishment, improved winter hardiness, and adaptation to grower management systems. Yield assessments, conducted at the Pendleton and Sherman Research Stations, provide information about the yield potential of advanced and elite club lines. Quality evaluations, conducted by the Western Wheat Quality Laboratory, provide milling and baking information for early generation and advanced breeding lines. The integration of the research areas provide effective selection criteria to identify superior club wheat lines.

Research is conducted at the Columbia Basin Agricultural Research Center, composed of the Sherman Station at Moro, OR and the Pendleton Station, near Pendleton, OR. The two locations differ in precipitation, growing degree days, and soil depth. The 20-year precipitation average is 17.28 inches at Pendleton and 11.29 inches at Moro. Moro is located at an elevation of 1870 feet in comparison to Pendleton at 1487 feet. The difference in elevation is reflected in fewer growing degree days each month at Moro than at Pendleton. The two research sites provide different environments to select and assess the early and advanced breeding populations and lines.

Conservation tillage is practiced at both research centers so that breeding populations are challenged to biotic and abiotic factors similar to those affecting yield performance in grower's fields. The fertilizer regime is 80 and 40 lb/a nitrogen (anhydrous ammonia) at Pendleton and Moro, respectively. The weed control program consisted of Bronate and Lexone, Harmony Extra and 2,4-D Amine, and Harmony Extra and Banvel in crop years 1990, 1991, and 1992 at both Pendleton and Moro. Hoelon was used each year as a preplant herbicide to control downy brome.

Early generation breeding populations were primarily planted at the Pendleton location for the first three years of the program, however in the last two years F_3 and F_4 populations were sown at the Sherman Station. Preliminary, advanced and elite club yield trials are conducted at both locations. Lines evaluated in yield trials for at least three years are designated elite, whereas lines evaluated for two years are designated advanced. The data collected for yield performance, agronomic characters, disease resistance, and quality are used to identify superior lines.

Funding from the Oregon Wheat Commission, STEEP, and a special USDA grant for Russian wheat aphid research support the research efforts in the club wheat breeding program.

PROGRESS IN 1992:

New releases. OR855 was named Rohde and assigned the number PI562529. Seed was lodged with the National Small Grain Collection at Aberdeen, Idaho. The name was selected to honor Charles Rohde, wheat breeder for Oregon State University at the Columbia Basin Agricultural Research Center. The development of this selection was a cooperative effort with Corvallis-based scientists Robert Metzger and Warren Kronstad, making the cross, Charles Rohde making the selections, and Pamela Zwer collecting yield data, disease reactions, and milling and baking data to support the release as well as moving forward with the seed increase. Foundation seed will be available for purchase after the 1993 harvest.

A spring club, WUC657, was evaluated by the OSU Pre-variety Release Committee. The spring club was developed by Calvin Qualset and Herb Vogt at the University of California, Davis. A cooperative effort to evaluate the spring club in the tri-state area was initiated with Calvin Konzak, Washington State

University, Edward Souza, University of Idaho, and Pamela Zwer, Oregon State University. The pre-variety release committee agreed the advanced line should be sent on to the Variety Release Committee for final consideration.

Quality. Promising advanced club lines were selected from yield trials for milling and baking assessment at the USDA-ARS Western Wheat Quality Laboratory, Pullman. A Buhler mill was used to produce flour samples for 21 promising advanced club lines grown in the 1992 elite club yield trials at Pendleton and Moro. Grain hardness, grain protein, flour yield, break flour yield, flour ash, milling score, flour protein, mixograph absorption, mixograph type, cookie diameter, cookie top grain score, sponge cake volume, and sponge cake score were assessed for the elite lines. Approximately 190 elite and advanced club lines were milled on a quad mill and analyzed for all characteristics except sponge cake volume and score. Two elite club lines, 90C172 and 90C155, possessed milling and baking characters equal to or better than the club check varieties Omar and Tres. An additional 45 advanced and preliminary club lines look promising for both milling and baking characters. Seed harvested from 1720 F_6 headrows was sent for grain protein and grain hardness values.

Stripe Rust. Puccinia striiformis, the causal agent of stripe rust, was inoculated onto F_2, F_3, F_4, and F_6 populations and headrows in the field at the Pendleton Research Station. Due to unfavorable climatic conditions, the inoculation was not successful. Therefore, stripe rust reaction data were not taken for the breeding populations. Stripe and leaf rust inoculum was collected from Tres club whear at Joe Temple's farm. The inoculum has been increased in the growth chamber for distribution in the 1993 field season at Pendleton.

Strawbreaker foot rot. A strawbreaker foot rot screening nursery composed of 117 entries, three rows per entry and two replications, was planted at the Pendleton Research Center. Advanced club wheat lines, released varieties, and germplasm from France and Australia were evaluated in the nursery. Several club selections from this program with parentages containing tolerant parents were evaluated for a second year. Inoculum of *Pseudocercosporella herpotrichoides*, the causal agent of strawbreaker foot rot, was dispersed onto the rows in December 1991 and January 1992. Evaluations were based on a sample of 25 random tillers per replication. The assessment scale was based on the percent of necrosis in a culm cross section, where 0 to 2.5 had less than 50 per cent culm necrosis (resistant to tolerant class) and 2.6 to 4.0 had more than 50 per cent culm necrosis (susceptible class). Flora triticale was the most tolerant entry in the two test years. Ten advanced club lines had mean scores between 1.4 and 2.4 for the 2-year period. Madsen and Hyak, two tolerant wheat variety checks, had scores of 2.0 and 3.0, respectively. The French and Australian lines (mean scores between 1.0 and 2.0) will provide new germplasm in the crossing program for strawbreaker foot rot tolerance.

Russian Wheat Aphid. The genetics of resistance in PI294994 to Russian wheat aphid (RWA) was evaluated in the field and greenhouse using F_2 seedlings, F_2 adult plants, and F_3 seedling families from the crosses Moro/PI294994 and Hyak/PI294994. Resistance in PI294994 was conferred by two genes, one dominant and one recessive. Data collected from the greenhouse and field confirmed the same genetic model. Data collected for grain weight and dry matter from adult plants confirmed that resistance in PI294994 is effective in the field. PI294994 is being used as a source of resistance in the club wheat breeding program.

Effective sources of resistance were utilized in the crossing program. Five sources of resistance, PI137739, PI262660, PI294994, PI48650, PI47545, and PI372129, were used as parents in previous years' crossing blocks.

F_2 and F_3 seedlings from crosses between tolerant common lines and susceptible club lines were vernalized and infested with RWA. Several early generation club lines were identified with RWA tolerance. The lines will be used in the backcrossing program.

Emergence study. The evaluation of advanced club lines and germplasm for rate of emergence in warm soil with deep seed placement was initiated. The material was also tested for germination percentage. The experiment, composed of 75 entries, was sown August 26, 1992 at the Pendleton Research Station. The genotypes were compared using an emergence rate index (ERI), which was calculated by multiplying the number of seedlings that emerged on day 1, 2, 3, and 4 by 4, 3, 2, and 1. The

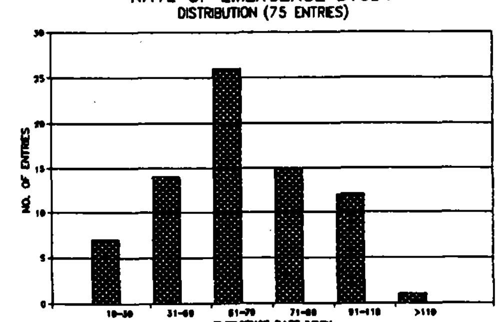

Figure 4. Distribution of lines for rate of emergence index.

ERI and germination percentages differed for the entries (P<.001). Figure 4 shows the distribution of the 75 lines for ERI. The line, PI137739, had a mean ERI of 116 compared to 104 and 99 for PI178383 and Moro, respectively. 91C128, 90C026, 90C148, and 90C168 had superior rates of emergence when compared to Tres, Hyak, and Rely. The ERI for the four elite club lines was not significantly different from PI178383 and Moro. Germination was above 94 per cent in this group of lines. The ERI for PI262660, PI47545, and PI178383 was greater than 101, however germination percentages were 85, 83, and 89 per cent, respectively. The advanced club line, 91C001, possessed an ERI of 19, however the germination was 60 per cent, significantly lower than the mean, 91 per cent. Low ERI values were not always associated with low germination values. The elite club, 88C124, had an ERI of 23 and normal germination of 95 per cent. Six club lines with similar ERI as PI178383 and Moro had acceptable disease resistance and quality for further consideration as new varieties. Elite club lines with promising yield potential, quality, and disease resistance are shown in Figure 5. Several lines used for Russian wheat aphid resistance will also be excellent sources for emergence in warm soil and deep seed placement.

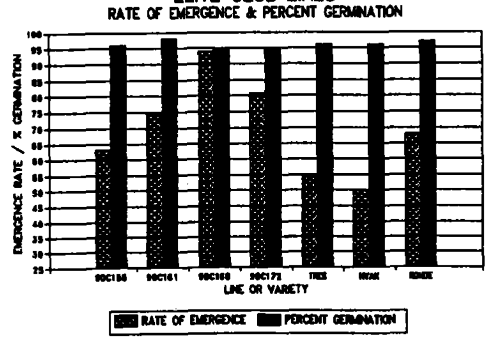

Figure 5. Rate of emergence and percent germination for elite club lines.

Breeding program. The greenhouse crossing program generated 418 single and three-way crosses. Crossing strategies emphasized improved milling and baking quality, stripe rust resistance, strawbreaker foot rot tolerance, Russian wheat aphid resistance, and enhanced yield potential.

Early generation winter club material planted at the Pendleton Research Station consisted of approximately 400 F_2 populations, and 12,200 F_4, 11,500 F_5, and 4,000 elite club headrows. Approximately 6,600 selected F_3 bulks were planted at the Sherman Research Station.

Yield trials were conducted at the Sherman and Pendleton Research Stations. The elite and advanced club trials consisted of 36 and 30 entries, respectively. A club mix yield trial compared 30 entries, which consisted of three-way mixtures of advanced club lines. Seven preliminary club yield trials compared 315 club lines at the Pendleton Research Station. Promising club lines have been identified in the elite and advanced yield trials. Quality and yield data shown in the graphs represent averages from five years and several locations. The yield data were collected from locations with less than 14 inches average annual precipitation (Arlington, Lexington, Heppner, and Moro) and locations with more than 16 inches average annual precipitation (Athena, Helix, LaGrande, and Pendleton). Disease resistance notes were taken for at least two years.

Drill strips of five promising elite club lines were sown at Don Miller's farm, Sherman County, in September 1992. The five lines, 90C122, 90C131, 90C133, 90C155, and 90C171, show promising yield potential, quality, and disease resistance.

Figures 6 to 9 show the milling and baking quality of the five elite lines in comparison to three checks, Tres, Hyak, and Rohde (OR855).

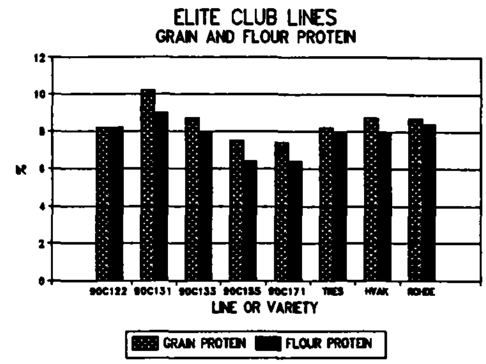

Figure 6. Flour and grain protein for elite club lines.

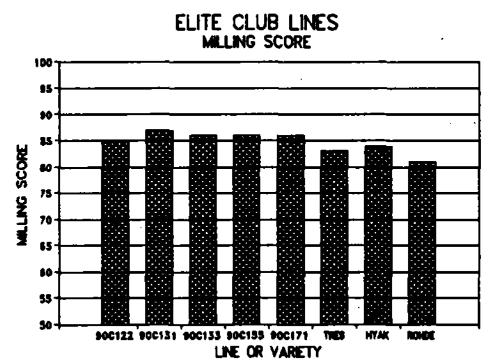

Figure 7. Milling score for elite club lines.

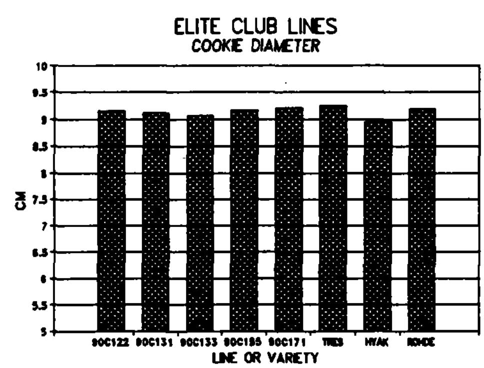

Figure 8. Cookie diameter for elite club lines

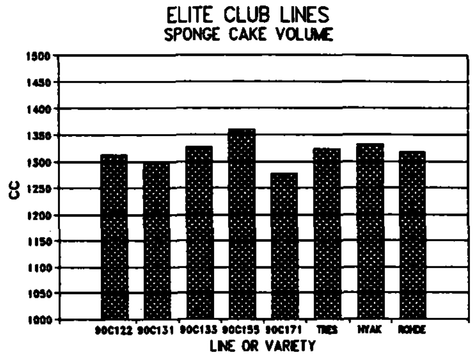

Figure 9. Sponge cake volume for elite club lines.

Grain protein was equal or less than the check varieties, except for 90C131. High values are desireable for milling score, cookie diameter, and sponge cake volume. Milling scores were higher for all elite lines when compared to the checks. Cookie diameter was similar for all lines. The elite line, 90C155, shows outstanding quality for all characters, whereas 90C171 is outstanding except for sponge cake volume. Additional sponge cake data will be collected for 90C171.

The yield data for this same group of elite lines are presented in the Figures 10 and 11. The two most promising quality lines yielded more in the low precipitation locations than the checks. Yields at the higher rainfall locations were less for 90C171 and 90C155 when compared to Tres, Hyak, and Rohde. The average yield for all locations is shown in Figure 11.

Another group of elite lines with promising quality are shown in Figures 12 to 15. Grain protein was slightly higher in 90C172 and 90C124, however flour protein was less than the checks. The elite line, 90C126, was higher in both grain and flour protein than Tres, Hyak, and Rohde. All lines had improved milling scores when compared to Tres, Hyak, and Rohde. Cookie diameters were equal or larger than the checks. Sponge cake volume in 90C126 was better than Tres, Hyak, and Rohde. The remaining five elite lines were equal or better than the checks. The two most promising elite quality club lines in this group are 90C172 and 90C168.

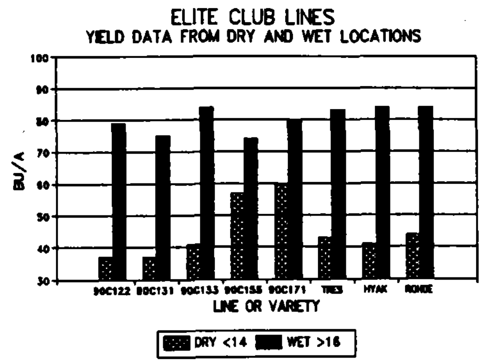

Figure 10. Elite club yield data from locations with <14 and >16 inch rainfall.

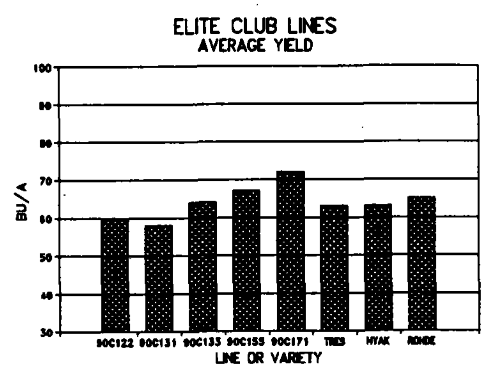

Figure 11. Elite club yield data averaged for all locations.

Figures 16 and 17 show yield data for promising elite quality club lines. Although 90C138 and 90C124 yielded similar to the checks, most of the elite lines yielded less than Tres, Hyak, and Rohde in the higher precipitation locations. However, the elite lines performed significantly better in the drier locations. The average yields for all lines except 90C124, 90C126, and 90C150 were equal or greater than the check varieties.

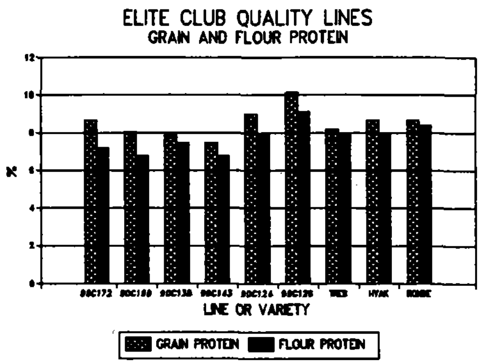

Figure 12. Grain and flour protein for promising elite club quality lines.

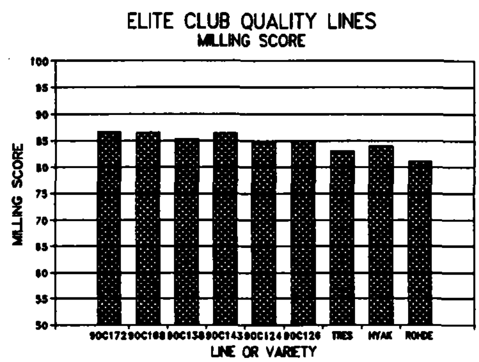

Figure 13. Milling score for promising elite club quality lines.

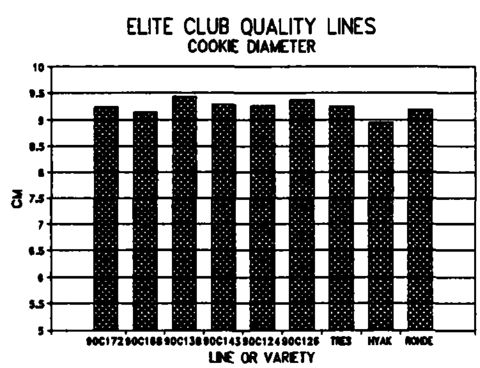

Figure 14. Cookie diameter for promising elite club quality lines.

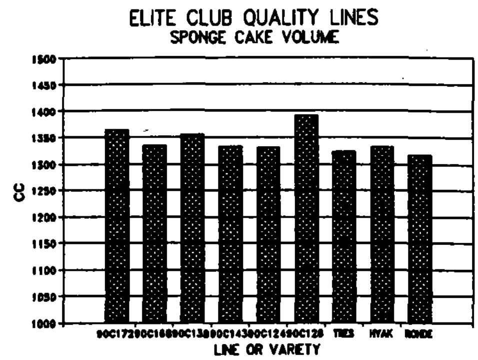

Figure 15. Sponge cake volume for promising elite club quality lines.

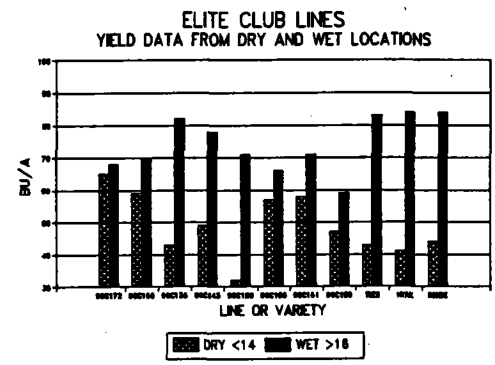

Figure 16. Yield data for promising elite quality lines at locations with <14 and >16 inch rainfall.

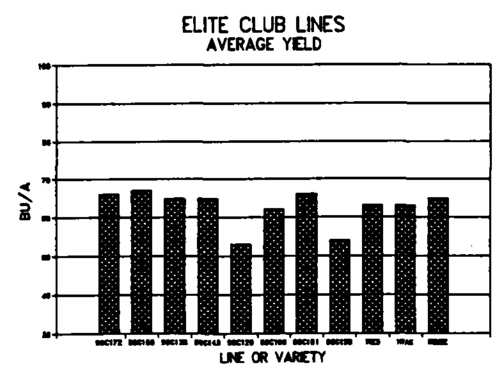

Figure 17. Yield data for promising elite club lines averaged for all locations.

Stripe rust and strawbreaker foot rot reactions are listed in Table 1 for the most promising elite club lines. Advanced club lines with promising quality, yield potential, and disease resistance are also summarized in Table 1. All lines are resistant or moderately resistant to stripe rust. Three lines, 91C004, 91C005, and 91C006, were similar to Madsen, a common variety resistant to strawbreaker foot rot.

Yield Performance Summaries for Winter and Spring Varieties. Winter and spring grain yield trials, comparing released varieties were planted at both research stations to provide data to growers, Extension agents, and other interested parties. Tables 2 and 3 show six-year yield averages for winter and spring wheat varieties respectively.

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Table 1. Yield, quality, emergence rate index, and disease resistance for elite and advanced club lines grown at Moro and Pendleton, Oregon for 2 to 3 years.

Line or[1] variety	Test weight	Grain protein	Milling score	Cookie diameter	Cake volume	Cake score	Average yield	Stripe rust	Strawbreaker[2] foot rot	Rate of[3] emergence	Germination
	lb/bu	%		cm	cc		bu/a		0 to 4		%
90C132	60.5	7.3	84	9.30	-	-	74	R	3.5	67	98
90C155	58.4	7.5	86	9.17	1360	80	67	R	3.1	63	96
90C161	60.1	8.2	87	9.25	-	-	66	R	2.5	75	98
90C168	60.3	8.1	87	9.14	1335	78	67	R	2.7	94	95
90C172	60.5	8.7	87	9.23	1363	81	66	R	2.9	81	95
91C001	60.8	8.2	83	9.28	-	-	84	R	2.4	19	60
91C004	60.5	8.1	86	9.22	-	-	78	R	2.2	45	84
91C005	60.7	8.0	87	9.43	-	-	79	R	2.1	35	83
91C006	59.8	8.0	86	9.36	-	-	81	R	1.8	32	83
91C016	61.0	8.1	87	9.31	-	-	72	R	3.3	60	95
91C019	61.0	7.5	84	9.30	-	-	71	R	3.4	30	98
91C023	60.4	8.4	84	9.43	-	-	70	R	2.5	23	74
Hyak	58.9	8.7	84	8.95	1332	78	63	MR	3.1	50	96
Rohde	61.2	8.7	81	9.19	1318	76	65	R	3.7	68	97
Tres	60.4	8.2	83	9.25	1323	76	63	S	3.4	55	96

1 Lines with 90C designation grown in yield trials for 3 years and lines with 91C designation grown for 2 years.
2 0 to 4 scale, where 0 is no infection, 1 ≤ 10%, 2 ≤ 30%, 3 ≤ 60% and 4 ≥ 60%.
3 Values near 100 are similiar in rate of emergence to the club variety, Moro.

Table 2. Yield for winter grain varieties grown at Pendleton and Moro, 1985-1992.

Line or cultivar	Pendleton No. yrs[1]	Pendleton Yld	Moro No. yrs[1]	Moro Yld
		bu/a		bu/a
		HARD RED		
Andrews	5	64	5	50
Batum	3	70	4	61
Hoff	4	65	5	46
Wanser	5	50	5	41
		SOFT WHITE		
Basin	4	74	5	57
Cashup	4	67	5	58
Daws	7	74	8	51
Dusty	6	80	7	53
Hill81	8	75	8	51
Lewjain	6	79	7	54
Madsen	6	78	5	54
Malcolm	8	78	8	55
OR830801Gene	4	72	4	65
Oveson	8	72	8	50
Stephens	8	78	8	54
		CLUB		
Hyak	7	72	6	54
Rohde	6	80	7	54
Tres	8	76	8	51
		TRITICALE		
Flora	4	80	5	59
Whitman	4	83	4	52

[1] Number of years evaluated

Table 3. Yield for spring grain varieties grown at Pendleton and Moro, 1985-1992.

Line or cultivar	Pendleton No. yrs[1]	Pendleton Yld	Moro No. yrs[1]	Moro Yld
		bu/a		bu/a
		HARD RED		
Bronze Chief	2	39	3	43
McKay	7	50	8	36
Wampum	7	51	7	28
Westbred 906R	7	52	8	34
Yecoro Rojo	7	48	8	35
		SOFT WHITE		
Dirkwin	7	54	8	37
Edwall	7	42	7	36
Owens	7	53	8	36
Penawawa	7	42	1	29
Twin	7	53	8	38
Wakanz	7	57	7	35
Waverly	7	56	7	35
		HARD WHITE		
Klasic	4	57	4	37
Wadual	4	51	4	33
		TRITICALE		
Juan	4	61	4	40
Karl	4	57	4	38

[1] Number of years evaluated.

EFFECT OF LIQUID INJECTION ON CANOLA EMERGENCE

Dale E. Wilkins and Daryl A. Haasch

INTRODUCTION

Canola or low erucic acid rapeseed (*Brassica napus* or *Brassica campestris*) is used as a rotation crop with wheat in the dryland production region of the Pacific Northwest. Growing a non-cereal crop, such as canola in rotation with wheat, provides weed and disease management benefits. About 15,000 acres of canola were grown in eastern Oregon in 1992, twice the acreage of the previous year.

Fall seeded winter canola consistently out-yields spring seeded canola in eastern Oregon (Wysocki et al., 1992). For maximum yield of fall seeded canola in this region, sowing should be completed before October (Wysocki et al., 1992). Stand establishment is a critical canola production problem because seedbeds are normally hot and dry in September requiring seeding 3 or 4 in deep to place seed into wet soil. The preferred seeding depth is 1/2 to 1 in, and seeding over 1.8 in deep often delays emergence, reduces seedling vigor and delays crop development (Kephart and Murray, 1990; Domier et al., 1992).

Injecting water with seed at planting has been shown to increase emergence and early plant development in wheat (Noori-Fard and Bolton, 1981) and range grass (Roohi and Jameson, 1991). This plant response to added water is associated with dry seedbeds. Canola may also benefit from water injection at planting when seed zone soil water is marginal.

"Sta-Wet", is a starch based superabsorbent material that increases plant available soil water content. "Sta-wet" is based on a USDA patent and is manufactured by Polysorb, Inc., Smelterville, ID.

This research was conducted to determine the influence on canola emergence of injecting water and "Sta-Wet" solution in seed furrows when soil water is marginal for germination and emergence.

MATERIALS AND METHODS

A randomized complete block design with 6 replications and 7 treatments was used to evaluate water injection at planting on canola emergence. Treatments consisted of no water injected, 25, 50, and 100 gal/acre of water, and 25, 50, and 100 gal/acre of a water and "Sta-Wet" mixture. "Sta-Wet" was mixed with water at a ratio of 1 part of "Sta-Wet" to 150 parts of water by weight. The field site was located near Pendleton on a Walla Walla silt-loam soil that had been fallowed. Several shallow secondary tillage operations were done prior to seeding to dry seed zone soil. Canola (var. "Ceres") was planted 1.8 in deep in 16 in rows at 7.5 lb/acre (20 seeds/ft^2) with a John Deere model HZ deep furrow drill on September 21, 1992. The drill was modified to inject water with seed. Seed was directed from the drill seed box through a 0.5 in diameter stainless steel tube to an exit point slightly above and directly behind a standard HZ drill opener point. Water and the "Sta-Wet" solution was injected through a "Y" into the seed tube, approximately 12 in below the seed box.

After seeding, incremental soil water content measurements were taken in the two center rows of treatments with no water, 100 gal/acre of water, 100 gal/acre of "Sta-Wet" and solution and from an undisturbed area between the center two rows. Four-inch-deep soil cores were taken with a 2 in square sampler. These soil cores were sectioned into 3/8 in increments. Corresponding increments from the two center rows were composited and oven dried for 24 hours at 105°C. These incremental soil samples were examined for canola seed to determine planting depth.

Emergence observations were made daily for one meter of row in each of the center two rows. Daily maximum and minimum air temperatures observed at the Research Center's official weather station were used to calculated growing degree days accumulated from date of seeding. Accumulated growing degree days (AGDD) were calculated from the following:

$$AGDD=\sum_{i=1}^{n}\left[\frac{T_{max_i}+T_{min_i}}{2}\right]-(base\ temp)$$

where T_{maxi} was the maximum air temperature in °F for the *i*th day; T_{mini} was the minimum air temperature in °F for the *i*th day: and base temperature was 32 °F. "TableCurve" a computer curve fitting program by Jandel Scientific was used to determine the best fit of the equation:

$$y = a + (b/x) + (c/x^2) + (d/e^x)$$

where y is the percent of plants emerged, x is the accumulated growing degree days and a, b, c and d are fitted constants. Equations were fitted for each plot. From these equations the accumulated growing degree days to 1 and 10 percent emergence were calculated.

RESULTS

Figure 1 shows the seed zone soil water profile immediately after planting. The bottom curve represents soil that was undisturbed by drill openers, and the top three curves represent soil within rows from treatments with no liquid, from rows treated with 100 gal/acre of water from rows treated with and 100 gal/acre of "Sta-wet" solution injected with the seed. "Sta-Wet" solution applied at 100 gal/acre created a slightly wetter soil condition in the top 2 in of soil than either the 100 gal/acre of water or the no liquid injected treatment, but this difference was not significant (P = 0.05).

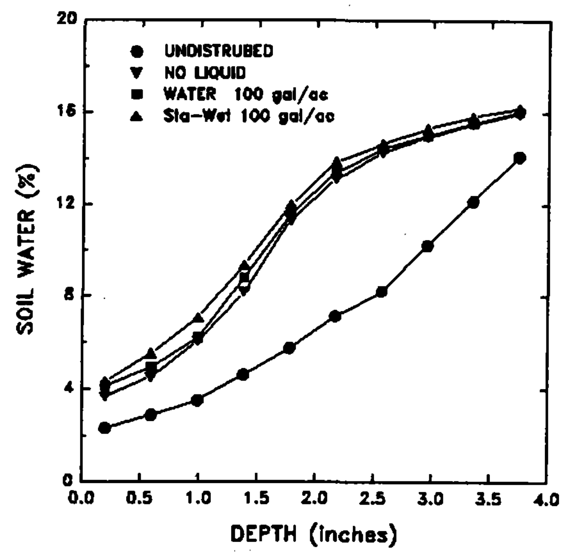

Figure 1. Seed zone soil water content.

Mean seed depth was 1.8 in as determined by the incremental samples. Liquid injection did not influence seed depth.

Table 1 shows canola emergence results. The R^2 values of the emergence curves ranged from 0.96 to 0.99. Early emergence (1 percent emergence) was not influenced significantly (P = .05) by injecting liquid with the seed. At 10 percent emergence, increased rates of water tended to increase the amount of heat units required for emergence. Mean heat units accumulated at 10 percent emergence were 634 for water injected compared to 579 for "Sta-Wet" mixture. This difference was significant at P = .05. Considering the emergence observations, only the final stand in plots injected with 100 gal/acre of water was significantly different (P = .05) from the control. In that case the control had a better stand. Injection of liquid, as either water or water plus "Sta-Wet", reduced the final stand from 10 to 45 percent.

DISCUSSION

Deep furrow openers had a far greater influence on the seed zone soil water content than liquid injection. HZ deep furrow drill openers move dry soil away from the rows and bring moist soil up into the seed zone. This action corresponds to removing from 1 to 2 in of dry soil (Wilkins, et al., 1983).

Three days after seeding, 1/2 in of rain caused the seedbed to crust before any plants had emerged. The rain eliminated

Table 1. Effect of liquid injection on canola emergence.

Liquid Injected		Heat Units for Emergence		
Water	"Sta-Wet"	1 % Emerged	10% Emerged	Final Stand
Gal/ac		Accumulated growing degree days		Plants/ft^2
NONE	NONE	544 A[1/]	601 ABC	9.4 A
25	NONE	530 A	576 BC	8.3 AB
50	NONE	544 A	647 AB	6.5 AB
100	NONE	549 A	679 A	5.1 B
25	YES	539 A	543 C	7.9 AB
50	YES	523 A	605 ABC	8.0 AB
100	YES	530 A	591 ABC	7.4 AB

[1/] Means within a column followed by the same letter are not significantly different (P = .05) as test with Duncan's multiple range test.

the dry, stressful condition and provided sufficient soil water for germination and emergence. Although the original objective of the experiment was to study the effect of liquid injection on canola plant emergence from a dry seedbed, the study was continued to evaluate the effect of liquid injection on canola emergence from a crusted seedbed. A crusting condition occasionally is encountered with September seedings in the Pendleton area, and it was thought this experiment might provide valuable information about canola emergence in a crusted seedbed.

The first canola plants began to emerge eight days after seeding when approximately 550 growing degree days had accumulated. Liquid injection at seeding did not speed canola emergence (fewer accumulated growing degree days required) as compared to no liquid injection. The highest rate of water injection, 100 gal/acre, required the most heat units to reach 1 and 10 percent emergence and resulted in the lowest final stand. "Sta-Wet" added to water reduced the detrimental effect of liquid injection at 50 and 100 gal/acre rates.

Largest final stand was in the control plots where no liquid was injected. There were 9.4 plants/acre in these plots, which represented less than half of the seeds that were planted per square foot. Injecting 100 gal/acre of water produced the lowest final stand. It is possible that the liquid injected at seeding contributed to crusting.

CONCLUSIONS

Injecting water, or water plus "Sta-Wet", with canola seed did not improve plant emergence in a crusted seedbed. "Sta-Wet" added to water at a ratio of 1:150 tended to reduce the negative influence of liquid injection.

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ABOVE-GROUND DEVELOPMENT OF FIVE WEED SPECIES AND THREE CEREALS COMMON IN OREGON CEREAL PRODUCTION

D. A. Ball, Betty Klepper,
and D. J. Rydrych

INTRODUCTION

Winter annual grass weeds are a serious problem in current cereal production systems in the Pacific Northwest. Control of grass weeds in cereals with crop protection chemicals requires proper application timing for maximum effectiveness. Further, in some situations, grass weeds compete severely with cereals, while at other times weed competition may be slight depending on the prevailing conditions for cereal and weed growth.

Seedling development rates of five common annual weedy grasses were compared with development rates of wheat (*Triticum aestivum* L. "Stephens"), barley (*Hordeum vulgare* L. "Hesk"), and triticale (*X Triticosecale* "Breaker"). The weeds included bulbous bluegrass (*Poa bulbosa* L.), downy brome (*Bromus tectorum* L.), jointed goatgrass (*Aegilops cylindrica* Host.), Italian ryegrass (*Lolium multiflorum* Lam.), and wild oat (*Avena fatua* L.). Approximately 2 million acres of small grains in Washington, and 1 million acres in Oregon and Idaho are infested with one or a combination of these annual grass species (Rydrych, 1974). Successful methods of control for these weeds could increase winter cereal yield by 35 percent in Oregon (Rydrych, 1974). Cultural and chemical systems provide varying degrees of control for downy brome, bulbous bluegrass, Italian ryegrass, and wild oat. Only cultural control methods are effective on jointed goatgrass.

This study emphasized observations during the seedling stage of development since current weed control practices are the most effective at that stage. Comparisons were made between a) main stem leaf development rates between species based on accumulated growing degree days (GDD) from time of planting, b) measurements of time of tiller appearance relative to main stem leaf appearance, and c) plant height for each species at various growth stages. A better understanding of the growth of grassy weeds in comparison to the growth of cereal grains can lead to improved weed control through more effective herbicide application timings, and through a better understanding of how weeds compete with cereal crops.

MATERIALS AND METHODS

The experimental work was conducted during the 1990-91 and 1991-92 field seasons at the Columbia Basin Agricultural Research Center, Pendleton, OR. Data from a weather station at the site were used for calculating GDD with a base temperature of 0°C. Grass seedling parts were identified using a system developed by USDA-ARS researchers at Pendleton (Klepper et al., 1982, 1984).

Each fall, small replicated plots were planted to pure stands of each weed and cereal. For each grass, periodic samples were taken during the seedling growth period to evaluate the main stem leaf number, tiller number and position, and plant height. At each sampling time, GDD from planting were calculated. The percentage of sampled plants having tillers T0 through T4 were determined. Seed bed conditions were considerably different between 1991 and 1992, so observations for each year were evaluated separately, and pooled if year differences were insignificant. In 1991, dry, rough seed bed conditions existed, while in 1992, pre-irrigation of the seed bed produced more desirable conditions for seedling emergence and development.

RESULTS AND DISCUSSION

Individual seed weight averaged less than 4 mg for bulbous bluegrass, downy brome, and Italian ryegrass, between 10 and 15 mg for jointed goatgrass and wild oat, and over 30 mg for the three cereals. These weights were determined after removal of extraneous parts down to the fruit coat. Thus potential resources for seedlings are very much larger in cereals than in weeds and better for jointed goatgrass and wild oat than for the other weeds studied. Species in order of increasing seed weight were bulbous bluegrass < downy brome < Italian ryegrass < jointed goatgrass < wild oat < barley < wheat < triticale. The larger-seeded species (cereals and jointed goatgrass) had a distinct growth advantage prior to the 5-leaf stage that would tend to give them an early competitive advantage.

The rate at which each species produced leaves was measured by plotting main stem leaf number of plants vs. GDD accumulated since planting. All eight species exhibited a linear fit for this relationship. Thus, like wheat, other cereals and weedy grasses could be modelled using GDD as the primary predictor. The slope of this linear relationship between main stem leaf number and cumulative GDD is an indication of the rate at which each species produces leaves and tillers. Of the species evaluated, downy brome produced leaves at a significantly faster rate than all of the other species except wild oat. Environmental factors play a role in determining the leaf development rate. However, the rank between species on leaf development rate was fairly consistent from year to year. In 1992 better seed bed conditions permitted more convincing comparisons. In 1992 the rate of leaf development from most rapid to slowest was bulbous bluegrass > downy brome > barley > wild oat > Italian ryegrass > wheat > triticale > jointed goatgrass.

Wheat and the larger seeded weed species usually produced coleoptiler (T0) tillers. In general, beginning with Tiller 1 (T1), the tillers of all species appeared at approximately the same leaf development stage (Haun stage) as seen in wheat. Further, in the weedy grasses main stem leaf number, when individual tillers appeared, was not significantly different when compared across the two years of the study with the exception of jointed goatgrass. Tiller appearance in the cereals, however, was slowed by the less desirable conditions in 1991 compared to 1992 plots where seed bed conditions were much better. Because of less ideal seed bed conditions in 1991, T1 tillers were delayed by 0.25 phyllocrons in wheat, barley, triticale, and jointed goatgrass. T2 tillers were delayed an average of 0.15 phyllocrons for wheat and jointed goatgrass. These results are consistent with previous research showing that early tillers in wheat are delayed with respect to their normal appearance time under poor seed bed conditions (Wilkins et al., 1989; Rickman and Klepper, 1991). The weeds were generally less responsive to environment with respect to the timing of tiller appearance than were the cereals. This may indicate that these grassy weeds would tend to be more competitive with cereals under poor growing conditions.

Wild oat and bulbous bluegrass produced T3 tillers significantly later in main stem development that did the other species in both years. However, the general pattern for tiller production was remarkably like wheat for all of the species.

Plant height also increased between the full emergence and 6-leaf sample for all species in each year except for wild oat in 1991, wheat in 1992, and triticale in 1992. At the seedling stages of these grasses, plant height is actually a measure of leaf length. Generally, heavier seed produced taller seedlings at all three sampling times. The cereals and the large-seeded weed species tended to have leaf lengths that increased very little from emergence to the 6-leaf stage, whereas the smaller-seeded weeds show distinct increases in height over time. Thus, by the 5 to 6 leaf stage, the smaller-seeded weed species generally improved their competitive situation with respect to canopy stature and presumably light capture.

Information derived from this study helps explain why grass weeds vary in their competitive ability with cereal grains from year to year and between geographic locations. Comparing development rates between weeds and wheat also provides information needed to develop growth models of important weeds. Growth models can be used to help predict the emergence of grass weeds in wheat, and improve herbicide application timing. In the future, models could be used to determine the competitiveness of weeds growing in wheat, and perhaps limit herbicide applications to only those necessary for control of economically damaging weed infestations. This in turn would increase farm profitability due to more effective use of weed control.

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CROWN AND ROOT SYSTEMS OF FIVE WEEDS AND THREE CEREALS

Betty Klepper, D. J. Rydrych,
and D. A. Ball

Weeds in the grass family cause serious problems in cereal crops. Grassy weeds are very difficult to control with herbicides because they are so similar to cereals in their life-cycle and environmental requirements. It is difficult to obtain sufficient selectivity to control weeds without injuring the crop. We studied crown and root systems of five weedy grasses and three cereals from 1990 to 1992 to examine below ground differences for exploitation in weed-control programs.

Root systems and crowns of grasses can take several forms. For example, wheat has a coleoptile produced from the level of the seed. This coleoptile elongates to provide the emergence thrust of the seedling. In wheat crops seeded deeper than one inch or so, the sub-crown internode elongates to set the depth of the crown. The crown in wheat consists of the leaf bases, nodes and stems of the lower 4 to 6 leaves on the plant (Figure 1). Some grasses, such as downy brome, have a different anatomy and a different sequence of early internode elongation. They elongate the mesocotyl, the internode between the seed and the coleoptile. Therefore, these grasses have a crown that consists of the coleoptile, lower leaf bases, nodes, and their associated stems. This difference is important because of the difference in timing of crown root appearance that results from the two patterns. The downy brome type produces crown roots sooner than the wheat type.

The crops we studied included winter wheat, barley, and triticale. The weed species were bulbous bluegrass, downy brome, Italian rye grass, jointed goatgrass, and wild oat. The objective of the study was to determine the number and time of appearance of the seminal and crown root systems of each species.

MATERIALS AND METHODS

Seed of the cereals were obtained from commercial sources. Weed seed were collected from fields in eastern Oregon. Plots of each of the eight species were planted on the Pendleton Station in the fall of 1990 and 1991. Sample plants were collected for measurement at full emergence, the 3-leaf stage, and a later stage when plants had 5 to 6 leaves and several tillers. We usually measured seed depth, crown depth, mesocotyl length, coleoptile length, and numbers and order of branching of seminal and crown roots.

RESULTS AND DISCUSSION

Techniques developed to characterize wheat root systems worked very well for the other grasses (Klepper et al., 1982, 1984). Seminal root systems of the eight species decreased in relative vigor (size, branch production) in the following order: triticale > wheat > jointed goatgrass > barley > wild oat > downy brome > Italian rye grass > bulbous bluegrass. Generally this order of size of the seminal root system was similar to the order of seed size, with smaller seminal root systems from small-seeded species (Table 1).

Two of the weeds, bulbous bluegrass and goatgrass, and all of the cereals developed crowns like wheat; the coleoptile remained at the seed level (Figure 1). However, Italian rye grass and downy brome both had short mesocotyls and wild oat had a long mesocotyl (Table 2).

Table 1. For 8 species, mean seed weight (mg), average seminal root number for each year of the study, and average nodal root number for each of 3 destructive samples for each year of the study.

	Mean seed wt.* (mg)	Seminal axes 1991	Seminal axes 1992	Crown axis number 1991 Full emergence	1991 3 Lf	1991 5 Lf	1992 Full Emergence	1992 3 Lf	1992 6 Lf
Bulbous Bluegrass	1	3	3	0	4	7	0	1	6
Downy Brome	2	2	2	1	4	8	1	4	10
Italian Ryegrass	3	2	2	5	9	13	1	4	13
Jointed Goatgrass	10	4	4	0	2	4	2	2	8
Wild Oat	13	3	3	2	(3)▲	2	0	1	7
Barley	31	4	4	0	2	6	1	3	5
Wheat	50	5	5	0	1	3	0	2	6
Triticale	61	6	6	0	3	8	1	6	11

▲ ( ) indicates n $\leq$ 3.

* Mean seed weights were determined from approximately 10 randomly-selected seeds from the 1991 seed lots.

Table 2. Mean seed depth, coleoptilar length, and mesocotyl length (cm) at full emergence for 8 grass species in each crop year.

	1991 Seed Depth	1991 Coleoptilar Length	1991 Mesocotyl Length	1992 Seed Depth	1992 Coleoptilar Length	1992 Mesocotyl Length
Bulbous Bluegrass	0.6	0.6	NONE	0.5	0.7	NONE
Downy Brome	2.7	2.4	0.3	1.9	2.0	0.3
Italian Ryegrass	2.7	1.3	1.4	2.2	1.3	1.3
Jointed Goatgrass	3.2	3.6	NONE	3.2	3.5	NONE
Wild Oat	3.7	2.3	2.4	1.9	1.8	0.9
Barley	5.5	4.6	NONE	2.8	3.3	NONE
Wheat	5.2	5.2	NONE	3.0	3.5	NONE
Triticale	4.9	5.7	NONE	3.0	3.4	NONE

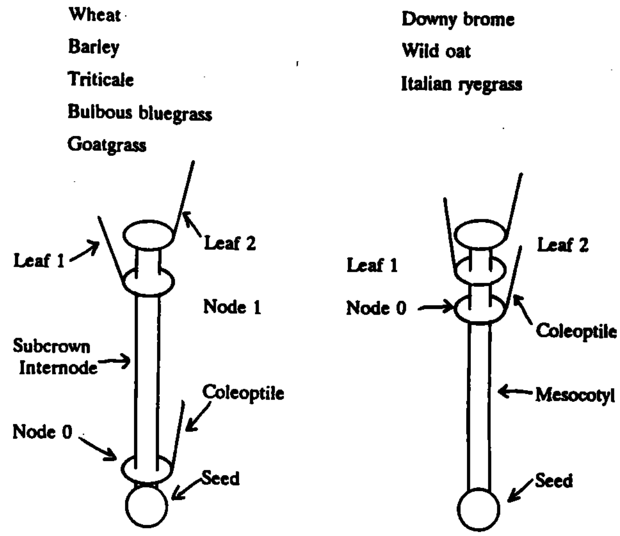

Figure 1. Diagram showing the placement of the coleoptilar node with respect to the seed and the crown in the two types of grass morphology found in the study.

Three weed species had a crown that included the coleoptiler node and its roots. In theory, they should have shown crown roots sooner than the other species. Table 1 shows that these three species tended to have fewer seminal axes relative to seed weight than other species and to have more crown axes than the others early in development.

CONCLUSIONS

The five grass species studied developed seminal roots and crown roots in a pattern determined by their crown morphology. Bulbous bluegrass and jointed goatgrass set their crowns by the elongation of the internode between the coleoptile and the first foliar leaf. They did not show much crown root development by the 3-leaf stage. On the other hand, downy brome, Italian rye, and wild oat had crown roots somewhat sooner than the others and set crowns by the elongation of the internode between the seed and the coleoptile (Figure 1).

The three weed species that produce crown roots early relative to the cereals may be vulnerable to certain herbicides or other weed control practices. The information obtained in this study may also improve understanding of the relative competitiveness among these eight species, especially in the Pacific Northwest wheat/fallow rotations where soil moisture is a limiting resource.

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MODWHT3, A NEW INSTRUMENT FOR YOUR MANAGEMENT TOOL KIT

R.W. Rickman, S.E. Waldman
and B.L. Klepper

Today's farmers seek to maintain profitable production while controlling loss of productive field soil to erosion by wind or water. Unfortunately, achieving both erosion control and profitable production can become conflicting goals. The balance of one against the other, or in the most desirable situation, achieving both with the same management practices, requires high knowledge and management skill - and a little luck. Increased knowledge about any farming system provides greater management flexibility and less reliance on luck. Knowledge is often condensed from a large amount of information. One way to condense information, and to distill required knowledge from it about crop response to farming practices, is to use crop growth models.

A model for winter wheat, MODWht3, was created at the USDA Columbia Plateau Conservation Research Center in Pendleton Oregon. The model utilizes daily weather and basic soil and planting information as input, and provides daily wheat growth and development predictions as output. MODWht3 can provide daily estimates of plant development in either Haun, Feekes, or Zadoks scales. It computes a daily water budget, keeping track of water lost to runoff, percolation below the root zone, evaporation, and transpiration. Nitrogen uptake and whole plant nitrogen content are calculated daily. The size, weight, and time of formation of each plant part is specified. The fraction of plants in a field that form specific tillers, and the number of tillers that survive to produce heads is estimated. The beginning date of each phenological growth stage (tillering, double ridge, jointing, boot, anthesis, heading) is specified. The relative weight of leaves, stems, heads, or roots to total plant weight, or relative to one another may be estimated for any day of the growing season.

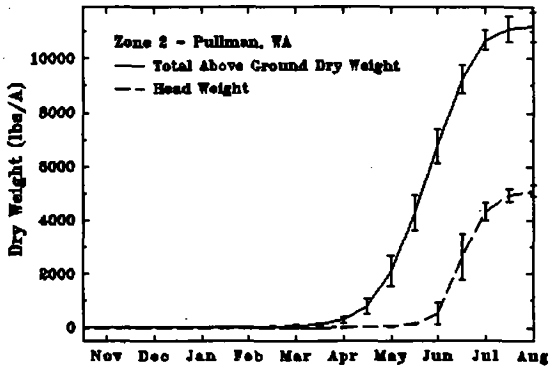
Any one item or all of the above information may be obtained as data output as frequently as daily. Usually it is only for research or validation purposes that all of the information is needed. The operator may create customized output files from any combination of the 100 or so variables in the program. Either English or metric units may be chosen for the variables with the exception of the degree-day. The centigrade temperature scale is used for all computations and output of degree-days. Fahrenheit temperatures may be used from original weather input files, but they will be converted internally and stored in working weather files in centigrade.

Weather data (daily maximum and minimum temperature, precipitation, and solar radiation - if available) from almost any tabular file, such as an output file from a spreadsheet, can be used for input. Weather files for most of the Pacific Northwest are available for calculating the ranges of production for any site. Specific site, soil, and management information are obtained by the program from an interactive session with the program operator.

The program automatically keeps a record of the names of all files used each time it is run. This record provides complete documentation of input information for comparison of outputs from various runs.

The following tables and figures provide examples of some of the outputs from MODWht3.

A.



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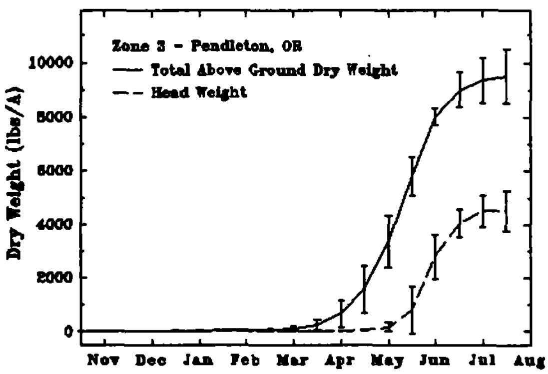

C.

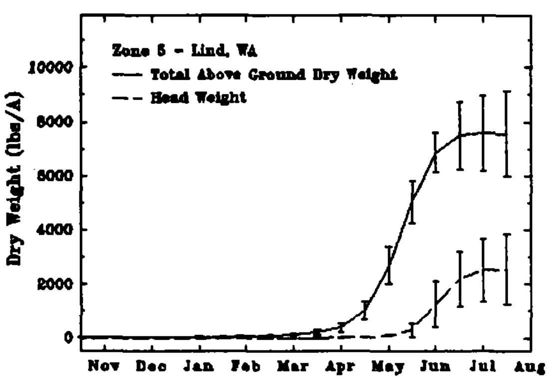

Figure 1. Total above ground dry weight and head weight of wheat for
A) Agronomic Zone 2, Pullman,
B) Agronomic Zone 3, Pendleton,
C) Agronomic Zone 5, Lind, WA.

Figure 1 illustrates the average and range of variation (±1 standard deviation) of 10 years of predicted total above-ground dry weight and head weight of wheat produced at locations characteristic of three of the major Agronomic zones in the Pacific Northwest (Douglas et al., 1990). The 10 years of weather data needed for these predictions at each site were obtained from the program Weather Wizard (Zuzel and Miller, 1990). Output files were read into a spreadsheet where the columns were averaged for plotting. The use of a spreadsheet for reading and summarizing the output files permits users to customize their analysis.

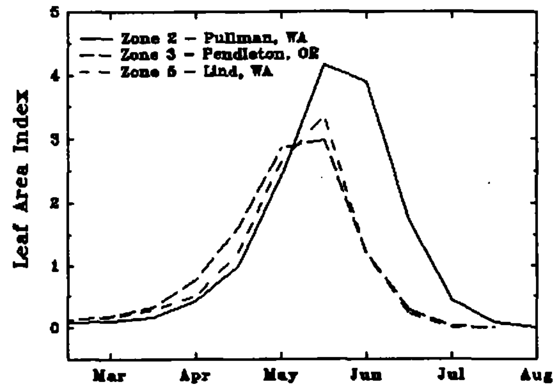

Figure 2. Leaf area index for three locations in the Pacific Northwest.

The seasonal development of leaf area index (ratio of green leaf area to soil area per plant) expected for the three locations is shown in Figure 2. Photosynthesis and growth depend upon the display of green leaves to capture sunlight. The leaf area index curves in Figure 2 show when crops begin their canopy development, the times of maximum canopy (and therefore maximum growth rates), and the times when green canopies decline at each location.

A summary file (Table 1) is automatically provided each time the program is run. Calendar dates of each phenological stage; yield, yield components, and residue production; and projected drainage of water below the root zone are displayed on the screen and recorded in the file.

Table 2 is an example of a customized output file. Of the 100 or more crop and environmental variables computed by the program, any combination can be selected for output at any interval from daily to once per season. The variables output for Table 2 were selected to provide values at 15-day intervals for input parameters to the RUSLE erosion prediction equation.

By selectively modifying values of inputs one can examine the projected consequences of changed field conditions or management practices on crop growth and production. Some items that might be modified include: the fraction of rainfall lost to runoff, nitrogen amount, planting date, planting rate, row spacing or soil water supply.

MODWht3 provides a relatively simple method for examining the day to day and seasonal response of winter wheat to the major variables. The program tracks daily development and growth of every plant organ. It is quite detailed and is currently a research level model. It is sufficiently easy to use however, so computer literate operators can use it with their own weather, soil, and management data. It runs on an IBM compatible PC with 640k RAM and a hard drive. The model is available from the authors for anyone who wishes to try it in its current 'research mode' form.

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Table 1. Standard summary file with dates of all phenological stages, yield components and drainage for the season.

Phenological stage	Cumulative degree days	day of year	mo.	day
1 planted	0	288	10	15
2 germinated	82	297	10	24
3 emerged	155	303	10	30
4 tillered	416	358	12	24
5 single ridge	421	359	12	25
6 double ridge	663	57	2	26
7 jointed	901	97	4	7
8 boot	1222	123	5	3
9 heading	1318	132	5	12
10 anthesis	1436	140	5	20
11 softdough	1857	168	6	17
12 mature	2180	185	7	4
13 ripe	2381	196	7	15

Yield Components
- Residue:567.5 gms/sq m Residue/Grain ratio 1.36
- Yield: 418.5 gms/sq m Culm count: 298 heads/sq m
- 62.2 bu/acre Stand: 104 plants/sq m

Water: 0.0 cm drained from the soil profile

Table 2. Customized output file for 15 day interval record of information needed as input for RUSLE erosion prediction model.

mo	day	cum deg day	headwt g/m^2	drywt g/m^2	Leaf Area Index	ht m	root length cm/cm^3
10	30	155	0	1	0	0	.25
11	14	246	0	2	0	0	.38
11	29	265	0	3	0	.121	.44
12	14	374	0	4	.1	.121	.51
12	29	436	.02	6	.1	.121	.58
1	13	471	.06	7	.1	.125	.61
1	28	507	.11	8	.1	.125	.63
2	12	570	.23	12	.2	.125	.7
2	27	670	.63	23	.2	.146	.88
3	14	720	1.07	38	.4	.146	1.04
3	29	800	2.02	71	.7	.181	1.34
4	13	996	6.7	207	1.9	.181	2.21
4	28	1163	13.88	385	2.8	.218	2.95
5	13	1332	69.09	586	2.7	.436	3.47
5	28	1522	289.03	802	1.6	.517	3.96
6	12	1767	450.13	938	.4	.549	4.29
6	27	2055	517.32	986	.1	.554	4.42
7	12	2325	534.38	987	0	.554	4.46

SUMMARY OF TWELVE YEARS OF RUNOFF AND EROSION MEASUREMENTS AT A SITE IN THE FOOTHILLS OF THE BLUE MOUNTAINS

John F. Zuzel, R. R. Allmaras, and
R. N. Greenwalt

INTRODUCTION

A long-term erosion monitoring site was established near Pendleton, Oregon in 1977 with the objective of measuring and evaluating the Universal Soil Loss Equation(USLE) factors under commonly used soil management systems in the climate of the southern portion of the Columbia River Basin. Thus, the USLE parameters would be verified and modified for application in this predominantly winter erosion regime. This site was operated for 12 years extending from the fall of 1978 through the summer of 1990. While the original objectives of the experiment were not met due to a lack of natural erosion events, analysis of the available runoff and erosion data do provide an insight into the frequency of runoff and erosion as influenced by climate and soil management. The objective of the research described herein was to quantify the temporal variability of runoff and erosion events under the unique climatic and physiographic conditions prevalent in much of the dryland grain growing region of the Pacific Northwest.

Because of this unique climatic regime, surface runoff and rilling during the winter months are the dominant erosion processes, while raindrop erosivity is only a minor factor (McCool et. al., 1982). A field study conducted during 1981-1983 indicated that rill erosion accounted for more than 90 percent of the total erosion from field plots located near Pendleton, Oregon (J. F. Zuzel, unpublished data).

The erosion site is located in the foothills of the Blue Mountains about 19 miles east of Pendleton at an elevation of 2400 feet above mean sea level. The annual precipitation at this site is 24 inches and about 80 percent occurs during the October-May period. Average monthly rainfall is shown in Figure 1. Monthly precipitation is evenly distributed during November through March, when 56 percent of the annual total occurs (Figure 1.).

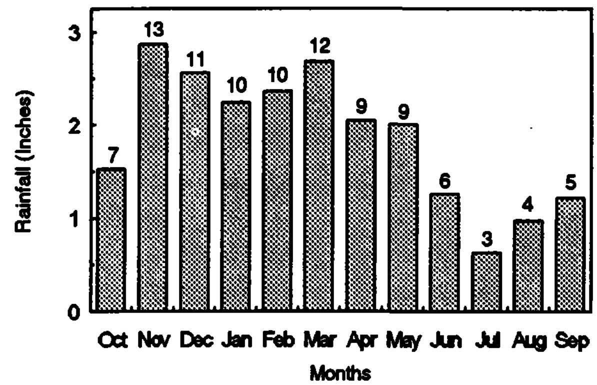

Figure 1. Average monthly rainfall at the experimental plots for 1978-1989. Numbers above the bars indicate the percentage of annual rainfall for the month.

METHODS

The site consists of six runoff and erosion monitoring plots on a 16-percent north-facing slope. Soil type is a Thatuna silt loam (fine-silty, mixed mesic Xeric Argialboll); the plow layer contains 32% clay and greater than 4% organic matter. Two plots were seeded to winter wheat (*Triticum aestivium*, L.) each fall after one year fallow, two plots were winter fallow following winter wheat harvest in August, and two plots were maintained in continuous fallow. The continuous fallow plots were maintained in a weed free condition with applications of herbicide as required. This sequence of operations has been maintained since the fall of 1984. Prior to 1984, the two winter fallow plots were seeded to peas each spring and peas were harvested in July. All plots, including those in permanent fallow, were moldboard plowed cross slope in late summer. Tillage operations on all of the plots were done in early fall and consist of a disking, spring tooth and/or harrow operation in an up-and-down slope direction. Seeding on the wheat plots was also done in an up-and-down slope direction using a double disk drill. The permanent fallow plots were prepared with a simulated seeding in the same manner as the wheat plots. This procedure produces a surface similar in roughness to the plots seeded to wheat. Up-and-down slope tillage is a poor soil management practice, but was done experimentally to give the practice (P) factor of the USLE a value of 1.

We measured runoff and erosion from the continuous fallow (CF), fall seeded winter wheat (WW), and fall plowed stubble after winter wheat (FP) each year from October through June for 12 years. The bordered plots were 110 by 13.3 feet and each treatment was replicated twice. Borders were generally installed in early October and removed in May. Plot borders were initially hand installed, galvanized sheet metal, but in later years were machine installed plastic coated cloth using the equipment and materials described by Warn et al. (1981). Each of the six plots was equipped with a system for the collection of a 24 hour accumulation of runoff and sediment. Each system consisted of a collector located at the extreme downslope position connected to a pipe that transported the runoff and sediment to a large holding tank. Runoff volumes were measured and sediment samples collected from the holding tanks as soon as possible after the event; usually within 24 hours. Water in the tanks was vigorously agitated and a sample of about 1 pint was removed for sediment analysis. In most cases, a duplicate sample was obtained for data quality estimation. Collectors and tanks were cleaned and rinsed after sampling was completed. Sediment concentrations were calculated from the differences in wet and dry weights after oven drying the sample for 24 hours at 221° F. Runoff and sediment data for each treatment were analyzed using standard hydrologic techniques. Events that produced sediment volumes of less than 225 pounds/acre were not considered to be significant erosion and were not included in the analysis. At the conclusion of the 12 year period measurements of coarse organic matter (>0.1 inches), soil bulk density, and soil biomass were made for the top 3 inches of soil on the WW and CF treatments. Coarse organic matter and bulk density were replicated five times at three slope positions for each treatment. Soil biomass measurements using the chloroform fumigation-incubation method of Jenkinson and Powlson (1976) were replicated six times at three slope positions for each treatment. Infiltration measurements were made on each treatment using the Palouse rainfall simulator at various times during the study (Bubenzer et al., 1985). Replications varied from two on the cropped plots to five on the continuous fallow. Simulated rainfall rates varied from 1.06 to 1.18 inches/hour with a mean replication rate of 1.14 inches/hour.

RESULTS AND DISCUSSION

In 12 years of operation, the CF produced only 86 runoff events with erosion greater than 225 pounds/acre; the WW 31, and FP 16. The largest single erosion event was 24 tons/acre while the largest runoff volume was 1.55 inches, and both were recorded from the CF treatment. A summary of erosion and runoff for 1977-1989 is given in table 1. Note that the CF treatment had over 4 times the runoff and 11 times the erosion as did the WW treatment.

Table 1. Summary of runoff and erosion for three treatments for water years 1978-1989.

Treatment	*Total Runoff* (Inches)	*Total Erosion* (Tons/Acre)
WW	6.18	18
FP	1.70	10
CF	27.0	206

Measurements of coarse organic matter (incorporated wheat straw) in the top 3 inches of the soil profile produced an average of 1.3 tons/acre for WW and only 0.1 tons/acre for the CF treatment. The presence of more incorporated coarse organic matter affects both the soil bulk density and the infiltration rate and should impact both runoff and erosion. The measured bulk density was 71 and 77 lb./ft^3 for the WW and CF respectively, while the infiltration rates were 0.24, 0.20, and 0.12 in/h for FP, WW, and CF respectively.

An analysis of the monthly distribution of runoff and erosion at the site indicates that the months of December through March account for about 88 percent of the runoff and erosion for all treatments. The distribution of average monthly runoff and erosion is illustrated in Figures 2 and 3. Approximately 11 percent of the runoff and erosion occurs in April and negligible amounts in May and June. Visual observations of the site after large precipitation events indicated that no significant runoff or erosion occurs during July through November. During the 12 yr. period, the WW treatment had a total of 100 runoff events while the FP and CF had 58 and 148, respectively. Of these occurrences, zero erosion was observed for 22, 21, and 20 events for the WW, FP, and CF, respectively. The zero erosion events were almost exclusively the result of slowly melting snow that produced runoff volumes as large as 0.17 inches, although the majority of these events produced less than 0.04 inches of runoff.

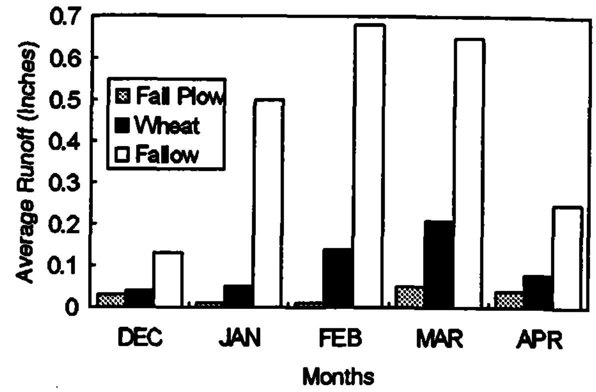

Figure 2. Distribution of average monthly runoff for erosion events greater than 225 lb./acre.

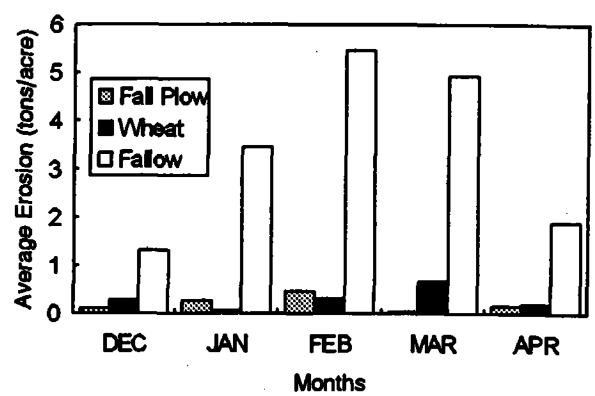

Figure 3. Distribution of average monthly erosion for events greater than 225 lb./acre.

Data from the present study suggests that major runoff and soil loss are the result of extreme weather events within a relatively narrow set of atmospheric and soil conditions. Curves plotted in Figure 4 illustrate this concept and show that nearly all of the total erosion (99%) was produced by only 50 percent of the runoff events for all treatments. Figure 4 also shows that only 10 percent of the runoff events produced 60 to 70 percent of the erosion, depending on treatment. This is strong empirical evidence to support the hypothesis that excessive soil erosion is associated with infrequent weather scenarios.

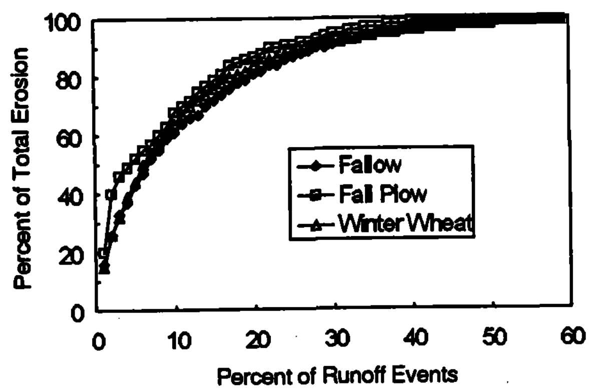

Figure 4. Relationship between the proportion of runoff events and the proportion of the total erosion for the three treatments, 1978-1989.

It is also important to assess the seasonal erosion (November-May) for a cropping sequence because seasonal erosion is the major factor in conservation planning. Because the period of record is only 12 years, it is not possible to develop a meaningful probability distribution that characterizes the total erosion by season. However, enumeration of seasonal erosion can provide some insights into the expected frequency of erosion amounts that are greater than the soil loss tolerance for this soil (5 tons/acre yr.$^{-1}$). Number of events and erosion volumes by treatment are presented for each water year (1 October-30 September) in Figures 5 and 6. Note that in 6 of the 12 years, no event occurred on the WW treatment while the FP had at least one event in only 3 of the 12 years (Figure 5). The soil loss tolerance was never exceeded for FP and exceeded only once for WW (Figure 6). Erosion totals shown in Figure 6 are the sum of individual events greater than 225 lb./acre for November through May. The 1983-1984 water year, in which the maximum soil erosion was noted on the WW and CF treatments (Figure 6), was also the wettest November-May period recorded at the experimental site with a rainfall total of 19.79 inches. At a site 9 miles to the west, with a 61-yr. record, 1983-1984 was the fourth wettest with a precipitation total of 11.91 inches while 1977-1978 was the second wettest with a rainfall total of 13.28 inches.

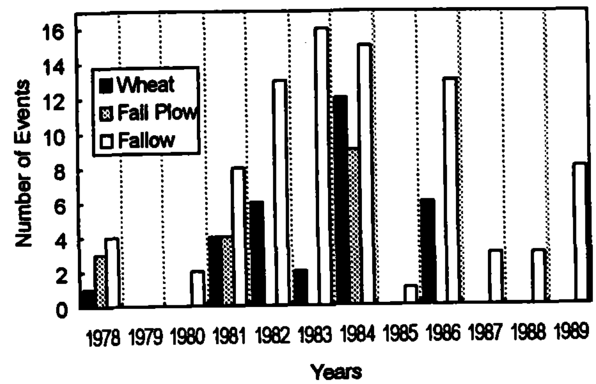

Figure 5. Number of erosion producing occurrences by water year for the three treatments.

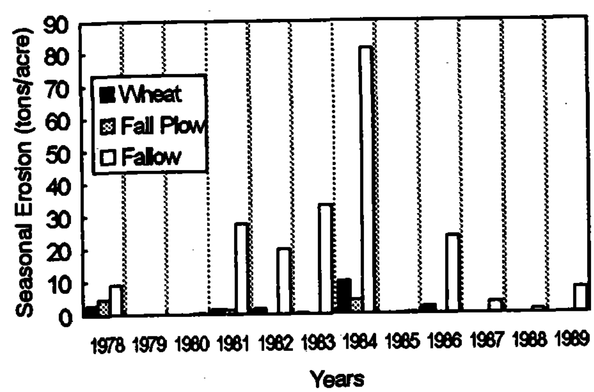

Figure 6. Seasonal erosion by water year for the three treatments.

Thus, the data shown in Figures 5 and 6 confirm that, like single storm events, large seasonal erosion losses occur infrequently and average yearly soil losses over a long-term should not exceed the soil loss tolerance under the conditions of this experiment.

SUMMARY AND CONCLUSIONS

Twelve years of runoff and erosion data from an experimental site in eastern Oregon were analyzed using hydrologic frequency analyses and probability theory. The soil management treatments involved were fall seeded winter wheat (WW), fall plowed wheat stubble (FP) and continuous fallow (CF) as the control. Measured physical, hydrologic, and biological characteristics of the three treatments are summarized in Table 2. Major runoff and soil loss appear to be the result of extreme events, and these extreme events are the major contributor to long-term soil losses. This seems to be the case for both discrete events and seasonal erosion volumes.

Table 2. Runoff and erosion plot differences after 12 years.

Varible	*Winter Wheat*	*Fall Plow*	*Continuous Fallow*
Runoff	6.14 inches	1.69 inches	26.97 inches
Erosion	19 tons/acre	10 tons/acre	205 tons/acre
Runoff Ratio	0.23	0.06	1.00
Soil Loss Ratio	0.09	0.05	1.00
Buried Residue	1.3 tons/acre	*	0.1 tons/acre
Bulk Density	71 lbs/ft³	*	77 lbs/ft³
Biomass	275 mg/kg	*	175 mg/kg
Infiltration Rate	0.20 in/hr	0.23 in/hr	0.12 in/hr

* Not measured on this treatment.

At this site, the soil loss tolerance of 5 tons/acre $yr.^{-1}$ was never exceeded for any single storm event for the WW and FP treatments. Seasonal erosion volume exceeded the tolerance only once in 12 yr. for the WW treatment and was never exceeded for the FP. This was associated with the largest November-May precipitation recorded at the site and the second largest in 61 yr. at a nearby site.

Data presented here demonstrate the large temporal variability associated with runoff and erosion. The data also show that significant soil erosion did not occur despite the use of sub optimal tillage practices and near-record precipitation volumes over the 12 yr. study period. The only significant differences between the treatments were the amount of coarse organic matter in the near surface soil and its effects on bulk density, infiltration, and biomass. This suggests that shallowly incorporated residue may be much more effective in erosion control than has been previously assumed, especially in an area where rill erosion is the dominant form of water erosion.

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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
63 year Average	.73	1.32	2.00	2.07	1.89	1.51	1.71	1.49	1.44	1.24	.36	.48	16.24
1972-73	.49	.66	1.14	2.47	.89	.89	1.27	.58	1.03	.12	0	.09	9.63
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						11.98
20 Year Average	.82	1.16	2.35	2.00	1.80	1.56	1.90	1.60	1.59	.97	.42	.83	16.98

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
83 Year Average	.60	.91	1.71	1.65	1.61	1.15	.98	.78	.80	.69	.22	.29	11.40
1972-73	.57	.43	.83	1.62	1.09	.34	.40	.21	.34	.25	0	.07	6.15
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						9.28
20 Year Average	.53	.78	1.64	1.65	1.39	1.12	1.11	.88	.80	.57	.35	.47	11.28

CUMULATIVE GROWING DEGREE DAYS
(BASE = 0°C)