Special Report 1061
June 2005

05 Dryland Agricultural Research Annual Report

Oregon State UNIVERSITY | Agricultural Experiment Station

USDA United States Department of Agriculture
ARS Agricultural Research Service

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Agricultural Experiment Station
Oregon State University

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Cooperating Research Units

Columbia Plateau Conservation Research Center
USDA-Agricultural Research Service

Columbia Basin Agricultural Research Center
Oregon State University

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INTRODUCTION

Staffs of the Columbia Basin Agricultural Research Center (CBARC, Oregon State University [OSU], Pendleton and Sherman Stations) and the Columbia Plateau Conservation Research Center (CPCRC, USDA-Agricultural Research Service [ARS], Pendleton) are pleased to present some of their research results. The title of this report was changed to "2005 Dryland Agricultural Research Annual Report" as needed to reflect the high degree of cooperation between CBARC and CPCRC as well as provide greater equity in the distribution of recognition for each Center. This Special Report contains a representative sample of the work in progress at these centers. A collection of Special Reports over a three-year period will give a more complete assessment of the productivity and applicability of research and education. The bulletins can be found on the CBARC website http://cbarc.aes.oregonstate.edu. Past issues are available through the extension office and the USDA, ARS website http://www.pwa.ars.usda.gov/pendleton/cpcrc/index.htm. Changes in staffing, programming, and facilities at these centers during the past year are summarized below.

Promotions and Awards

Paul Thorgersen received the Outstanding Classified Employee award from the College of Agricultural Sciences. This award is given to only one individual from the college each year and it is reflection of his outstanding work at CBARC.

Within the ARS Robert Correa, Tami Johlke and Mark Siemens received promotions. Spot awards were given to Richard Greenwalt, Linda Baugh, Chris Roager, Tami Johlke, Patricia Frank, Scott Oviatt, and Amy Baker.

Staff Changes

Ms. Sandy Ott resigned from the Extension Cereals program to accept a position with the Confederated Tribes of the Umatilla Indian Reservation. Mr. Nick Sirovatka was hired on grant funds to provide technical support to the Extension Cereal program. Ms. Annette Frye left to accept a position with the Morrow-Umatilla Educational Services District and Ms. Karen Binder was hired as office manager.

OSU summer student employees for 2004 included: David Dallas, Jenny English, Ashley Freeman, Rebecca Hildebrand, Jonathon Jackson, Glenn Jamison, Jennifer Lewis, Genna Melton, Jacob Mitchell, Matt Montgomery, Susan Sission, Tyler Stahl, Paul Wilkerson, and Tina Zeckman.

The summer workers provide invaluable assistance to the research programs and they make a significant contribution to the overall success of the research station.

In April 2005, Mr. Scott Oviatt left employment with the USDA, ARS to become data collection specialist with the USDA, NRCS in Bozeman, MT.

ARS summer student employees for 2004 included: Kari Dallas, Alan Wernsing, Kassandra Andrews, Mandy Wuest, Kasey Freston, Jeffrey Whitmus, Ben Greenwalt, Eric Boyle, Robert Johlke, Greggory Dallas, and Wesley Matlock.

New Projects and Grants Received

In 2004, Dan Long tested new on-line NIR spectroscopic sensors for use in measuring the grain protein concentration of wheat. Preliminary results obtained from a combine harvester during actual harvest are sufficiently promising to suggest that information from spectroscopic sensing can be useful in grain segregation, nitrogen management, and mapping straw yields. The manufacturers of these sensors: Zeltex, Inc. (Hagerstwon, MD) and NIR Technologies, Inc. (Bankstown, NSW, Australia), participated in this work.

Dr. Mark Siemens initiated a cooperative project with Alberta Reduced Tillage Linkages to further evaluate the USDA-ARS patented residue management wheel in Canadian conditions. Research will focus on the durability and performance of the device designed to improve the residue handling ability of hoe-type no-till drills.

Stewart Wuest, Tami Johlke, Steve Albrecht, and Katherine Skirvin initiated a new study designed to measure the effect of current surface residue on surface soil aggregation. The goal is to learn if soluble organic matter leached from fresh residues plays an important role in stabilizing the soil surface, which would improve water infiltration and reduce erosion.

The emphasis of the OSU plant pathology program shifted more formally from cultural management practices to the development of genetic resistance for wheat produced in regions and cropping systems where yields are constrained by Fusarium crown rot (dryland foot rot), root lesion nematode, and cereal cyst nematode. These efforts are coordinated with the USDA ARS Root Disease Laboratory at Pullman, WA, where emphasis is placed on Rhizoctonia root rot, take-all and Pythium root rot.

Facilities and Equipment

Improvement to the ARS facilities included the completion of Phase I of the HVAC upgrade; a heating system was installed in Bay 4 of the shop; an overhead door to the shop was installed; asbestos abatement was done on main building and mechanical room; a new faucet was installed in the pesticide shed; a new eyewash drain put in the Chemistry Lab; an electrical raceway, a window, and faucets and sink were installed in the microlab.

The ARS laboratory purchases in the last year included a near infrared whole grain analyzer. Field data acquisition equipment purchases included a Veris soil EC mapping system for spatial characterization of soil/landscape variability; two sets of calibration reflectance tarps and SPAD chlorophyll meters for supporting remote sensing research.

OSU purchased two trucks using grant funds, one for the club wheat breeding program and one for the weed research program. We also purchased a 12ft custom Fabro grain drill with a grant from the Research Equipment Reserve Fund at OSU and funds provided by the Sherman Station Endowment Fund. This drill will be used to seed the Long Term Experiments at the Sherman Station. Using grant funds from the Building Use Credit program we replaced the leaking roof on the woodshop and main shop. We replaced the head house roof and painted the interior of shop, office, and headhouse. A custom sprayer was fabricated for the weed research program.

Training

All OSU and ARS employees licensed to apply pesticides completed the appropriate recertification training. Safety training on specific topics was a regular part of the monthly OSU staff meeting. Many ARS and OSU employees participated in first aid, cardio-pulmonary resuscitation (CPR) and automatic external defibrillator (AED) training.

Sandra Easley and Jennifer Gourlie gained additional knowledge and skills for laboratory research through their participation in an intensive 10-day nematology workshop at Clemson University.

Mark Siemens, Hero Gollany and Dan Long attended New Scientist Orientation; Linda Baugh completed Administrative Training, and Contract Formulation I; Pat Frank attended OWCP Training, Relocation Travel Training, and Administrative Training; Amy Baker and Chris Roager, completed Ground Water training and Hazardous Waste Basics; and Judy Skjelstad completed Personal Property, and Simplified Acquisitions Training. Dan Long completed the New Research Leader Leadership Lab.

Outreach

Dr. Mark Siemens and Mr. Don Hulick served as agricultural engineer and engineering technician job shadows, respectfully, for Pilot Rock High School District Student. ARS and OSU scientists hosted a Whitman College Biology Class for a day at the Research Center. Dan Long and Stewart Wuest discussed their research in public schools in Pilot Rock and Pendleton. Amy Baker, Tami Johlke, Scott Oviatt, Katherine Skirvin, Hero Gollany, and Stewart Wuest represented ARS at Career Day, Outdoor School, and Watershed Field Days. John Williams and Dan Long served as proposal reviewers for the USDA, Cooperative State Research, Education, and Extension Service program: Solutions to Economic and Environmental Problems (STEEP). Dan Long served as the USDA, ARS representative on the Administrative Council for the Western Sustainable Agricultural Research and Education (WSARE) organization.

OSU Extension specialists and scientists made 75 presentations in 2004 to keep the stakeholders of the research center and citizens of Oregon informed of our activities to a wide range of groups including growers, the Oregon Wheat Commission, the Natural Resources Conservation Service, the Direct Seed Conference, and local schools. The pumpkin patch was visited by more 900 elementary school students were able to pick and take home pumpkins and ornamental corn and gourds.

Visitors

The Center hosted several special events, including numerous research and planning meetings. Visitors hosted by the staff at the center included:

Paul Gessler, Associate Professor of Remote Sensing and GIS, University of Idaho – Moscow
Urs Shulthess, owner, CropMaps, LLC, Denver, CO

Fran Pierce, Director, WSU Center for Precision Agriculture, Prosser, WA

Eileen Perry, Associate Director, WSU Center for Precision Agriculture, Prosser, WA

Gerald A. Nielsen, Professor of Soil Science (retired), Montana State Univ. – Bozeman MT

Senator and Mrs. David Nelson, Pendleton, OR

Sandy Halstead, USEPA

Patricia McDowell, Department of Geography, Univ. of Oregon State University

Charles Boyer, Associate Dean, College of Agricultural Sciences, OSU

Seminars

Steve Albrecht coordinated the 2004 OSU/ARS seminar series at the Centers. Seminars included the following topics and speakers:

Vegetation Assessment for the Patawa and Tutuilla Creek Watershed, Cheryl Shippentower, Confederate Tribes of the Umatilla Indian Reservation, Pendleton, OR, 6 April

Wheat Production in Argentina and the Wheat Breeding Program, Ruben Miranda, wheat breeder from Argentina, 16 June

Invertebrate Assessment for the Patawa and Tutuilla Creek Watershed, Sandra DeBano and David Wooster, Hermiston Agricultural Research and Extension Center, Oregon State University, Hermiston, OR, 29 July

Geomorphology of the Umatilla River Channel, Dr. Patricia McDowell, University of Oregon, Eugene, OR, 18 August

Farming in York, Clive Blacker, Nuffield Farming Scholar, York, England, 25, August

Resistance to the Root Lesion Nematode (Pretylenchus thornei) in wild relatives of wheat and in Iranian landrace wheats, Mr. Jason Sheedly, Leslie Research Center, Australia, 7 September

Agronomic and Biochemical Response of Direct-Seeded Glyphosate-Tolerant wheat to Fungal Pathogens, Mr. Jamie Baley, Washington State University, 13 September

Evaluations of Spring Cereals and Wild Wheat Relatives for Disease Reaction to Rhizoctonia solani, Ms. Jaya Smith, Washington State University, 22 September

Rangeland and Forage Management in Eastern Oregon, Dr. Tony Svejcar, Eastern Oregon Agricultural Research Center, Burns, OR, 28 September

Long-Term Tillage and Nitrogen Effects on Grain Yield of Continuous Annual Cropping Systems in the Pacific Northwest (PNW): Comparisons between Winter Wheat, Spring Wheat, and Spring Barley, Dr. Stephen Machado, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, OR, 26 October

Energy Crops in Oregon, Dr. Don Wysocki, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, OR, 16 December

Liaison Committees

Chairpersons Mark Hales and Ernie Moore led the Pendleton and Sherman Liaison Committees, respectively. In 2004, we decided to convert to joint OSU-ARS Liaison Committees for purpose of enhancing organizational synergy between CBARC and CPCRC. These Liaison Committees provide insightful guidance and recommendations on research directions, staffing needs, and facilities and equipment needs. They also provide a crucial communication link between growers and the research community. We encourage you to contact the Liaison Committee chairs with your concerns and suggestions for improvements regarding any aspect of the research centers.

Expressions of Appreciation

The staff expresses their appreciation to individuals, associations, and corporations that have given special assistance for the operation of experimental research plots during this past year, 2003-2004. The Oregon Wheat Commission continued to provide crucial funding to the OSU programs at the Center, and we gratefully acknowledge their generous support. We want also to express our sincere appreciation to those individuals, groups, and corporations who provided additional equipment, supplies, funds, and labor to help us carry out our mission. These include: Charles Betts, Sheldon King, the Pendleton Flour Mills, Pendleton Grain Growers, Agrium, Bayer, and Monsanto. For continued support, we thank the Umatilla Soil and Water Conservation District- Bev Kopperud and Ray Denny, and the Board of Directors of Oregon Wheat Growers League- Tammy Dennee, Karl Scronce, Brad Anderson, Don Coats, and Mike Noonan.

We also want to express our appreciation to those who donated labor, supplies, equipment, or funds for the Pendleton Station Field Day. These include:
Agri-Check
American Cyanamid Co.
Aventis CropScience
Bank of the West
Banner Bank
Bayer Corp.
BASF Corp.
Columbia River Bank
Community Bank
E. I. du Pont de Nemours
Farm Credit Service
FMC Corp.
Inland Chemical Service
Kuo Testing Labs
Main Street Cowboys
McGregor Co.
Mid-Columbia Bus Co.
Monsanto Co.
Pendleton Flour Mills
Pendleton Grain Growers
Pendleton Main Street Cowboys
Pioneer Implement
Rohm and Haas
UAP Northwest
Walla Walla Farmers Coop.
Western Farm Service
Wheatland Insurance
Wilbur-Ellis

We also want to acknowledge and thank the donors who provided buses, meals, and other services for the Sherman Station Field Day at Moro, including:
Anipro
Columbia River Bank
Bank of Eastern Oregon
Farm Credit Service
Gustafson
Klamath First Federal
Main Street Cowboys
Mid-Columbia Bus Co.
Mid Columbia Producers
Monsanto Co.
Morrow County Grain Growers
Richelderfer Air Service
Seed Prod +
Sherman Aviation
Wasco Electric Coop
Wilbur-Ellis

The local county agricultural agents throughout north-central and northeastern Oregon have provided invaluable local assistance in locating research sites, coordinating activities with farmer-

cooperators, and providing input to our research programs. These tireless individuals include Mary Corp, Tom Darnell, and Don Horneck in Umatilla County; Darrin Walenta in Union/ Baker/Wallowa counties; Larry Lutcher in Morrow County; Sandy Macnab in Sherman County; Brian Tuck in Wasco County; and Jordan Maley in Gilliam County. County agricultural agents in Washington have also been key members of our team, and we wish to thank Roland Sherman in Columbia County; Aaron Esser and Dennis Tonks in Adams/Lincoln Counties; and Debbie Moberg in Walla Walla County.

We wish to express special gratitude to the many regional producers who allowed us to work on their property during the past year (see separate listing). Not only have they performed field operations, loaned equipment, donated chemicals, forfeited yield, and adjusted their practices to accommodate our experiments, but they also voiced support for agricultural research at the local, regional, and national levels. The locations of these off-station plot sites are shown on the map that follows.

We gratefully appreciate the support and encouragement of growers, organizations, and businesses with missions common to ours: to serve in the best manner possible the crop production and resource conservation needs of our region. As we continue toward this goal, your suggestions on how we may improve our efforts are always welcome.

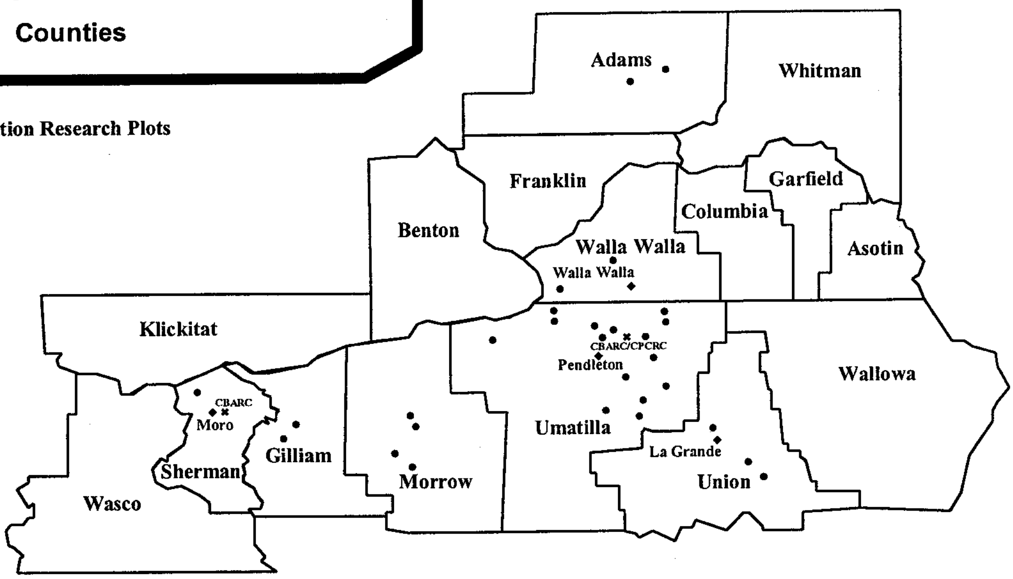
Steve Petrie
Superintendent
OSU-CBARC

Dan Long
Research Leader
USDA-ARS-CPCRC

RESEARCH PLOT LOCATIONS

Eastern Oregon - Eastern Washington Counties

• Off-Station Research Plots



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UNION, OR
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Dave Morel
Alan Ford
Mark Sherry

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POSSIBLE PRECIPITATION OUTCOMES AFTER AN ABNORMALLY DRY WINTER

Karl Rhinhart and Steve Petrie

Abstract

In the dryland wheat producing region of the Pacific Northwest (PNW) we rely on winter precipitation to produce wheat and other dryland crops. During the winter of 2004-2005 we experienced abnormally dry weather, resulting in reduced storage of soil water that has the potential to adversely affect crop yields during 2005. At Columbia Basin Agricultural Research Center in Pendleton, Oregon (CBARC-Pendleton) we have collected daily weather data, including precipitation, from the fall of 1929. The resulting database presented a unique opportunity to determine the possible precipitation outcomes for the rest of crop year 2005, following this abnormally dry winter. We divided the crop year into winter (September 1 to February 28) and spring and early summer (March 1 to June 30) precipitation periods. Using one standard deviation from the mean of all crop years as the basis for dividing each period into drier than normal, normal, and wetter than normal, we found that drier than normal winter precipitation was followed by normal or wetter than normal spring and early summer precipitation 8 of 12 years. Total annual precipitation was less than normal 8 years and normal in 4 years. These conclusions are based on statistical analysis of long-term weather data from the Pendleton Station and are not based on meteorological models and, therefore, are not meant to be predictive tools.

Keywords

Climate, weather, precipitation, drought.

Introduction

The intermountain region of northeastern and north central Oregon is marked by warm dry summers and cool, wet winters. On average, we receive about 16.5 inches of precipitation annually at the Pendleton Station of CBARC; the vast majority, 83 percent, occurs between October 1 and May 31. This winter precipitation is stored through tillage or chemical fallow and the added soil moisture is used to produce a crop in the following crop year.

We have collected daily weather data since the fall of 1929 and recently completed entering all this data into an electronic database that permits easy access to daily, monthly, and seasonal weather data. Information currently collected includes daily precipitation, maximum and minimum temperature, wind speed and direction, pan evaporation, and soil temperatures at 1 inch, 4 inches, and 8 inches deep. Not all data has been collected since 1929 but we have a complete database for daily precipitation and temperature.

Precipitation at the Pendleton Station of CBARC from September 1, 2004 to February 28, 2005 was only 5.32 inches compared to the 74-year average of 9.74 inches (Table 1). This made the winter period of crop year 2005 the third driest on record. Only two crop years, 1977 (3.45 inches) and 1937 (5.20 inches), were drier during this 5-month time period. Growers planting spring crops depend on stored soil moisture as well as spring and early summer rains to produce a crop. Questions about the likelihood of spring rain arose from many

Table 1. Monthly precipitation at Columbia Basin Agricultural Research Center-Pendleton for September 2004 through February 2005, compared to the 74-year mean.

	Monthly precipitation		
	2004-2005	74-year mean	% of 74-year mean
	------------- inches	---------------	
September	0.54	0.73	74.0
October	0.75	1.38	54.3
November	2.09	2.08	100.5
December	1.08	2.05	52.7
January	0.53	1.96	27.0
February	0.33	1.54	21.4
Total crop year to date	5.32	9.74	54.6

quarters, including farmers, bankers, and researchers. The objective of our research was to determine if there was an historical pattern that we could use to help growers make decisions regarding the potential for spring rains using the information in our long-term weather database. Such information could be used in the decision-making process to decide whether to sow a spring crop or to fallow the land to store scant precipitation.

Materials and Methods

Climate data, including precipitation, have been collected here at CBARC-Pendleton since the fall of 1929. Instrumentation consists of standard National Weather Service Cooperative Program instruments and is calibrated and serviced twice yearly by the local National Weather Service Office here at Pendleton. During the winter of 2004 we converted paper-based weather records into a comprehensive electronic database.

Subtotals were obtained for each crop year from 1930 through 2004 for the precipitation from September 1 to February 28 (winter period) and the precipitation from March 1 to June 30 (spring and early summer period) (Table 2). We chose to consider the precipitation that occurs in July and August as being unimportant for most spring seeded crops as they are near or at maturity by then and the mean precipitation for these 2 months is only 0.81 inch. We will refer to the 10-month period from September 1 to June 30 as the partial crop year. For both the winter and the spring and early summer period each list of crop years was then ranked from driest to wettest (Table 3). Using one standard deviation from the mean of all crop years as the basis for dividing each list into drier than normal, normal, and wetter than normal, we obtained for both the winter period and the spring period 12 years that were drier than normal, 51 years that were normal, and 12 years that were wetter than normal. For partial crop year precipitation we obtained 12 years that were drier than normal, 47 years that were normal, and 16 years that were wetter than normal. We then developed a matrix of winter period precipitation versus spring period precipitation (Table 4) and a matrix of winter period precipitation versus partial crop year precipitation (Table 5) in which

Table 2. Winter, spring and early summer, and partial crop year precipitation, Columbia Basin Agricultural Research Center-Pendleton, 1930-2004.

Crop year	Winter period	Spring period	Partial crop year total	Crop year	Winter period	Spring period	Partial crop year total
1930	11.82	4.94	16.76	1967	9.94	4.61	14.55
1931	7.58	6.46	14.04	1968	6.92	3.01	9.93
1932	9.19	5.85	15.04	1969	10.98	4.75	15.73
1933	7.65	6.14	13.79	1970	11.61	4.39	16
1934	9.22	3.29	12.51	1971	7.87	7.73	15.6
1935	8.5	4.58	13.08	1972	13.06	5.87	18.93
1936	8.95	3.98	12.93	1973	6.54	3.00	9.54
1937	5.2	9.44	14.64	1974	16.56	5.85	22.41
1938	9.95	5.71	15.66	1975	9.1	3.75	12.85
1939	8.09	3.99	12.08	1976	10.25	4.86	15.11
1940	10.36	4.85	15.21	1977	3.45	4.19	7.64
1941	10.37	8.43	18.8	1978	11.1	6.98	18.08
1942	11.86	7.53	19.39	1979	8.42	4.85	13.27
1943	11.23	8.08	19.31	1980	10.12	8.29	18.41
1944	6.65	4.98	11.63	1981	11.57	7.58	19.15
1945	8.05	7.39	15.44	1982	13.96	5.13	19.09
1946	11.03	6.74	17.77	1983	13.11	9.13	22.24
1947	8.56	7.37	15.93	1984	11.51	9.76	21.27
1948	12.35	8.66	21.01	1985	9.73	4.29	14.02
1949	9.65	3.69	13.34	1986	12.23	4.65	16.88
1950	8.94	7.45	16.39	1987	10.53	4.93	15.46
1951	13.94	4.24	18.18	1988	6.01	6.97	12.98
1952	9.72	5.74	15.46	1989	9.64	7.41	17.05
1953	9.2	7.41	16.61	1990	5.44	6.50	11.94
1954	8.27	4.28	12.55	1991	6.29	9.67	15.96
1955	6.41	5.03	11.44	1992	8.37	3.24	11.61
1956	14.11	6.38	20.49	1993	9.66	6.95	16.61
1957	7.75	7.69	15.44	1994	6.75	5.33	12.08
1958	11.19	8.92	20.11	1995	11.7	8.56	20.26
1959	11.71	4.99	16.7	1996	12.73	6.21	18.94
1960	7.46	6.28	13.74	1997	14.27	7.02	21.29
1961	10.06	6.28	16.34	1998	8.93	6.36	15.29
1962	6.71	7.27	13.98	1999	12.65	4.48	17.13
1963	10.74	4.25	14.99	2000	11.54	7.41	18.95
1964	7.57	3.42	10.99	2001	10.22	5.77	15.99
1965	12.4	3.77	16.17	2002	7.86	4.94	12.8
1966	6.50	3.65	10.15	2003	10.43	4.99	15.42
				2004	11.45	7.54	18.99

Table 3. Ranked winter and spring and early summer and partial crop year precipitation, Columbia Basin Agricultural Research Center-Pendleton, 1930-2004.

Winter period precipitation (in)				Spring period precipitation (in)				Partial crop year precipitation (in)			
Crop year	Total	Crop year	Total	Crop year	Total	Crop year	Total	Crop year	Total	Crop year	Total
1977	3.45	1985	9.73	1973	3.00	1932	5.85	1977	7.64	1971	15.60
1937	5.20	1967	9.94	1968	3.01	1974	5.85	1973	9.54	1938	15.66
1990	5.44	1938	9.95	1992	3.24	1972	5.87	1968	9.93	1969	15.73
1988	6.01	1961	10.06	1934	3.29	1933	6.14	1966	10.15	1947	15.93
1991	6.29	1980	10.12	1964	3.42	1996	6.21	1964	10.99	1991	15.96
1955	6.41	2001	10.22	1966	3.65	1960	6.28	1955	11.44	2001	15.99
1966	6.50	1976	10.25	1949	3.69	1961	6.28	1992	11.61	1970	16.00
1973	6.54	1940	10.36	1975	3.75	1998	6.36	1944	11.63	1965	16.17
1944	6.65	1941	10.37	1965	3.77	1956	6.38	1990	11.94	1961	16.34
1962	6.71	2003	10.43	1936	3.98	1931	6.46	1939	12.08	1950	16.39
1994	6.75	1987	10.53	1939	3.99	1990	6.50	1994	12.08	1953	16.61
1968	6.92	1963	10.74	1977	4.19	1946	6.74	1934	12.51	1993	16.61
1960	7.46	1969	10.98	1951	4.24	1993	6.95	1954	12.55	1959	16.70
1964	7.57	1946	11.03	1963	4.25	1988	6.97	2002	12.80	1930	16.76
1931	7.58	1978	11.10	1954	4.28	1978	6.98	1975	12.85	1986	16.88
1933	7.65	1958	11.19	1985	4.29	1997	7.02	1936	12.93	1989	17.05
1957	7.75	1943	11.23	1970	4.39	1962	7.27	1988	12.98	1999	17.13
2002	7.86	2004	11.45	1999	4.48	1947	7.37	1935	13.08	1946	17.77
1971	7.87	1984	11.51	1935	4.58	1945	7.39	1979	13.27	1978	18.08
1945	8.05	2000	11.54	1967	4.61	1953	7.41	1949	13.34	1951	18.18
1939	8.09	1981	11.57	1986	4.65	1989	7.41	1960	13.74	1980	18.41
1954	8.27	1970	11.61	1969	4.75	2000	7.41	1933	13.79	1941	18.80
1992	8.37	1995	11.70	1940	4.85	1950	7.45	1962	13.98	1972	18.93
1979	8.42	1959	11.71	1979	4.85	1942	7.53	1985	14.02	1996	18.94
1935	8.50	1930	11.82	1976	4.86	2004	7.54	1931	14.04	2000	18.95
1947	8.56	1942	11.86	1987	4.93	1981	7.58	1967	14.55	2004	18.99
1998	8.93	1986	12.23	1930	4.94	1957	7.69	1937	14.64	1982	19.09
1950	8.94	1948	12.35	2002	4.94	1971	7.73	1963	14.99	1981	19.15
1936	8.95	1965	12.40	1944	4.98	1943	8.08	1932	15.04	1943	19.31
1975	9.10	1999	12.65	1959	4.99	1980	8.29	1976	15.11	1942	19.39
1932	9.19	1996	12.73	2003	4.99	1941	8.43	1940	15.21	1958	20.11
1953	9.20	1972	13.06	1955	5.03	1995	8.56	1998	15.29	1995	20.26
1934	9.22	1983	13.11	1982	5.13	1948	8.66	2003	15.42	1956	20.49
1989	9.64	1951	13.94	1994	5.33	1958	8.92	1945	15.44	1948	21.01
1949	9.65	1982	13.96	1938	5.71	1983	9.13	1957	15.44	1984	21.27
1993	9.66	1956	14.11	1952	5.74	1937	9.44	1952	15.46	1997	21.29
1952	9.72	1997	14.27	2001	5.77	1991	9.67	1987	15.46	1983	22.24
		1974	16.56			1984	9.76			1974	22.41

each period for each year was classified as drier than normal, normal, or wetter than normal and assigned to one of the cells in the matrices.

Results and Discussion

A dry winter, such as we experienced in 2004-2005, does not seem to be a good indicator that the following spring will also be dry. Of the 12 drier than normal winters in our 75-year history, only 4 have indeed been followed by less than normal spring precipitation, and 6 have been followed by normal spring precipitation (Table 4). Only two wetter than normal springs have occurred after a dry winter. The precipitation pattern observed in the 1937-1938 crop year was unique. Precipitation during the winter was only 5.20 inches, the second driest on record, while spring and early summer precipitation was 9.44 inches, the third wettest on record. The total precipitation for the period from September to June was 14.64 inches, only about 1 inch below normal.

A dry winter, however, is a fairly reliable indicator that the final partial crop year precipitation total will be less than normal. Of the 12 drier than normal springs in our history, 8 have resulted in a drier than normal partial crop year, 4 have resulted in a normal partial crop year, and none has led to a wetter than normal partial crop year (Table 5).

It is important to recognize that the data presented in this paper are not a substitute for the long-range weather forecasting tools offered by the National Weather Service and other organizations. The information presented in this paper is simply a statistical analysis of the 75-year data record at the Pendleton Station of CBARC.

Individuals desiring additional information about weather records at the Pendleton Station are encouraged to visit our website at cbarc.aes.oregonstate.edu and go the weather link.

Table 4. Number of crop years classified by winter and spring period precipitation range.

	Number of years		
	Dry spring	Normal spring	Wet spring
Dry winter	4	6	2
Normal winter	7	36	8
Wet winter	1	9	2

Table 5. Number of crop years classified by winter and total crop year precipitation range.

	Number of years		
	Dry total crop Year	Normal total crop Year	Wet total crop Year
Dry winter	8	4	0
Normal winter	4	38	9
Wet winter	0	5	7

Conclusions

Cropping decisions in the spring following a dry winter must take into account several factors. The fact that a dry winter has occurred should not in and of itself lead a grower to conclude that spring precipitation will be less than normal. It is quite likely, however, that partial crop year precipitation at the end of June will be less than normal. Certainly one should consult with the National Weather Service or other weather prediction services to assess the likelihood of specific temperature and moisture patterns during the cropping period. Factors such as stored soil moisture, various government programs, and the benefits that spring cropping can bring to your cropping system should also be considered when planning any spring cropping operation.

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FERTILIZER PLACEMENT EFFECTS ON DIRECT-SEED WHEAT STANDS AND GRAIN YIELD

Steve Petrie, Karl Rhinhart, and Nathan Blake

Abstract

Fertilizer must be applied at planting in direct-seed systems and this can affect fertilizer source and placement options. Band applications of fertilizer with or near the seed may enhance the availability and uptake of nutrients such as phosphorus and micronutrients. However, fertilizers applied with seed at planting may adversely affect seed germination and seedling emergence due to either salt effects or ammonia evolution. The objective of this research was to evaluate the effects of applying phosphorus and sulfur fertilizers with the seed or in a deep band on the seedling emergence, head count, and grain yield of direct-seeded spring and winter wheat. We found that there was a tendency for band applications of fertilizer to reduce seedling emergence regardless of the fertilizer placement. Placing ammonium thiosulfate (Thio-Sul) with the seed at planting reduced stands, head count, and grain yield compared to placing it in the deep band.

Key words

Fertilizer, grain yield, stand count, wheat.

Introduction

Nutrient management plans are part of an integrated approach to overall farm management. A complete nutrient management plan should address at least five individual components including (1) which nutrients are needed, (2) the amount of each nutrient to apply, (3) the optimum source of the nutrients, (4) the optimum placement of the nutrients, and (5) the optimum time to apply the nutrients. Information on the first two questions, which nutrients are needed and how much to apply, has been developed in field trials using soil testing and soil test calibration. Literally hundreds, if not thousands, of field trials have been conducted by land grant universities in the Pacific Northwest as well as private industry to accurately answer these questions. Based on these trials, we have a relatively good understanding of the relationship between soil test values, crop yield goals and expectations, and the amount of various nutrients that need to be applied.

There are two main fertilizer placement options available to growers using direct-seeding techniques; the fertilizer can be broadcast or the fertilizer can be banded in the soil. Fertilizer that is banded in the soil can be placed with the seed at planting or at distance away from the seed. Foliar fertilizer applications are used in some crops but this technique is little used in dryland cropping systems.

Each application option has advantages and disadvantages that must be considered in the context of the overall nutrient management plan. Broadcast application of nitrogen fertilizer is faster and less expensive than other application methods but has been shown to increase infestation of weeds such as downy brome (Ball et al. 1996). Broadcast application of phosphorus fertilizer may result in greater fixation or "tie-up" in the soil which reduces the effectiveness of the fertilizer. In addition, non-mobile nutrients such as phosphorus (P) are positionally unavailable when they are broadcast and left on the soil surface.

Banding fertilizer with the seed at planting may reduce fixation and increase efficiency but can also adversely affect germination and emergence. Band application of fertilizer separate from the seed also reduces fixation but increases surface disturbance and may result in greater evaporative loss of soil moisture.

Questions about the optimum source of nutrients and the optimum placement of those nutrients arise because there are a number of nutrient sources available in the marketplace. For example, growers can choose from gaseous (anhydrous ammonia [83-0-0]), liquid (aqua ammonia [20-0-0], urea-ammonium nitrate solution [32-0-0]), or dry fertilizers (ammonium nitrate [34-0-0] or urea [46-0-0]) Phosphorus fertilizers come in both liquid (ammonium polyphosphate [10-34-0 or 11-37-0]) and dry (ammonium phosphate sulfate [16-20-0], monoammonium phosphate [11-52-0] and diammonium phosphate [18-46-0]) formulations. Common sulfur fertilizers include ammonium sulfate (21-0-0-24), ammonium thiosulfate (Thio-sul® [12-0-0-26], and ammonium polysulfide (Nitro-sul® [20-0-0-40]. These fertilizers have specific characteristics that can affect the crop response.

Essentially any fertilizer can be safely broadcast at agronomically sound application rates with little fear of any crop injury.

Band application of fertilizers, especially when the fertilizer is placed with or close to the seed, can result in crop injury. The crop injury can be due to either salt effects, ammonia evolution, or pH effects. Salt effects occur when the fertilizer increases the osmotic potential of the soil solution adjacent to the seed, making it more difficult for the seed or seedling to take up water from the soil. Symptoms of salt injury include delayed and reduced germination and emergence and reduced crop stands. Certain fertilizers, such as urea, diammonium phosphate, and ammonium thiosulfate, can release ammonia that can injure seeds and seedlings. These fertilizers should not be placed directly with the seed. Finally, the soil acidity or basicity can be markedly altered in the fertilizer band and this can adversely affect root growth in the band.

The salt index is a measure of fertilizer capacity to increase the osmotic potential of the soil solution. The greater the salt index, the more likely that the fertilizer will adversely affect germination and emergence. Table 1 shows the salt index of many common fertilizers. Notice the wide range of salt index values among the nitrogen (N) sources. The salt index of most P fertilizers is much less than nitrogen (N) or potassium (K) fertilizers because the P fertilizers are much less soluble than the N or K fertilizers.

Table 1. Salt index of some common nitrogen, phosphorus, potassium, and sulfur fertilizers.

Material	Salt index per equal weight of material	Partial salt index per unit of plant nutrient
Anhydrous ammonia	45	0.57
Ammonium nitrate	105	2.99
Ammonium phosphate (11-48-0)	27	2.44
Ammonium polysulfide (20-0-0-40)	44	2.18
Ammonium polyphosphate (10-34-0)	20	0.46
Ammonium sulfate	69	3.25
Ammonium thiosulfate (12-0-0-26)	84	7.04
Calcium nitrate	52	4.41
Calcium sulfate (gypsum)	8	0.25
Diammonium phosphate	30	1.61 (N)
		0.64 (P_2O_5)
Monoammonium phosphate	34	2.46 (N)
		0.49 (P_2O_5)
Monocalcium phosphate (0-45-0)	15	0.27
Potassium chloride	116	1.94
Potassium sulfate	46	0.85
Urea	75	1.62
Urea-ammonium nitrate solution (32-0-0)	95	2.30

From Ludwick 1995.

Table 2. Soil test values for the fertilizer placement studies.

Crop & Year	Depth	NO_3-N	NH_4-N	P	SO_4	Cl	Zn
	ft	ppm					
SW 2003	0-1	5.3	7	18	10	32	0.4
	1-2	4			8		
	2-3	1					
	3-4	1					
SW 2004	0-1	1	14	20	4	25	0.7
	1-2	1		14	5	15	0.3
	2-3	3.5					
	3-4	6					
WW 2004	0-1	1	14	20	4	25	0.7
	1-2	1		14	5	15	0.3
	2-3	3.5					
	3-4	6					

The likelihood of either salt, ammonia, or pH injury depends on a host of factors such as the rate of fertilizer applied, the row spacing, crop species being grown, soil moisture content, the soil temperature, the clay content, the organic matter content, and weather conditions after seeding. Because of the individual effects and the interaction of these factors, it is extremely difficult to predict with accuracy the effect of any specific fertilizer application rate and placement.

Fertilizer must be applied at seeding in direct-seed systems, so the increasing interest in direct-seeding systems has led to more questions about fertilizer placement options. The objective of this field research was to measure the effect of placing various liquid fertilizer sources with the seed or in a deep band on crop emergence, crop stand, and grain yield of winter and spring wheat.

Materials and Methods

Spring wheat field trials were established in 2003 and 2004 and a winter wheat trial was established in the fall of 2003. All trials were planted following conventionally tilled winter wheat. Soil test values are shown in Table 2. All trials were seeded with a John Deere 1560 double-disc drill that was modified to permit liquid fertilizers to be placed either with the seed or in a band that was located about 2 inches deeper than the seed row centered between the seed rows. Seed rows were 7.5 inches apart. The fertilizer treatments are shown in Table 3. All treatments except the unfertilized check received 80 lbs N/acre, 0 or 20 lbs P_2O_5/acre, and 0 or 20 lbs S/acre. The primary N source was urea-ammonium nitrate solution, often referred to as UAN solution or solution 32. Phosphorus was applied as ammonium polyphosphate solution (10-34-0) and S was applied as ammonium thiosulfate, often referred to as Thio-sul. Treatments were arranged in randomized block design with four replications. Individual plots were 10 ft wide by 50 ft long. We seeded 'Alpowa' and 'Zak' spring wheat on April 17, 2003 and on March 31, 2004, respectively and 'Stephens' winter wheat on October 28, 2003. Seeds were placed into moist soil. Spring wheat was seeded at 29 and winter wheat was seeded at 25 seeds/ft^2. Stand counts were taken from 3 ft of row at 2 locations within each plot on each sample date. The areas were marked and all stand counts as well as head counts were taken from the same location. Spring wheat yields were estimated by harvesting with a plot combine and the winter wheat yields were estimated by hand harvesting 1-m^2 quadrants.

Table 3. Effect of fertilizer source and placement on seedling emergence, head count, and grain yield of spring wheat, CBARC, 2003.

Treatment			Stand count					Head count	Grain yield
#	Fertilizer	Placement	April 30		May 2		May 5		
			#/ft	%[a]	#/ft	%[a]	#/ft	#/ft	Bu/acre
1	Check		12	81	14	97	15	17	22.6ab
2	Sol'n 32	Deep band	11	72	14	91	15	18	23.7a
3	Sol'n 32 10-34-0	Deep band Deep band	10	72	13	94	14	17	23.4ab
4	Sol'n 32 10-34-0	Deep band With seed	10	71	13	92	14	18	21.7ab
5	Sol'n 32 Thio-sul	Deep band Deep band	13	77	16	93	17	17	23.4ab
6	Sol'n 32 Thio-Sul	Deep band With seed	8	63	11	84	13	16	20.5b
7	Sol'n 32 Thio-Sul 10-34-0	Deep band Deep band With seed	11	75	13	91	14	19	23.6a

[a]Expressed as a percent of final stand for each treatment
Numbers in a column followed by the same letter are not significantly different at the $P<0.05$ level.

Results and Discussion

Spring wheat – 2003

Spring wheat began to emerge about 10 days after seeding and treatment effects were visually evident. Stand counts taken on April 30 revealed marked differences in emergence (Table 3). Seedling counts were taken again on May 2, May 5, and May 8. There were 11.8 seedlings/ft of row in the unfertilized treatment on April 30 and the seedling counts increased on May 2 and May 5 as seedlings continued to emerge.

Seedling counts increased dramatically between April 30 and May 2 with smaller increases between May 2 and May 5.

Seedling counts in all treatments on May 8 were essentially identical to the counts on May 5 indicating that all seedlings had emerged.

The rate of emergence can be estimated by comparing the stand count at the initial and second dates with the final stand count. Seedling emergence was delayed whenever fertilizer was banded, regardless of whether the fertilizer was placed in the deep band or with the seed. In the unfertilized check, 81 percent of the seedlings had emerged by April 30 compared to 77 percent or fewer in the treatments that received banded fertilizer. Treatments 2 and 3 received no fertilizer with the seed yet the stand count was only 72 percent of the final count. Band application of 10-34-0 with the seed resulted in the same rate of emergence and final stand count as placing the 10-34-0 in the deep band.

Band application of ammonium thiosulfate with the seed (treatment 6) markedly reduced the rate of emergence and resulted in the fewest seedlings of any treatment. In contrast, placing the ammonium thiosulfate in the deep band did not reduce the rate of seedling emergence or the final stand count.

Head counts at harvest were positively correlated with final stand counts. This trial was conducted in a recrop situation and grain yields were less than expected due to less spring rainfall than normal. Precipitation from April 1 to July 31 was 2.79 inches compared to the long-term average of 4.54 inches and no precipitation was recorded in June or July. The reduced yield potential may have masked the adverse effects of the treatments that delayed and/or reduced seedling emergence. Soil test values for P and S were adequate and we did not expect a yield response to these nutrients. It is worthwhile to note that application of ammonium thiosulfate with the seed resulted in the lowest grain yield.

Spring wheat – 2004

The same treatments, including rates and methods of application, were used in the 2004 spring wheat trial. Sequential stand count data were not collected but one stand count was taken when the crop was fully emerged and established. The crop stand was somewhat variable within each plot due to residue variation so efforts were made to assure that the stand counts were taken from areas where the residue was uniform.
Final stand counts were only about one-half of the stand counts recorded in 2003.

Band application of fertilizer, except for one treatment, reduced stand counts compared to the unfertilized check (Table 4). The fewest plants were recorded in the plots that received Thio-sul with the seed, although the difference was not statistically significant compared to most other treatments that received banded fertilizer. In contrast to the stand counts, the check plot had the fewest heads/ft^2. All banded fertilizer treatments had about the same number of heads/ft^2 except for treatment 7 which had significantly more heads heads/ft^2 than other treatments. Treatment 7 also had the most heads/ft^2 in the 2003 spring wheat trial.

There was abundant spring and early summer rainfall in 2004; from April 1 to July 30 we received 6.81 inches of precipitation compared to only 2.79 inches in 2003. Yields were much greater than in 2003 permitting greater discernment of treatment differences. All fertilizer treatments produced more grain than the unfertilized check. There was a tendency for those treatments that received P to produce more grain than treatments that did not receive P. For example, treatments 3, 4, 5 and 7 produced the largest grain yields and treatments 3, 4, and 7 received P, either with the seed or in the deep band. Treatment 3 produced 6.4 more bu/acre more than treatment 2, a difference that was significant at the P<0.10 level. The P soil test value for this site was greater than the established critical value (Lutcher et al. in press) so we did not expect a P response at this site.

Table 4. Effect of fertilizer source and placement on stand count, head count, and grain yield of spring wheat, CBARC, 2004.

Treatment			Stand count	Head count	Grain yield
#	Fertilizer	Placement	#/ft	#/ft	Bu/acre
1	Check		18a	18.c	40.6c
2	Sol'n 32	Deep band	15b	32ab	48.5b
3	Sol'n 32 10-34-0	Deep band Deep band	17b	29b	54.9ab
4	Sol'n 32 10-34-0	Deep band With seed	16b	31ab	58.5a
5	Sol'n 32 Thio-sul	Deep band Deep band	17a	33ab	54.6ab
6	Sol'n 32 Thio-Sul	Deep band With seed	15b	31ab	49.6b
7	Sol'n 32 Thio-Sul 10-34-0	Deep band Deep band With seed	15b	33a	54.2ab

Numbers in a column followed by the same letter are not significantly different at the $P<0.05$ level.

Banding Thio-sul with the seed resulted in 5.0 bu/acre less grain than placing Thio-sul in the deep band, a difference that was significant at the P<0.10 level.

Winter wheat - 2003-04

The crop stand was somewhat variable within each plot due to residue variation so efforts were made to assure that the stand counts were taken from areas where the residue was uniform. However, the adverse effect of the crop residue from the previous crop on overall seedling emergence was more pronounced in the winter wheat crop than on the spring wheat crops. We attribute this difference to the fact that some residue decomposition occurred during the winter and the reduced residue had less effect on seedling emergence.

The treatment effects on the final stand counts differed somewhat from the effects we noted in the spring wheat. Banding Thio-sul with the seed reduced stand count, an effect that we observed in spring wheat in 2003 and 2004 (Table 5). Deep band placement of solution 32 and 10-34-0 also reduced stand counts; this treatment was similar to other fertilizer treatments in spring wheat. Precipitation from September 1 to November 30 was only 67 percent of normal in 2004 and the soil disturbance and increased soil drying may have contributed to the reduced stands.

The lowest head density was observed in the unfertilized check and the greatest head density was observed in treatments 5 and 7, the two treatments that received 10-34-0 banded with the seed at planting. Head counts in the other treatments were intermediate between the unfertilized check and treatments 5 and 7.

All fertilizer treatments increased grain yield compared to the unfertilized check. Applying Thio-sul with the seed reduced yield by 13 bu/acre compared to placing the Thio-sul in the deep band. The greatest yields resulted from placing solution 32 and Thio-sul in the deep band and banding 10-34-0 with the seed.

Summary and Conclusions

1. There was a tendency for banded fertilizer applications to reduce seedling counts, regardless of whether the band was placed with the seed or between the seed rows.
2. There was a tendency for the seedlings to emerge more slowly when fertilizer was banded.
3. Ammonium thiosulfate reduced stand counts and yield when placed with the seed at planting. The adverse effects of ammonium thiosulfate were less evident when it was placed in the deep band.
4. Banding 10-34-0 with the seed resulted in reduced stand counts in one trial but no adverse effects were noted in two trials.

Table 5. Effect of fertilizer source and placement on stand count, head count, and grain yield of winter wheat, CBARC, 2003-04.

Treatment			Stand count	Head count	Grain yield
#	Fertilizer	Placement	#/ft	#/ft	Bu/acre
1	Check		15	13d	52.1c
2	Sol'n 32	Deep band	16	19abc	79.6ab
3	Sol'n 32 10-34-0	Deep band Deep band	16	21ab	77.4ab
4	Sol'n 32 10-34-0	Deep band With seed	12	17bcd	72.4b
5	Sol'n 32 Thio-sul	Deep band Deep band	17	22a	85.6ab
6	Sol'n 32 Thio-Sul	Deep band With seed	13	16cd	72.8b
7	Sol'n 32 Thio-Sul 10-34-0	Deep band Deep band With seed	13	23a	91.1a

Numbers in a column followed by the same letter are not significantly different at the $P<0.05$ level.

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SMALL GRAIN ACREAGE AND MANAGEMENT TRENDS FOR EASTERN OREGON AND WASHINGTON

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Abstract

Small grain acreage and management trends over the past 20 years were evaluated for counties and regions in eastern Oregon and Washington. Data were obtained from surveys conducted by the Conservation Technology Information Center (CTIC) and National Agricultural Statistics Service (NASS). Small grain acreages of dryland and irrigated winter wheat, spring wheat, and barley are reported as a percent of the total acreage in each region of each state. Also reported are trends for tillage practices, cropping frequency, and timing in terms of percent of total acreage. Winter wheat acreage has remained relatively constant over the last 20 years for most regions and comprised over 60 percent of the nearly 3.5 million acres planted to small grains in eastern Oregon and Washington. Acreage planted to barley has generally declined by 5 percent, with production shifting to spring wheat. Use of intensive tillage has decreased by over 50 percent in most regions, with production shifting to reduced tillage and no-till. No-till acreage for all wheat in Oregon increased from 1 percent in 1996 to 17 percent in 2004 and from 3 percent to 13 percent in Washington. For spring wheat, no-till acreage increased from 2 to 21 percent in Oregon and from 2 to 18 percent in Washington.

Key Words

Management trends, cropping practices, tillage practices, Oregon, Washington, agriculture statistics, small grain, wheat, barley, acreage

Introduction

Agricultural tillage and cropping practices in the inland Pacific Northwest have changed over the past 20 years. It is difficult, however, to find data that summarize the changes. The purpose of this study was to acquire, organize, and present acreage and management trends for selected small grain crops in dryland and irrigated agriculture for the primary regions where these crops are produced in Oregon and Washington.

Methods

Crops of interest for this study were winter wheat, spring wheat, barley, and oats from eastern Oregon and Washington. Acreage and crop management data for these crops from 1985 to 2004 were acquired from USDA-Natural Resource and Conservation Service (NRCS) personnel, using data supplied by NRCS and organized into a national database by the Conservation Technology Information Center (CTIC), West Lafayette, Indiana. County-level data for Oregon and Washington were acquired through cooperation of authors Tom Gohlke (NRCS, Oregon) and Joel Poore (NRCS, Washington).

Fall- and spring-planted small grains are not differentiated by crop species in the CTIC database. The crop species were determined by accessing data by the National Agricultural Statistics Service (NASS) for Oregon (NASS 2005a) and Washington (NASS 2005b). All years available in the databases were used in this summary, but databases differed in numbers of years included for crop acreage and management data, resulting in data presented in this report covering intervals from 1985 to 2003, from 1990 to 2004, and from 1985 to 1995.

Data of interest included dryland and irrigated acreage planted to winter wheat, spring wheat and barley, crop rotation, and tillage practices. Tillage practices were classified by the NRCS into the following five categories depending on tillage intensity and residue cover.

1. *Intensive tillage* is also called conventional tillage, and is designated as full-width tillage that disturbs the entire soil surface, resulting in less than 15 percent residue cover after planting, or less than 500 lb/acre of small grain residue equivalent throughout the critical wind erosion period. Equipment used to meet this standard often includes tillage tools such as moldboard plows, disks, or chisels.

2. *Reduced tillage* is designated as full-width tillage that disturbs the entire soil surface, resulting in 15 to 30 percent residue cover after planting, or 500 to 1,000 lb/acre of small grain residue equivalent throughout the critical wind erosion period. Equipment used to meet this standard often includes tillage tools such as disks, chisels, or field cultivators.

3. *Mulch tillage* is designated as full-width tillage that disturbs the entire soil surface, resulting in 30 percent or more residue cover after planting, or more than 1,000 lb/acre of small grain residue equivalent throughout the critical wind erosion period. Equipment used to meet this standard often includes tillage tools such as disks, chisels, field cultivators, sweeps, or blades.

4. *No tillage* also includes strip tillage, in which the soil is left undisturbed from harvest to planting, except for strips up to one-third the row width. Other names include direct drilling, slot planting, zero-till, row tillage, and slot tillage. These practices result in 30 percent or more residue cover after planting, or more than 1,000 lb/acre of small grain residue equivalent throughout the critical wind erosion period. Equipment used to meet this standard includes no-till drills equipped with disk openers, hoe openers, or coulters.

5. *Conservation tillage* is the sum of acreage reported for mulch tillage and no tillage.

Unfortunately, the categorization scheme used by the NRCS may not accurately reflect the conservation practices used in the Pacific Northwest. The system limits no-till soil disturbance to no more than one-third the row width, which is difficult to achieve when common hoe-type drills are used to seed cereal crops planted in narrow rows. Because of this, many acres of wheat and barley seeded using no-till practices are categorized as mulch till rather than no-till.

The NASS groups multiple counties within each state into regions and summarizes data for each county and region. Three regions in eastern Oregon and four regions in eastern Washington were of interest in this study (Fig. 1). The NRCS collects data for each county. Consequently, data in this article are presented by region and county. A preferred classification method would be by agro-climatic zones as defined by Douglas et al. (1992) where regions are grouped by similar soil and climatic conditions. However, data were not available for groupings by agro-climatic zones. The NASS regions roughly define agro-climatic zones but in most regions and several large counties there are two or more different zones where typical cropping practices also differ. This information should be taken into account when analyzing the data presented. Data used for this study were for planted acres rather than harvested acres. Using data for

2000, the regions reported in this paper represented 96 and 98 percent of all wheat, and 98 and 99 percent of all barley planted in Oregon and Washington, respectively (Table 1). Total acreage and percentages of wheat and barley acres planted in the principal counties and regions are shown in Table 1.

The following discussion is organized by region in each state to allow readers to focus on the regions of interest. The discussion is also organized for irrigated and dryland crops reported and by the NASS and CTIC databanks utilized. Some discrepancies were noted between these databanks, likely due to the different process by which data were collected by each agency. The NASS databank was based on surveys of agricultural practices in each county. The CTIC databank was based on self-reporting by growers to their local USDA-NRCS office. Small discrepancies are expected when different methods are used to collect data of this type.

Results and Discussion

Oregon

Northcentral region: There were 498,000 acres of wheat and 60,600 acres of barley planted in the region during 2000, representing 53 percent of wheat and 40 percent of barley acreage in Oregon (Table 1).

Dryland acreage (NASS data): Winter wheat dominated the small grains acreage, increasing from 70 percent in 1985 to 85 percent in 1995 (Fig. 2). For winter wheat, the rotation with summer fallow was by far the dominant production system, consisting of about 90 percent of acreage, and slightly increasing in proportion over the period 1985 to 1995 (Fig. 3). The 10 percent of winter wheat acreage planted in an annual crop sequence slightly decreased over that decade (Fig. 3). A 10 percent increase in the acreage of plantings to spring wheat occurred during that time interval (data not shown). Also, the proportion of barley following fallow decreased, from 20 percent to about 5 percent, and barley in annual cropping decreased, from 5 to 2 percent. Patterns and proportions were essentially identical for Gilliam, Morrow, Sherman, and Wasco counties.

Residue management (CTIC data): During 1990 to 2004, the proportion of acreage planted to spring grains increased by 10 percent and the proportion planted to winter cereals declined by 10 percent (Fig. 4). The shift was more pronounced in Gilliam and Morrow counties than in Sherman and Wasco counties. For spring-planted small grains, the proportion of intensive tillage declined from 40 to 10 percent over the 14-year time interval, with a 10 percent increase in reduced tillage, an increase in no-till from 0 to 30 percent, and a 10 percent reduction in mulch tillage (Fig. 5). There was a 30 percent increase in no-till between 1996 and 2004, and a 10 percent reduction in mulch tillage. For spring grains, the increase in no-till after 1996 appeared to represent a shift directly from intensive tillage. Before 1996, intensive tillage declined but no-till was still virtually absent. There was no increase in percentages of spring grains planted annually over the 1985 to 1995 time interval (Fig. 6). For fall-planted small grains, proportions of intensive tillage and mulch tillage declined slightly, with a concomitant increase in reduced tillage and no-till (Fig. 5). An increase from 0 to 20 percent in no-till occurred between 1996 and 2004, with a corresponding reduction in mulch tillage, indicating that production shifted from mulch tillage to no-till (Fig. 5). Region-wide, during 2004, no-till represented 30 percent of spring-planted small grain acreage and 20 percent of fall-planted small grain acreage (Fig. 5). About 90 percent of both spring- and fall-planted small grains are now planted under mulch-till or no-till systems in Wasco and Gilliam counties.

Irrigated acreage (NASS data): Irrigated small grains acreage decreased from 9 percent in 1985 to 4 percent in 2003 (Fig. 7). The proportion of spring wheat and barley were consistently less than 2 percent of the total acreage for irrigated plus dryland acreage (Fig. 8). The proportion of irrigated winter wheat ranged from 6 to 7 percent of total small grains production from 1986 to 1996 but declined to 3 percent after the year 2000 (Fig. 8).

Northeast region: There were 346,200 acres of wheat and 33,700 acres of barley planted in the region during 2000, representing 37 percent of wheat and 23 percent of barley acreage in Oregon (Table 1).

Dryland acreage (NASS data): Winter wheat dominated the small grains acreage, with 55 percent in 1985 and 75 percent in 1995 (Fig. 2). For winter wheat, the rotation with summer fallow was by far the dominant production system, consisting of about 60 percent of acreage over the decade (Fig. 3). The proportion of winter wheat in rotation with summer fallow decreased steadily, from 80 to 60 percent. Winter wheat planted in an annual crop sequence increased significantly over that time interval, increasing from 20 percent in 1985 to 35 percent in 1995 (Fig. 3). The increase in winter wheat matched a decrease in barley acreage. There was no increase in the acreage of plantings to spring wheat during that time interval, either in annual cropping or following fallow (data not shown). Spring wheat was planted on about 5 percent of the acreage during the decade. Acreage in barley decreased, from 20 percent to less than 5 percent following fallow, and from 10 percent to 5 percent in annual cropping (data not shown). Patterns for cropping practices in the northeast region were dominated by production in Umatilla County, which had 83 percent of the planted acres (Table 1).

In Union County, winter wheat increased from 20 to 40 percent following summer fallow, and remained relatively static at 35 percent for winter wheat in annual cropping (data not shown). Less than 10 percent of small grain acreage was planted to spring wheat or barley following fallow. More barley and spring wheat in Union County was planted in annual crop sequences than after summer fallow, owing mostly to a high proportion of irrigated fields and crop rotation practices in Union County. Barley in annual cropping sequences decreased in acreage from about 15 to 5 percent during the decade.

Barley was planted on more acreage in Wallowa County than in other counties in the northeast region (data not shown). In Wallowa County, barley acreage in annual cropping sequences decreased from 50 to 30 percent of total from 1985 to 1995. In contrast, winter wheat in rotation with summer fallow increased from 15 to 30 percent over the same decade. The proportion of spring wheat in annual cropping sequences increased over the decade, and reached a peak of 15 percent of the acreage at the end of the reporting period.

Residue management (CTIC data): During 1990 to 2004, the proportion of acreage planted to spring grains increased by 10 percent of total and the proportion of winter cereals declined by 10 percent (Fig. 4). The shift was more pronounced in Umatilla and Wallowa counties than in Union County. For spring-planted small grains, the proportion of intensive tillage declined from 65 to 20 percent over the 14-year time interval, with significant increases in both reduced tillage and no-till systems (Fig. 5). Within the conservation tillage statistics for spring-planted small grains, there were increases of 10 percent in total acreage in both no-till and mulch tillage between 1994 and 2004. For spring grains, the increase in no-till appeared to mostly represent a shift directly from intensive tillage. Percentages of spring grains planted in annual crop sequences declined over the 1985 to 1995 time interval (Fig. 6). For fall-planted small grains, proportions of intensive tillage increased 10 percent while conservation tillage remained nearly steady, and reduced tillage declined from 40 to 20 percent (Fig. 5). Within the conservation tillage statistics for fall-planted small grains, there was an increase in no-till from 0 to 10 percent of total acreage between 1996 and 2004, and a corresponding reduction in mulch tillage. Region-wide, during 2004, no-till represented 15 percent of spring-planted small grain acreage and 10 percent of fall-planted small grain acreage (Fig. 5). These trends were reasonably similar for each of the counties in the northeast region.

Irrigated acreage (NASS data): Irrigated small grains in Oregon decreased from 20 percent of all small grains acreage in 1985 to 17 percent in 2003 (Fig. 7). The proportion of spring wheat and barley were consistently less than about 5 percent of the total acreage for irrigated plus non-irrigated acreage (Fig. 8). The trend was for a steady increase in spring wheat, reaching a peak of 5 percent in the early 2000's, and for a steady decrease in barley, reaching a minimum of less than 2 percent in the early 2000's (Fig. 8). The proportion of irrigated winter wheat reached a peak of about 15 percent of total small grains production in 1990, to a minimum of about 10 percent in the early 2000's (Fig. 8).

Southeast region: There were 57,500 acres of wheat and 52,400 acres of barley planted in the region during 2000, representing 6 percent of wheat and 35 percent of barley acreage in Oregon (Table 1).

Dryland acreage (NASS data): Less than 20 percent of the southeast Oregon acreage was planted to non-irrigated small grains (Fig. 2). Winter wheat planted into annual crop sequences was highly variable, with up to 30 percent of the dryland acreage at the beginning and end of the 1985 to 1995 period, but with a low of less than 5 percent in about 1990 (Fig. 6). Plantings of dryland winter wheat, spring wheat, and barley were almost always higher in annual crop sequences than following summer fallow. Winter wheat and barley in annual cropping sequences shared the dominance of dryland plantings (data not shown). From 1985 to 1995 there was a decreasing amount of dryland winter wheat and a comparable increase of acreage planted to barley. Percentages of spring grains planted in annual crop sequences were highly variable during 1985 to 1995 (Fig. 6), but were generally dominated by spring barley.

Residue management (CTIC data): During 1990 to 2000, the proportion of acreage planted to spring cereals increased by 20 percent and the proportion of winter grains decreased by a comparable amount, but then returned to 1990 levels in 2004 (Fig. 4). For spring-planted small grains, the proportion of intensive tillage and reduced tillage were highly variable over the 14-year time interval, and almost no acreage was planted under mulch tillage or no-till (Fig. 5). For fall-planted small grains, proportions of intensive tillage increased from 40 to 90 percent at the expense of both mulch tillage and reduced tillage (Fig. 5). No-till is essentially absent for spring- and fall-planted small grains in the southeast region

(Fig. 5), possibly because more irrigated small grains acreage was managed in mixtures with livestock and forage enterprises in this region, compared to the north central and northeast regions.

Irrigated acreage (NASS data): Irrigated small grains were always more than 80 percent of all small grains planted in the southeast region (Fig. 7). Irrigated crops increased from 80 to 95 percent from 1985 to 1995, remained at 95 percent until 2001, suddenly decreased to 80 percent in 2003, and then returned to 88 percent in 2004. Barley was planted in higher proportions than winter wheat from 1985 to 2000 (Fig. 8). After 2000, the proportion of barley decreased markedly and winter wheat plantings increased in about the same proportion. About 15 to 20 percent of the acreage was planted to spring wheat from 1985 to 2003 (Fig. 8).

Overall tillage trends for Oregon: Over the last 14 years, and particularly since 1996, no-till planting systems have increased dramatically in Oregon (Fig. 9). For the total wheat industry, no-till acreage went from 1 percent in 1996 to 17 percent (151,400 acres) in 2004, with gradual decreases in proportions of intensive tillage, reduced tillage, and mulch tillage (Fig. 9). No-till plantings increased for both winter wheat and spring wheat (Fig. 10). No-till acreage for winter wheat went from less than 1 percent in 1996 to 16 percent (102,000 acres) in 2004. No-till acreage for spring wheat went from 2 percent in 1994 to 21 percent (43,400 acres) in 2004.

Washington

Central region: There were 212,000 acres of wheat and 15,100 acres of barley planted in the region during 2000, representing 8 percent of wheat and 3 percent of barley acreage in Washington (Table 1).

Dryland acreage (NASS data): Winter wheat dominated the small grains acreage, increasing from 55 percent in 1985 to 65 percent in 1995, and then declining to 50 percent in 2004 (Fig. 2). For winter wheat, the rotation with summer fallow was by far the dominant production system, but it slowly declined from 95 percent of all wheat planted in 1985 to 90 percent in 1995 (Fig. 3). There was only a very slight increase in winter wheat planted in annual crop sequences, representing 5 percent of wheat acreage in 1985 and about 8 percent in 1995. Spring wheat was planted on up to 25 percent of the dryland acreage during 2 years, but was generally less than 10 percent of the acreage of small grain plantings (data not shown). Most spring wheat was planted following summer fallow, with very little planted in an annual crop sequence. The proportion of barley decreased from 15 percent in 1985 to less than 2 percent during 1995, and then remained at that level through 2004 (Fig. 2).

Residue management (CTIC data): During 1990 to 2004, the proportions of acreage planted to spring- and fall-planted cereals remained nearly constant in central Washington, with about 30 percent to spring cereals and 70 percent planted to winter cereals (Fig. 4). A far different trend occurred in Klickitat County, where fall-planted cereals declined steadily from 75 percent of the small grains crop in 1990 to 35 percent by 2000, and then remained constant through 2004 (data not shown). Also in Klickitat County, spring-planted cereals increased from 25 percent in 1990 to 65 percent in 2000, again stabilizing at that level through 2004. For spring-planted small grains, the proportion of intensive tillage declined from 80 to 40 percent of the total acreage over the 14-year time interval, with an increase from 10 to 40 percent in reduced tillage and an increase from 0 to 15 percent in no-till (Fig. 11). Within the conservation tillage statistics for spring-planted small grains, there was no acreage planted until 1998, when up to 35 percent of the small grains were planted without tillage for several years; by 2004 the proportion of no-till spring grains declined to 15 percent of the acreage. Percentages of spring grains planted in annual crop sequences increased for wheat and declined for barley between 1985 and 1995, but both were generally under 5 percent (Fig. 6). Region-wide, for fall-planted small grains, proportions of intensive tillage declined from a maximum of 80 percent in 1994 to 30 percent in 2004, with a concomitant increase in reduced tillage (Fig. 11). Mulch tillage was at 15 percent at the beginning of that time interval but had disappeared by 1994 and then remained at less than 5 percent of the fall-planted acreage. Essentially none of the fall-planted cereal acreage in this region was categorized as no-till (Fig. 11).

Irrigated acreage (NASS data): Irrigated small grains varied from 12 to 25 percent of the total small grains acreage in central Washington from 1985 to 2003 (Fig. 7). There was a dramatic increase from 15 to 25 percent after the year 2000. The proportion of spring wheat and barley steadily declined over the 19-year interval and, during 2003, these crops represented less than 5 percent of the total small grains acreage in the region (Fig. 8). The proportion of irrigated winter wheat accounted for the increase in the proportion of irrigated small grains after 2000. Acreage of irrigated winter wheat increased from 6 percent of the total small grains acreage in 1999 to 20 percent of the acreage in 2003 (Fig. 8).

East central region: There were 1,960,000 acres of wheat and 169,600 acres of barley planted in the region during 2000, representing 48 percent of wheat and 34 percent of barley acreage in Washington (Table 1).

Dryland acreage (NASS data): Trends were very similar to those in the central region. Winter wheat dominated the small grains acreage, increasing slowly from 60 percent in 1985 to 65 percent in 2004 (Fig. 2). For winter wheat, the rotation with summer fallow was by far the dominant production system, but it declined from 95 percent of all wheat planted in 1985 to 90 percent in 1995 (Fig. 3). There was only a slight increase in winter wheat planted in annual crop sequences: 5 percent of wheat acreage in 1985 and about 8 percent in 1994. Spring wheat was planted on 35 percent of the dryland acreage during 1989 but during other years was always less than 7 percent of the small grain acreage (Fig. 2). The strong but temporary shifts in proportions of winter and spring wheat during several years were caused by low-temperature damage to winter wheat. Spring wheat was planted following summer fallow in about the same proportion as in annual crop sequences (data not shown). The proportion of barley decreased from 25 percent in 1985 to less than 10 percent during 1995 (data not shown). Percentages of spring grains planted in annual crop sequences declined for barley and increased for wheat during 1985 to 1995 but were generally less than 10 percent of total acreage (Fig. 6). All of these trends were dominated by changes in production practices in Adams and Lincoln counties.

Residue management (CTIC data): During 1990 to 2004, the proportion of acreage planted to winter cereals gradually declined from 82 to 72 percent with concomitant increases in spring grains (Fig. 4). The shift was more pronounced in Lincoln County than in Adams County. For fall-planted small grains, the proportion of intensive tillage decreased from 45 to 10 percent but was highly cyclic in pattern, with a resurgence of intensive tillage during 2000 and 2002, and then declining again in 2004 (Fig. 11). Reduced tillage was also highly cyclical but generally increasing, as was no-till. No-till acreage was always less than 5 percent of the total for fall-planted grains. For spring-planted small grains, the proportion of intensive tillage declined from 40 to 10 percent over the 14-year time interval, with concomitant increases in mulch till and no-till (Fig. 11). Within the conservation tillage statistics for spring-planted small grains, there was an increase from 0 to 10 percent in no-till and an increase from 20 to 35 percent in mulch tillage between 1990 and 2004. For spring grains, the increase in no-till and mulch tillage appeared to represent a shift directly from intensive tillage, with the acreage planted in reduced tillage remaining relatively constant at 45 percent.

Irrigated acreage (NASS data): Irrigated small grains in east-central Washington decreased from 20 percent of the acreage in 1985 to 15 percent in 2003 (Fig. 7), due mainly to a decrease in acreage of irrigated winter wheat, from 13 to 9 percent (Fig. 8). The proportion of spring wheat and barley were consistently less than 5 percent of the total small grains acreage, with both declining slightly over the 19-year interval.

Southeast and northeast regions: There were 1,060,000 acres of wheat and 312,000 acres of barley planted in these regions during 2000, representing 42 percent of wheat and 62 percent of barley acreage in Washington (Table 1).

Dryland acreage (NASS data): Winter wheat dominated the small grains acreage; increasing from 60 percent in 1985 to 70 percent in 1995 and then returning to 60 percent in 2004 (Fig. 2). For winter wheat, the rotation with summer fallow was by far the dominant production system, but it declined slightly from 70 percent of all wheat planted in 1985 to 60 percent in 1995 (Fig. 3). Winter wheat planted in annual crop sequences increased, representing 20 percent of wheat acreage in 1985 and about 35 percent in 1994 (data not shown). The proportion of barley decreased from 40 percent in 1985 to 15 percent during 1995 (Fig. 2). Barley planted into annual crop sequences dominated the barley production, declining from 25 percent in 1985 to 15 percent during 1995 (Fig. 6). The proportion of barley following summer fallow decreased from 15 percent in 1985 to 0 in 1995 (data not shown). Over these two regions, spring wheat was planted on 20 and 35 percent of the non-irrigated acreage during 1989 and 1991, respectively, but during other years was always less than 15 percent of the acreage of small grain plantings (data not shown). The proportion of acreage planted to spring wheat increased steadily in Spokane County, from 2 percent in 1985 to 10 percent in 1995 for spring wheat in annual crop sequences. Less than 5 percent of the acreage was planted to spring wheat after summer fallow in Spokane County. In the five southeast counties, spring wheat was planted following summer fallow (data not shown) in about the same proportion as in annual crop sequences (Fig. 6).

Residue management (CTIC data): During the 1990 to 2004 time interval the proportion of southeast and northeast Washington acreage planted to winter cereals declined from 82 percent to 68 percent and the proportion of spring grains increased by a comparable amount (Fig. 4). In several counties (Asotin, Columbia and Spokane) the trends were greater from 1990 to 2002, but then there was a reversion back toward a greater proportion of fall-planted cereals in 2004. Whether this trend back towards fall-planted production continues won't be known until the expanded survey is repeated during 2006. For fall-planted small grains, proportions of intensive tillage decreased from 65 percent to 15 percent with concomitant increases in reduced tillage from 15 percent to 40 percent, mulch tillage from 15 percent to 20 percent, and no-till from 5 percent to 15 percent (Fig. 11). In Spokane County the conversion from intensive tillage to reduced tillage, mulch tillage and no-till was even greater at 65 percent. For spring-planted small grains, the proportions of intensive tillage and reduced tillage were highly cyclic over the 14-year time interval (Fig. 11), a pattern dominated mostly by highly cyclic tillage practices in counties such as Columbia County and Whitman County. Trends were more uniform in Walla Walla County and Spokane County. Region-wide, intensive tillage of spring-planted small grains reached low points of 13 percent in 1992 and 2004, but increased as high as 40 percent during the intervening years. In contrast, in Spokane County, intensive tillage of spring grains decreased from 80 percent in 1990 to 12 percent in 1996, and remained at about 15 percent through 2004. A comparable immediate drop and then stabilization at a low level occurred for intensively tilled spring grains in Walla Walla County. Region-wide, mulch tillage sporadically increased from 12 percent in 1990 to nearly 22 percent in 2004, and no-till increased steadily from 3 percent in 1990 to 20 percent in 2004.

Irrigated acreage (NASS data): Irrigated small grains were always less than 3 percent of all small grains planted in the southeast and northeast regions (Fig. 7). None of the individual crop species occupied more than 2 percent of the total small grains acreage (Fig. 8).

***Overall tillage trends for Washington*:** Over the past 14 years, intensive tillage has declined dramatically and each of the three conservation tillage systems has increased steadily in Washington (Fig. 9). Reduced tillage and no-till increased more rapidly than mulch tillage. For the total wheat industry, no-till acreage went from 3 percent in 1990 to 13 percent in 2004 (322,100 acres). No-till plantings increased for both winter wheat and spring wheat (Fig. 10). No-till acreage for winter wheat went from 3 percent in 1990 to 11 percent (182,900 acres) in 2004. No-till acreage for spring wheat went from 2 percent in 1990 to 18 percent in 2000, where it remained steady through 2004 (139,200 acres).

***Forces driving evolutions in crops and management*:** Proportions of small grain species and crop management systems have clearly changed over time in Oregon and Washington. Forces driving these changes are complex and presumably due to a number of factors including economics, farm programs, and new technologies. An analysis of these factors in each region is well beyond the intent of this report. Nevertheless, it seems worthwhile to conclude by listing some of the interactive forces that are influencing changes in agricultural systems in these states.

Economics is clearly a principal driving force. For wheat and barley, government programs such as deficiency payments and crop insurance have significant influences on growers' decisions on cropping practices. The Federal Crop Insurance Program, for instance, played a strong role in helping growers convert to no-till during recent drought years. Conservation districts and the USDA-NRCS also became more aggressive in promoting no-till and provided more technical assistance and funding for cost-share through sources such as U.S.

Environmental Protection Agency grants and the EQIP program (USDA-NRCS Environmental Quality Incentives Program, a component of the Federal "Farm Bill" that provides incentive payments for farmers and ranchers to implement conservation practices that promote agricultural production and environmental quality). Additional emphasis was placed on off-farm costs associated with soil erosion from water and wind, including passage of air quality legislation that led to additional monitoring of air quality.

During the past 15 years, farmers also gained better understandings of commercial and public sector research that improved their capabilities for managing weeds, diseases, and insects. Recognition and implementation of the green bridge concept led to immediate yield improvements for spring wheat and barley in annual cropping systems. Strong advances have been made in breeding spring wheat varieties with higher levels of resistance to Hessian fly. Also, great advances have been made in commercially produced no-till drills and fertilizer application technologies, and costs were reduced for some widely used herbicide technologies, particularly associated with no-till systems. New herbicides for controlling grass weeds in crops have also been introduced, reducing the dependence on tillage for weed control. A deepening commitment to more conservation-friendly farming systems was reflected by formation of the Pacific Northwest Direct-Seed Growers Association and by transforming the annual STEEP Conference (USDA-CSREES special PNW-regional grant "Solutions to Environmental and Economic Problems") into the annual Northwest Direct-Seed Cropping Systems Conference.

There are undoubtedly many other economic, sociological, environmental, and biological factors associated with the trends summarized in this paper. It would, for instance, be interesting to understand factors that limit or promote adoption of conservation technologies in various regions. For example, in areas of comparable rainfall (11 to 12 inches) and temperature, the transition from winter wheat rotated with mulch-tilled summer fallow to no-till winter wheat rotated with chemical fallow has seemingly been effective in Wasco County, Oregon, but the same system in adjacent Sherman County appears to have failed due to heavy infestations of Russian thistle, which has forced growers to retain the fallow system with mulch tillage. An analysis of factors associated with contrasting experiences in such counties and regions would be enlightening.

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Table 1. Proportions of all wheat and barley produced in counties and regions[1] of Oregon and Washington during 2000.

State and region	County	Total wheat planted	Proportion of all wheat planted in each: region	Proportion of all wheat planted in each: state	Proportion of all barley planted in each state
Oregon		*acres*	%	%	%
Northcentral region					
	Gilliam	107,500	22	12	13
	Morrow	206,200	39	21	3
	Sherman	105,900	24	13	17
	Wasco	78,400	14	7	8
	total	498,000	-	53	40
Northeast region					
	Umatilla	285,500	83	31	10
	Union	36,800	11	4	5
	Wallowa	18,400	5	2	6
	total	346,200	-	37	23
Southeast region					
	Crook	3,900	6	<1	<1
	Jefferson	14,100	23	1	1
	Klamath	6,600	12	1	26
	Malheur	31,400	57	4	5
	total	57,500	-	6	35
Oregon State total		965,000		96	98
Washington					
Central region					
	Benton	114,900	55	5	-
	Klickitat	46,500	22	2	2
	Yakima	36,400	18	1	<1
	total	212,000	-	8	3
East Central region					
	Adams	321,200	27	13	2
	Douglas	199,800	17	8	-
	Franklin	110,700	9	4	-
	Grant	196,700	16	8	2
	Lincoln	367,600	31	15	27
	total	1,196,000	-	48	34
Southeast region					
	Columbia	84,400	9	3	4
	Garfield	78,100	8	3	8
	Walla Walla	239,400	26	10	5
	Whitman	498,100	54	20	34
	total	926,000	-	37	52
Northeast region					
	Spokane	125,200	94	5	9
	Stevens	8,300	6	trace	1
	total	134,000	-	5	10
Washington State total		2,475,000		98	99

[1] Listings are for selected regions that collectively represented more than 95 percent of all wheat planted in each state, and for counties that collectively represented more than 90 percent of all wheat planted in each region. Figures for regional and state totals represent actual planting data and may therefore differ slightly from the sums of acreages and percentages shown for the selected counties shown in this table.

Figure 1. Counties and regions in which most small grains are produced in eastern Oregon and Washington.

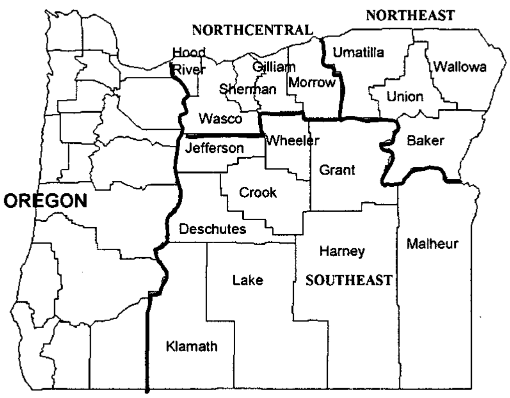


Figure 2. Proportions of dryland winter wheat, spring wheat, or barley planted from 1985 to 2003, expressed as a percentage of the total small grains acreage planted in each region; data are for three regions of eastern Oregon and four regions of eastern Washington.

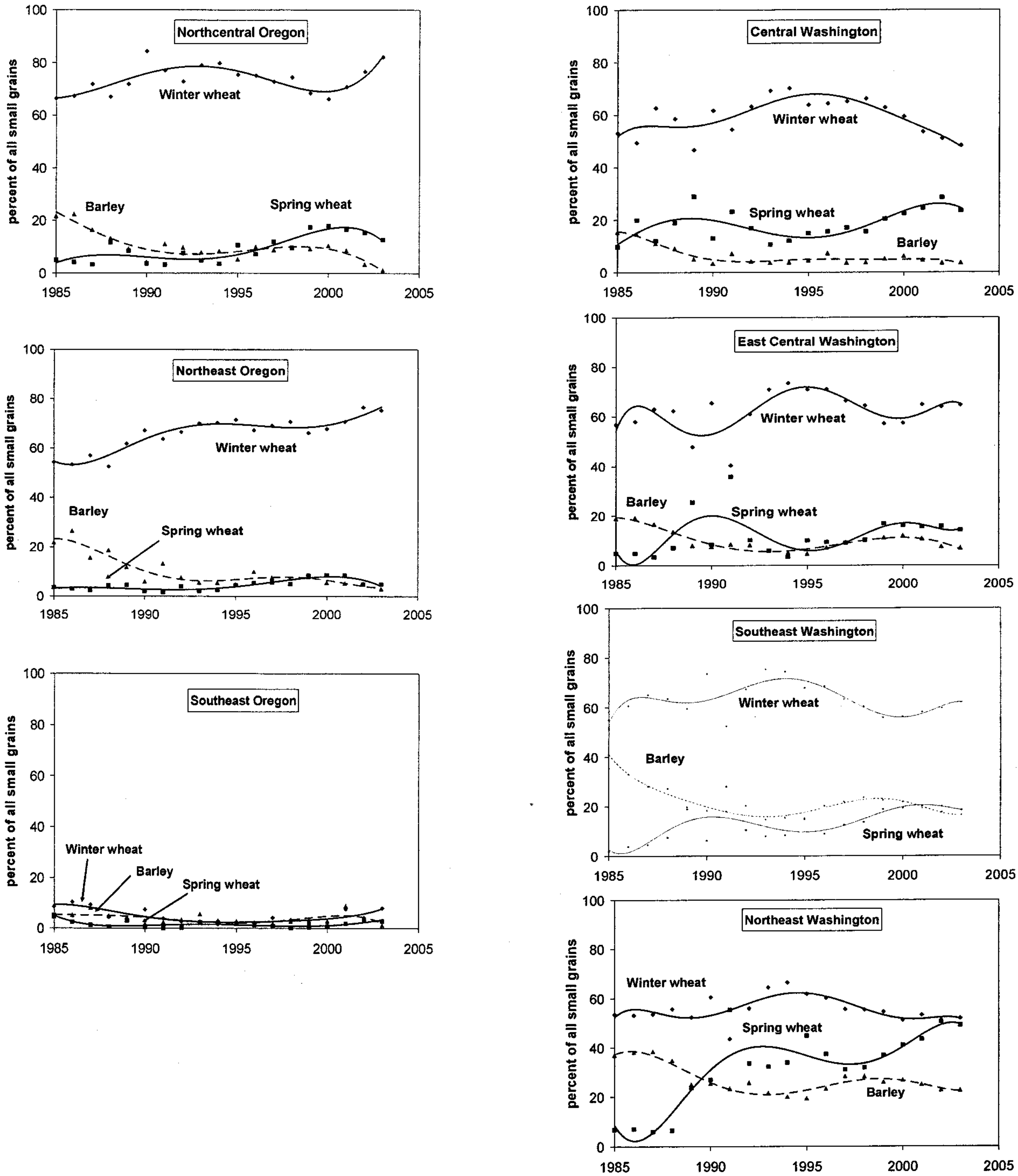


Figure 3. Proportions of dryland winter wheat planted after summer fallow and annual crop sequences in three regions of eastern Oregon and in four regions of eastern Washington; data are presented as a percentage of total winter wheat acreage in each region.

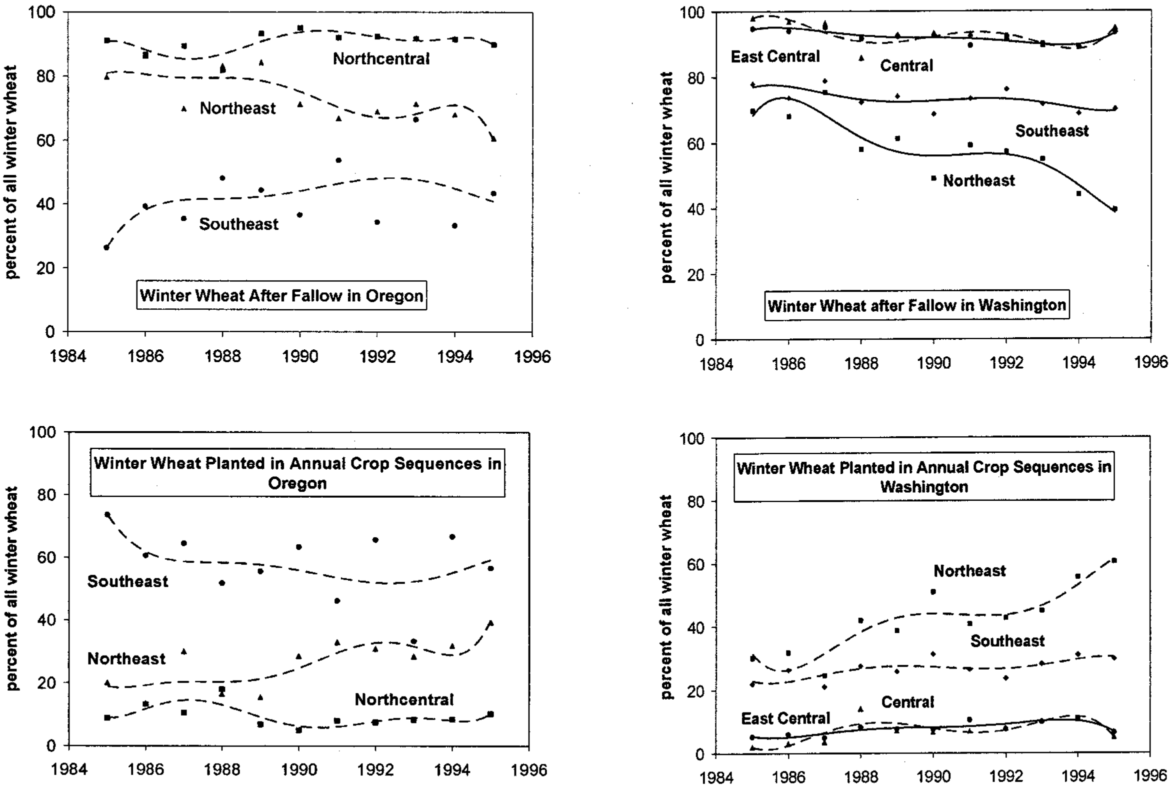


Figure 4. Proportions of all small grains (wheat, barley, and oats) planted during the fall and spring in three regions of eastern Oregon and in three regions of eastern Washington; data are presented as a percentage of the total small grains acreage planted in each region.

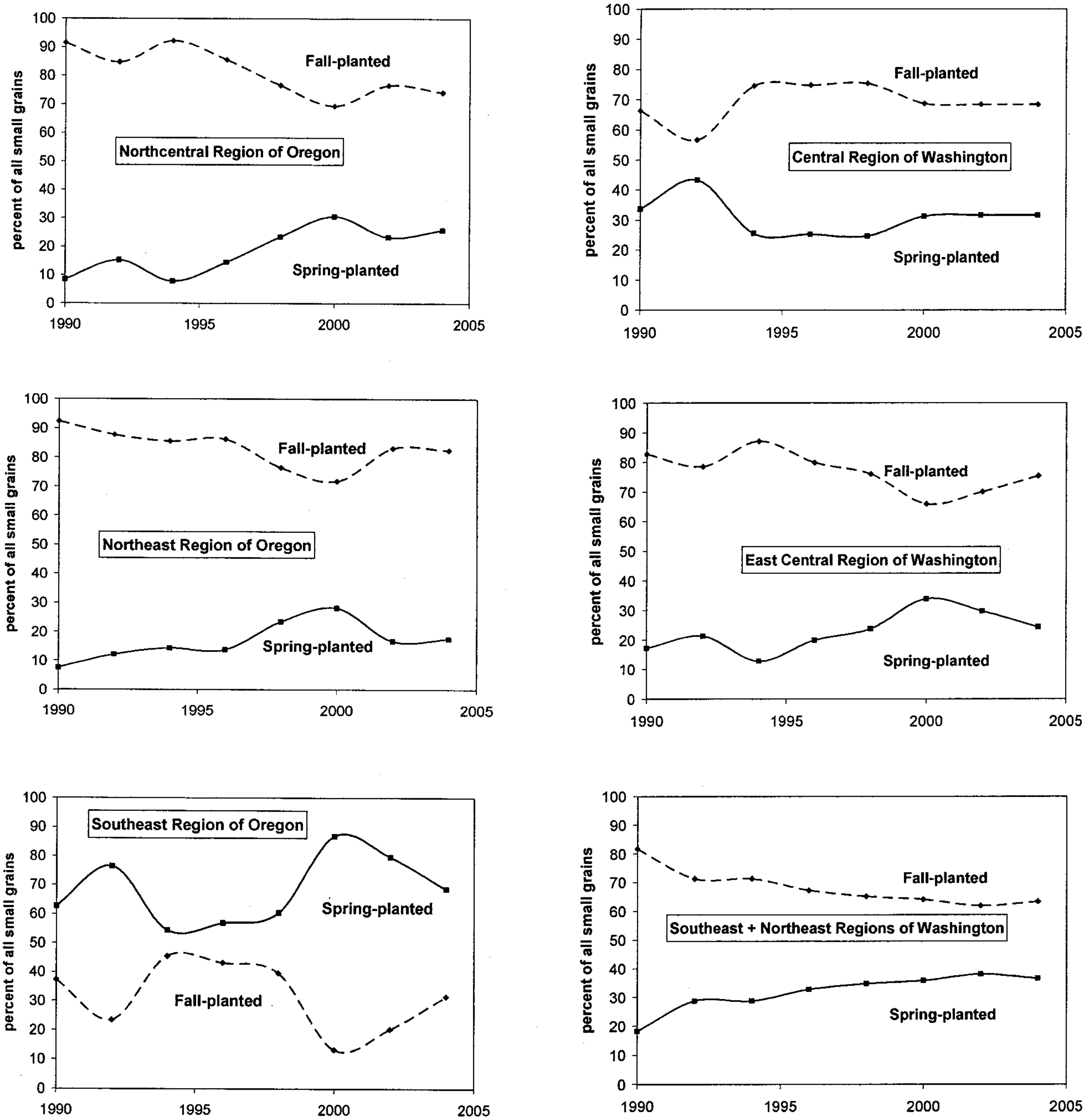


Figure 5. Proportions of spring- and fall-planted small grains managed under four types of tillage practices (intensive, reduced, mulch, no-till) in Oregon; data are presented as a percentage of the total small grains acreage planted in each region.

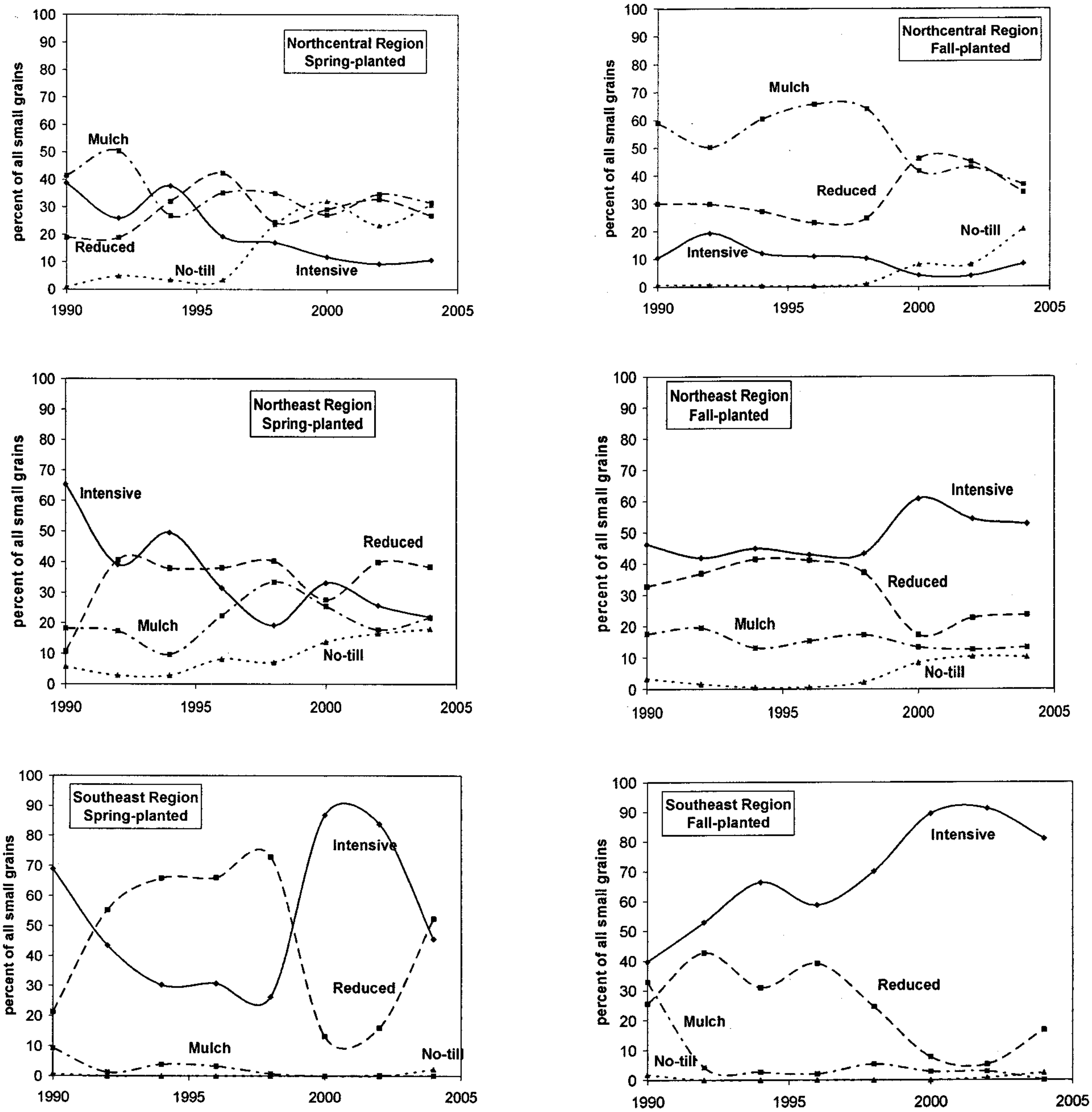


Figure 6. Proportions of dryland spring wheat and spring barley planted in annual crop sequences as a percentage of the total dryland small grains acreage in three regions of eastern Oregon and in three regions of eastern Washington.

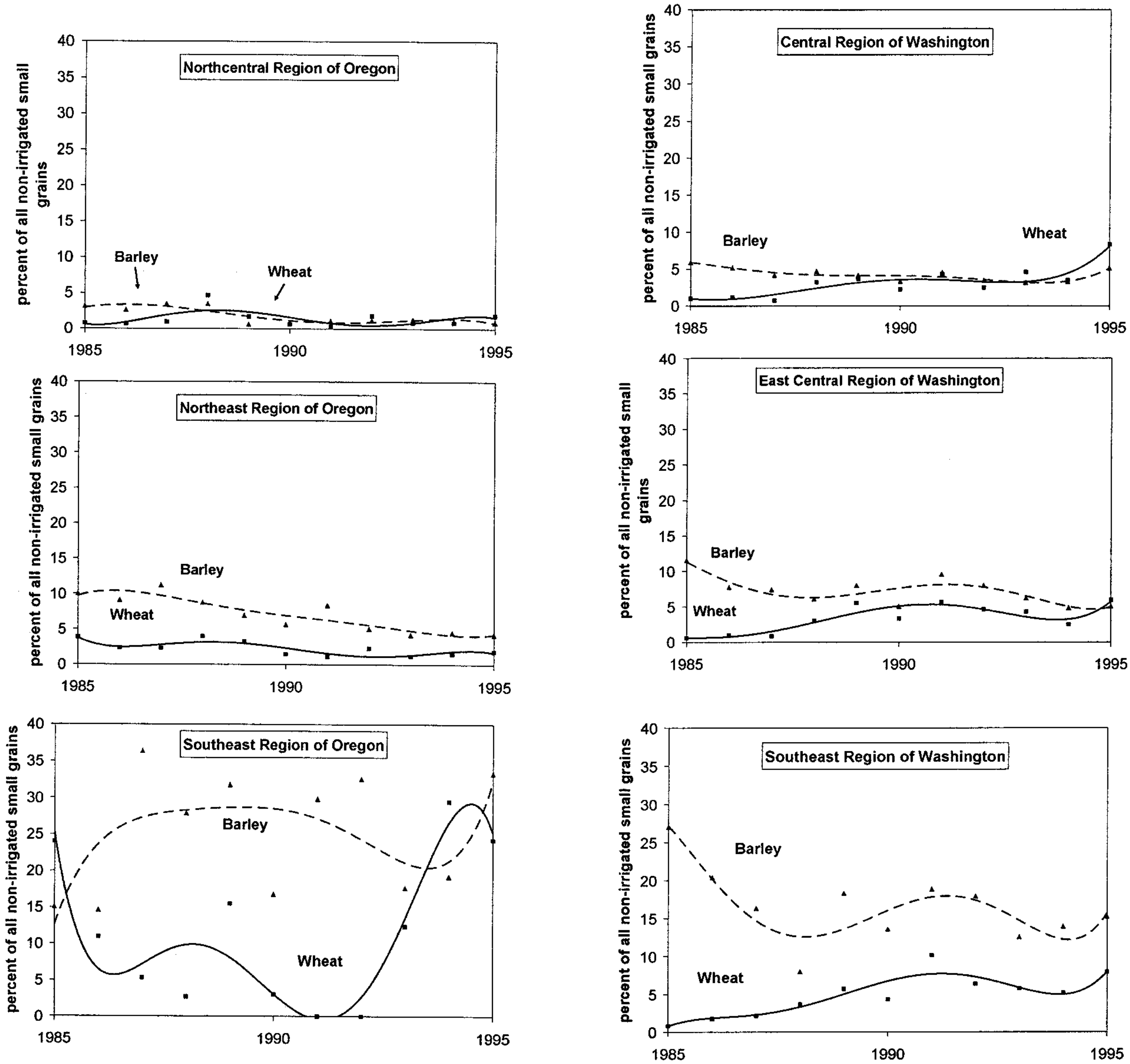


Figure 7. Proportions of irrigated small grains as a percentage of the total small grains acreage planted in three regions of eastern Oregon and in four regions of eastern Washington.

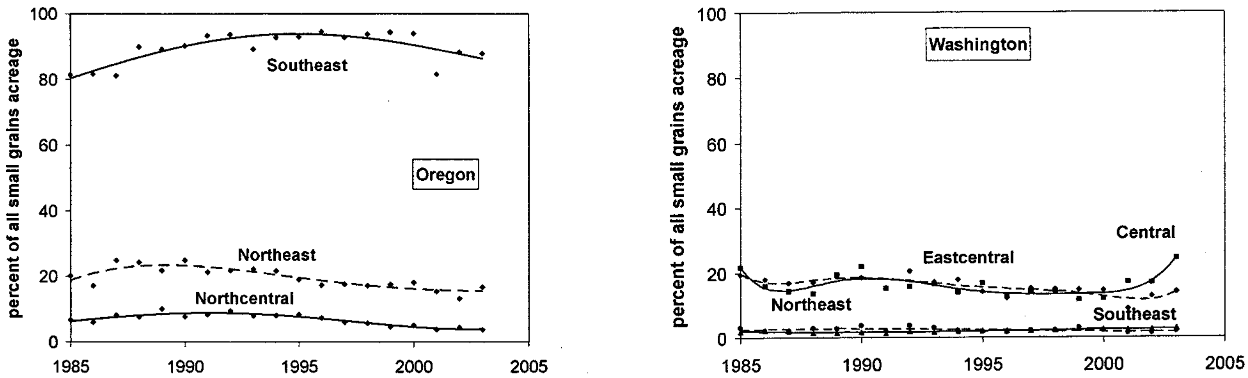


Figure 8. Irrigated winter wheat, spring wheat, and barley plantings as a percentage of the total planted small grain acreage from 1985 to 2003 in three regions of eastern Oregon and three regions of eastern Washington.

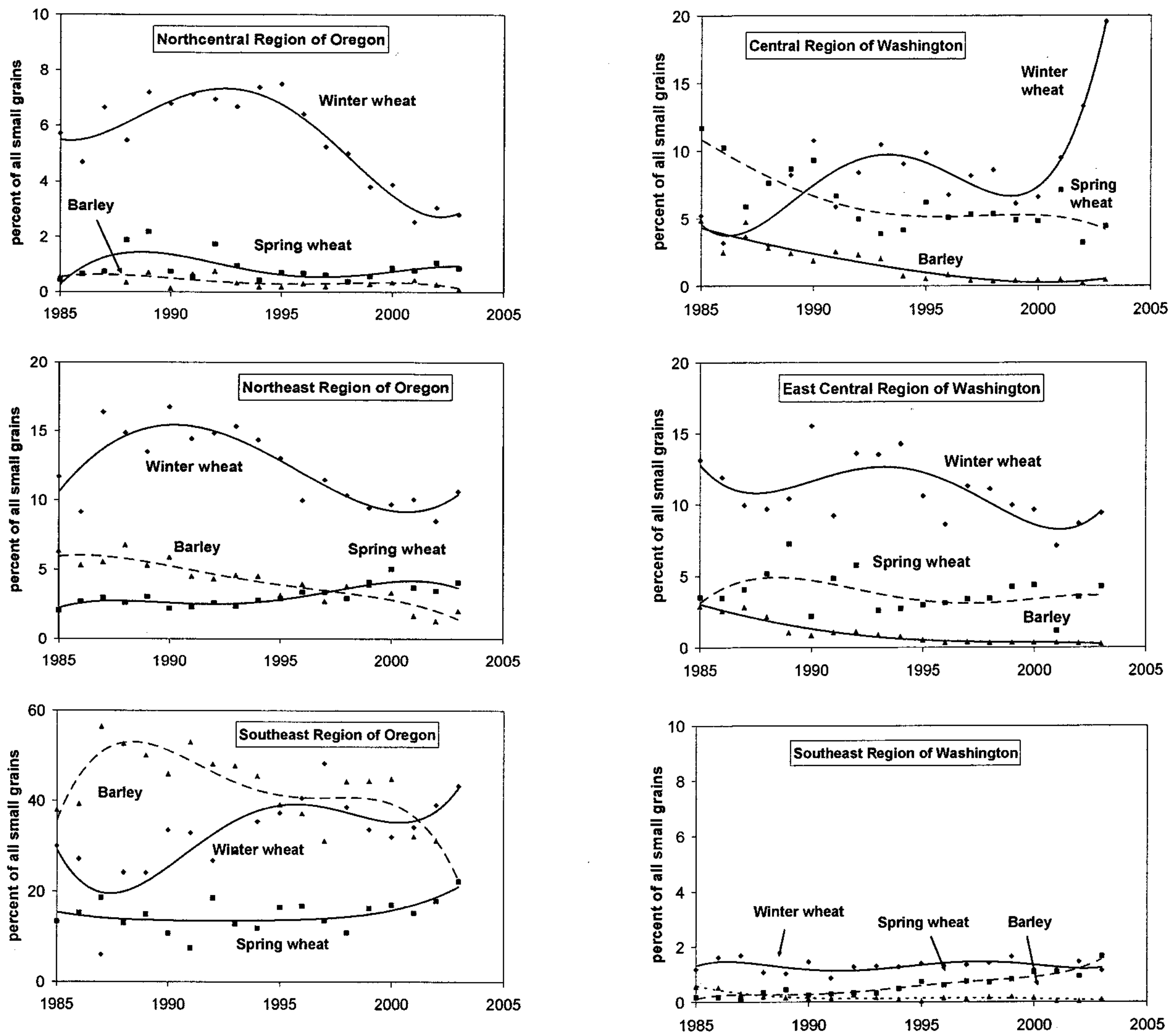
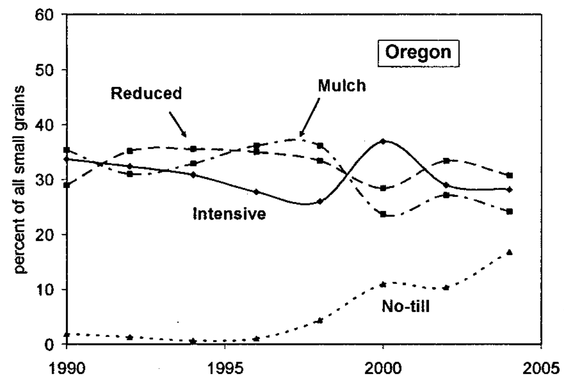


Figure 9. Trends in tillage practices for all small grains in Oregon and Washington; data are expressed as a percentage of the total acreage planted to winter wheat, spring wheat, and barley in each state, including irrigated and dryland production systems.



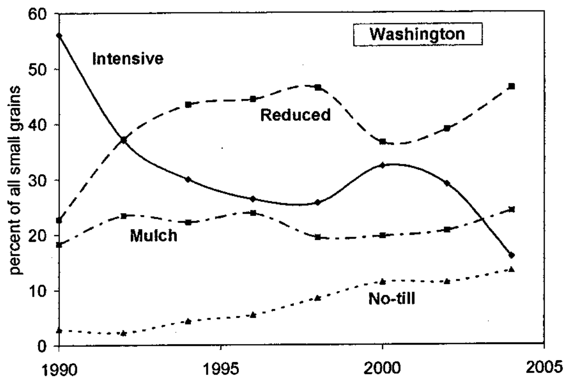
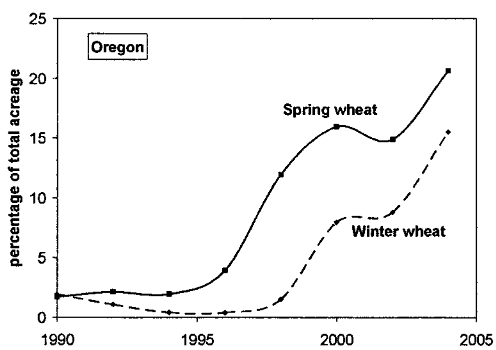


Figure 10. Proportions of statewide no-till wheat acreages in Oregon and Washington; data are expressed as a percentage of the total acreage planted to small grains in each state.



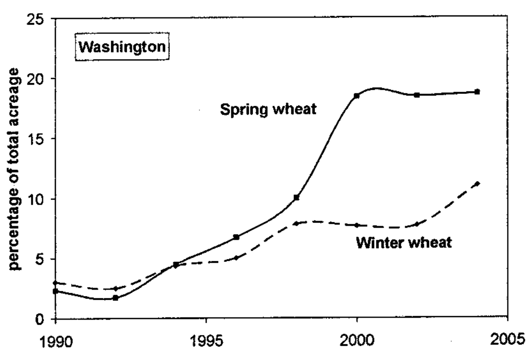
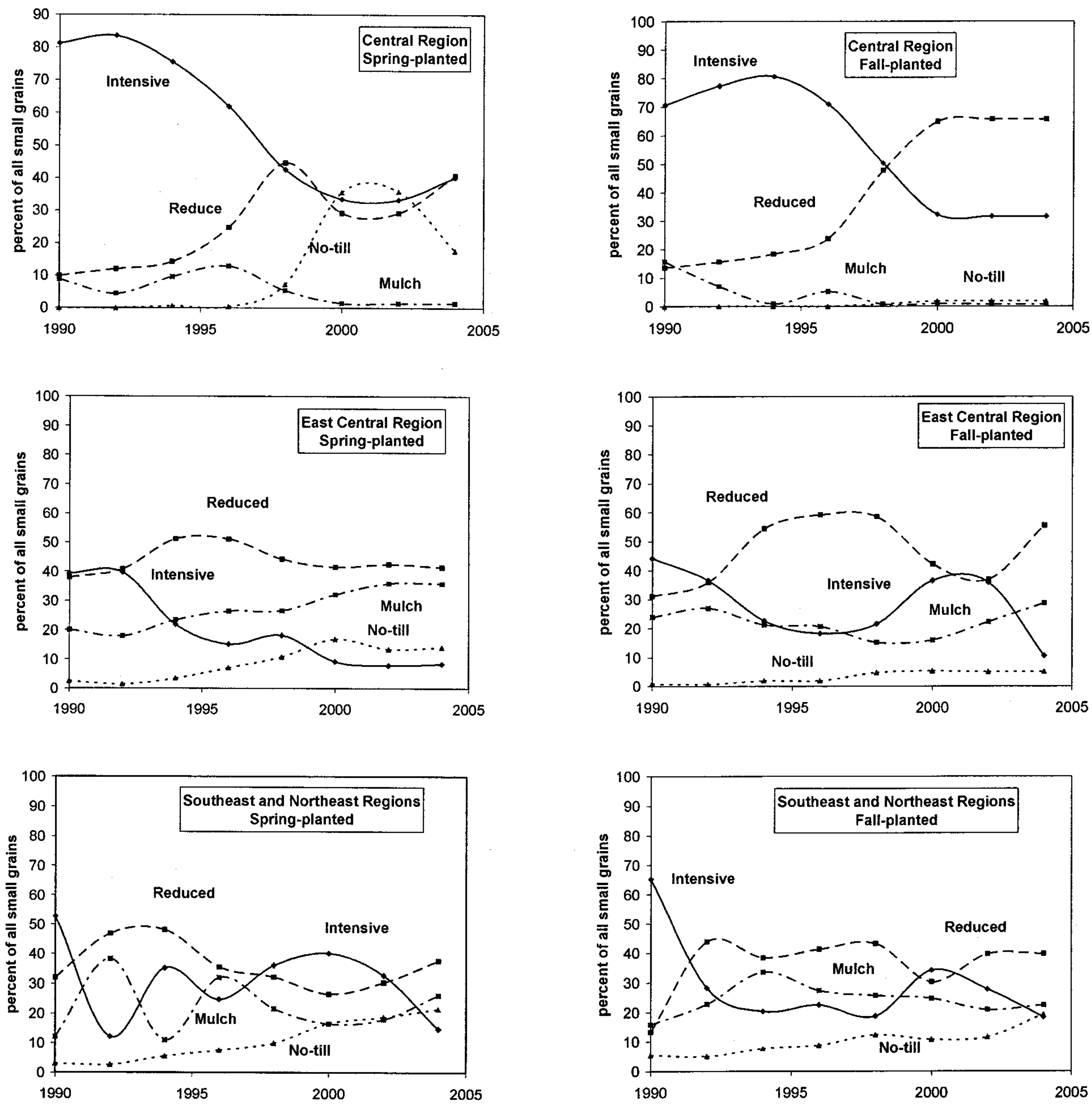


Figure 11. Proportions of spring- and fall-planted small grains managed under four types of primary tillage (intensive, reduced, mulch, no-till) in Washington.



USDA-ARS CLUB WHEAT BREEDING IN OREGON

Nathan Blake, Kimberly Garland Campbell, Steve Petrie, and Lynn Little

Abstract

Club wheat was planted on over 40,000 acres in Oregon and 215,000 acres in Washington for the 2004 harvest year. Club wheat is sold to domestic and foreign millers as pure club or as mixture with soft white marketed as 'Western White' and is used in cakes, sponge cakes, pastries, and crackers. The objective of this research was to evaluate winter club breeding lines at diverse Oregon locations with the goal of developing high quality, competitive winter club cultivars suited to northeastern Oregon growing conditions. Breeding lines were evaluated at four Oregon sites for yield, test weight, plant height, heading date, and quality and crosses were done in the greenhouse. Coleoptile length and leaf breadth measurements were taken.

Key words

Triticum aestivum, Triticum compactum, wheat breeding

Introduction

The USDA-Agricultural Research Service (ARS) Wheat Breeding Program is located in Pullman, Washington at the USDA-ARS Wheat Genetics, Quality, Physiology, and Disease Research Unit. Kimberly Garland Campbell is head of the Wheat Breeding/Genetics Program and the Western Regional Cooperative Nurseries. The Oregon sites are managed by Nathan Blake.

Materials and Methods

Four northeastern Oregon sites (Hermiston, Lexington, Moro, and Pendleton) were used for 17 breeding and 3 Western Regional nurseries. All sites were non-irrigated except Hermiston. The Pendleton and Moro nurseries were located at the Columbia Basin Agricultural Research Center (CBARC) and the Sherman Experiment Station. The other two sites were on Kent Madison's farm near Hermiston and Starvation Farms (Chris Rauch cooperator) north of Lexington.

Pendleton
Winter wheat nurseries were seeded October 4, 2003 at CBARC. Yield trials evaluated at CBARC included the USDA-ARS Elite, Tall Late, Oregon Early, and Preliminary 1 and 2, and comprised a total of 28 entries replicated 2 times. The yield trial, Shadow, included 14 entries replicated 3 times. All breeding nurseries were planted using a partially balanced lattice design. Two cooperative regional nurseries, the Western Regional Soft Winter Wheat Nursery and the Western Regional Hard Winter Wheat Nursery, comprised of 30 and 23 entries respectively, used a randomized complete block design with three replications. All seed was treated prior to planting with Raxil-Thiram® (Gustafson) and Gaucho® (Bayer) at recommended label rates. Seeding rate was approximately 20 seeds/ft^2. Ninety pounds of nitrogen (N) as anhydrous ammonia was incorporated into

conventional fallow in July to increase the N amount to 210 lb/acre. This is based on 2.7 lb N/acre/bu multiplied by 80 bu/acre estimated yield. No fertilizer was applied in the spring. Plots were seeded approximately 1 inch deep using a Hege drill with five-row double-disk openers. Plot size was approximately 82.5 ft^2. Moisture was good at planting and emergence was good. Hoelon® (Bayer) was applied at 2.67 pints/acre to control downey brome. Spring broadleaf weed control was obtained by spraying plots with Bronate® (Bayer) (20 oz/acre) on April 6 with wheat in mid-tillering stage.

Plots were evaluated for spring stand (percentage), heading date, height, spike morphology, harvested plot length, grain yield, and test weight. Heading date was noted as days from January 1 until 50 percent of the plot had headed. Height was measured on an inside row of the plot from the soil surface to the bottom of the spikes. Disease notes were not taken at Pendleton because foliar diseases were few. Plots were harvested on July 27, 2004 using a Hege small plot combine. Harvested plot length was determined just prior to harvest. Grain samples were measured for grain yield, cleaned using a small-sample Hege cleaner, and test weighed.

Hermiston

The USDA-ARS Elite and Shadow replicated yield trials were planted at Hermiston on October 8, 2003 using the same experimental design as at Pendleton. Seeding was done using a Hege drill with 7 Accu-Plant® double-disk openers at approximately 20 seeds/ft^2. Planting depth was approximately 1 inch deep. Moisture and emergence were good. Fertility and weed control were managed by the cooperator. Experimental design and data collected were as described above. Plots were harvested on July 19, 2004.

Lexington

The USDA-ARS Elite and Shadow replicated yield trials were planted at Lexington on September 25, 2003 using the same experimental design as at Pendleton. Plots were direct seeded using a Hege drill with Accu-Plant® double-disk openers at approximately 20 seeds/ft^2. Planting depth was approximately 1.5 inch deep. Moisture was inadequate and emergence was uneven. There was extensive seed loss before emergence due to mice. Fertility and weed control were managed by the cooperator. Experimental design and data collected were as described for Pendleton. Plots were harvested on July 16, 2004.

Moro

Nurseries evaluated at the Sherman Experiment Station included the USDA-ARS Elite, Tall Late, Oregon Early, Shadow, Preliminary 1 and 2, and the two cooperative regional nurseries, Western Regional Soft Winter Wheat Nursery and Western Regional Hard Winter Wheat Nursery. Nitrogen fertility included 109 lb/acre residual N, with an application of 35 lb N/acre of anhydrous ammonia in late July 2003, which increased the total N to 144 lb/acre. Plots were seeded on October 10, 2003 at approximately 20 seeds/ft^2 using a Hege drill with 4 double-disk openers. Planting depth was approximately 1.25 inch deep. Moisture was adequate and emergence was good. Bronate® (Bayer) (16oz/acre) and Harmony Extra® (DuPont) (0.5oz/acre) were used for weed control in the spring. Experimental design and data collected were as described for CBARC. Plots were harvested on July 22, 2004. A 400-g sample was saved from selected plots and sent for evaluation at the Western Wheat Quality Laboratory in Pullman, Washington. Quality data are not available at this time. Quality data for the 2003 crop are included in Table 2.

Pullman

The Pullman nurseries were planted September 24, 2003, using a Wintersteiger® 7 row drill at 7 in spacing. Plot size was trimmed to 44 ft ft^2. The field was summer fallow, fertilized with 80 lbs of N as ammonium sulfate. Weeds were controlled by a May application of Bromoxynil and Harmony Extra® (DuPont) at labeled rates. Plots were harvested on August 10, 2004 using a Winterstieger® plot combine.

Milling and baking quality

The quality tests were conducted at the USDA Western Wheat quality laboratory using standard AACC approved procedures. A 600 g sample was taken from the first replication of each field nursery. The quality tests reported here are from the 2003 crop year.

Coleoptile testing

Coleoptile length of breeding lines from the USDA-ARS program were evaluated as described in Hakizimana et al. (2000). Ten seeds were placed 1 cm apart with the germ down and 1.2 in from the bottom of a wet germination towel. The towels were folded over, rolled loosely, and placed upright in plastic trays. The samples were placed in a dark incubator at 39°F for 4 days. After 4 days the samples were removed and placed in another dark incubator at 59°F for 16 days. Coleoptile lengths were measured to the nearest mm to identify genotypes with long coleoptiles that will emerge readily from deep planting

Leaf breadth testing

Leaf breadth of breeding lines from the USDA-ARS program are being evaluated at Pendleton as described in Richards et al. (2002). Twelve seeds of 240 lines with 2 replications were germinated and put in a growth chamber at 70°F for 10 days. The first two leaves were measured to the hundredth mm at the widest point using a digital micrometer. The goal is to select for genotypes that compete better with weeds and use water and sunlight more efficiently through more rapid canopy closure.

Results

Yield data at Moro and Lexington were extremely variable due to unequal fertilizer application at Moro and rodents and herbicide injury at Lexington. Above average rainfall in April and May resulted in higher than average yields at Pendleton. Only one line, A00248, had comparable yields with the check, Tubbs, at Pendleton, but several other experimental lines had yields similar to Eltan, Residence, Finch, and the other checks (Table 1).

Test weights of the experimental lines across locations were the same or higher than the checks. In the past, club varieties generally had lower test weights than commons, but through the selection of high test weight lines in early generations, higher test weights are now common for club wheats in the program.

Heading dates of the experimental lines in the Elite Nursery generally averaged several days later than the variety Tubbs. The line A99123 headed the same day as Tubbs and three other lines were one day later. These four lines would be well adapted to northeastern Oregon's need for early maturing varieties.

Two lines, ARSC96059-1 and A00154, had better than average milling and baking quality characteristics. Both lines had below 9.5 flour protein, low Udy hardness, below average ash content, high mill score and good cookie diameter. Other lines did very will with some characteristics, but were deficient in others.

Table 1. Agronomic traits for 2004 USDA-ARS Elite Nursery

	Hermiston	Lexington	Moro	Pendleton	Pullman	Average over all locations		
	Grain yield (bu/acre)					Heading date (fr. 1/1)	Height (cm)	Test weight (lb/bu)
A00154	117	43	60	107	88	155	83	58.3
A00248	109	42	61	111	84	155	90	57.4
A00258	115	48	65	104	86	155	87	58.5
A99123	134	41	73	102	91	152	81	59.3
A99165	120	47	55	95	92	156	91	59.4
C960097	118	47	59	87	92	154	88	58.2
C96059-2	123	43	57	102	93	154	93	59.2
X950424-1	114	41	68	99	89	155	89	57.0
X950424-2	91	41	55	98	87	156	100	58.2
X960407	115	39	60	95	93	157	84	58.1
X960414-1	109	43	61	85	90	156	87	59.6
X960414-2	115	46	64	97	88	156	89	59.5
X960418-1	116	44	73	105	81	156	87	59.5
X960418-2	107	48	64	103	91	156	89	60.0
X960491	129	34	65	105	99	154	86	59.3
X960749-1	115	48	56	102	97	156	89	58.0
X960749-2	116	43	62	109	97	158	89	59.1
ELTAN (a)	117	32	70	99	100	156	87	56.6
RESIDENCE	128	31	71	97	107	154	80	57.9
CHUKAR	111	36	57	105	97	157	88	56.0
FINCH	110	46	66	105	97	157	87	57.9
FINCH	104	44	66	96	91	157	85	58.4
FINCH	109	45	53	113	91	157	84	58.1
FINCH	104	47	67	104	102	157	83	58.2
TUBBS	133	39	63	99	87	152	86	56.4
TUBBS	132	42	71	111	105	152	88	55.8
TUBBS	123	48	74	111	110	152	90	56.8
TUBBS	131	50	59	112	103	152	88	56.6
Loc. Mean	117	43	63	102	94			

(a) Yield data were from Lexington and Moro were variable due to rodent damage and problems with fertilizer application, respectively. Yield data from Pullman, WA are reported for reference.

(b) All named cultivars are included as checks. Finch and Tubbs were each included four times in each replication as variability checks.

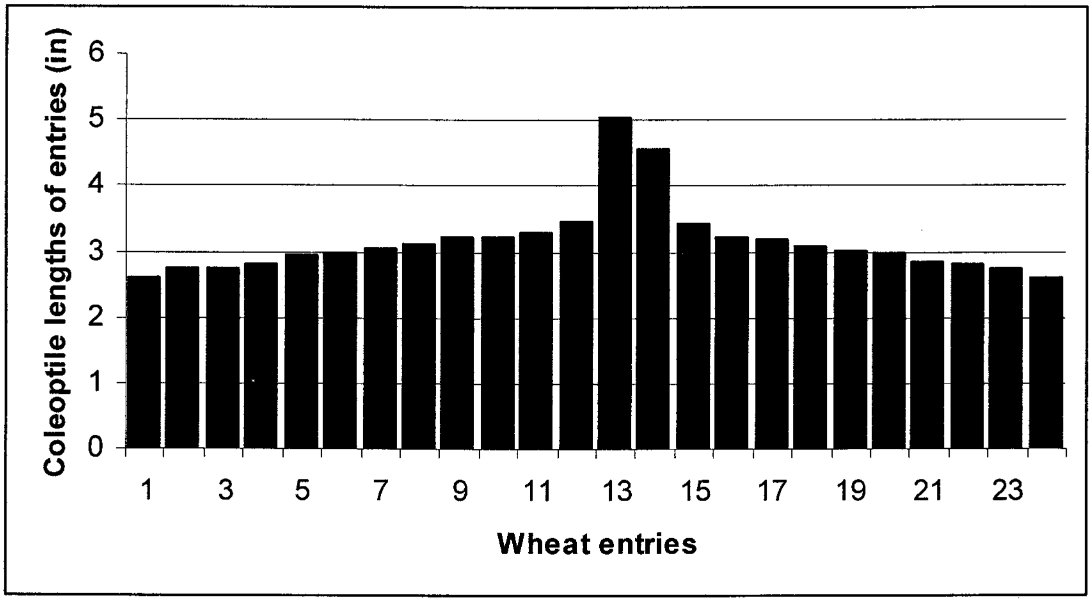
Table 2. Milling and baking quality characteristics of advanced genotypes in USDA-ARS Wheat Breeding Program, 2004

NAME	Test Weight	Flour Protein Conc.	Udy Hardness	Flour Yield	Break Flour Yield	Flour Ash	Mill Score	Cookie Diameter	Viscosity	Cake Volume
	(lb/bu)	(%)	(%)	(%)	(%)	(%)		(cm)		(cc)
CHUKAR	58.1	9.1	37	67	53	0.40	82	9.6	64	1263
FINCH	59.7	9.2	30	66	50	0.43	78	9.2		1263
ARS00127	60.6	8.9	34	68	53	0.35	85	9.6		
ARS00173	59.1	9.0	36	67	52	0.38	82	9.3		
ARS00226	59.9	8.6	31	67	51	0.42	79	9.3		
ARS00235	59.8	9.0	36	67	51	0.42	79	9.3		
ARS96277	60.7	9.0	27	64	48	0.38	79	9.1		
ARS97135-9	57.6	9.7	34	69	53	0.41	83	9.5		
ARS97173-16	60.5	7.8	34	69	52	0.37	85	9.5		
ARS99105	59.4	8.5	33	66	51	0.37	82	9.1		
ARSC96059-1	60.5	9.3	32	67	51	0.28	89	9.6	71	1253
ARSX960411-2	59.9	8.8	33	67	52	0.32	86	9.4	75	1213
A00154	61.3	7.0	35	70	55	0.35	88	9.6	39	1395
A00248	58.4	9.3	30	68	52	0.44	79	9.6	64	1373
A00258	60.1	9.3	27	65	49	0.45	75	9.1	90	1320
A99123	59.8	8.9	32	69	53	0.38	84	9.2	88	1313
A99165	61.2	9.4	36	68	51	0.37	84	9.6	88	1245
C960097	58.4	10.1	33	68	51	0.41	81	9.6	70	1275
C96059-2	59.0	9.4	36	67	52	0.31	86	9.4	73	1340
X950424-1	57.7	9.9	32	66	50	0.47	75	9.2	73	1223
X950424-2	58.1	10.4	26	66	49	0.43	77	9.3	81	1283
X960407	60.0	9.4	36	66	49	0.39	80	9.2	70	1295
X960414-1	61.5	8.5	37	67	51	0.39	81	9.4	58	1273
X960414-2	61.4	8.5	34	68	52	0.39	82	9.3	58	1250
X960418-1	61.2	8.0	35	68	52	0.32	87	9.4	58	1300
X960418-2	63.9	6.6	36	69	53	0.31	89	9.5	40	1308
X960491	60.9	9.3	31	66	49	0.40	79	9.4	83	1260
X960749-1	59.9	9.0	31	67	51	0.39	81	9.4	68	1265
X960749-2	59.6	9.4	32	67	52	0.37	83	9.5	72	1305

(a) Data are from Moro, Pendleton, and Pullman for 2003 season. All traits were analyzed at the USDA-ARS WWQL, Pullman WA

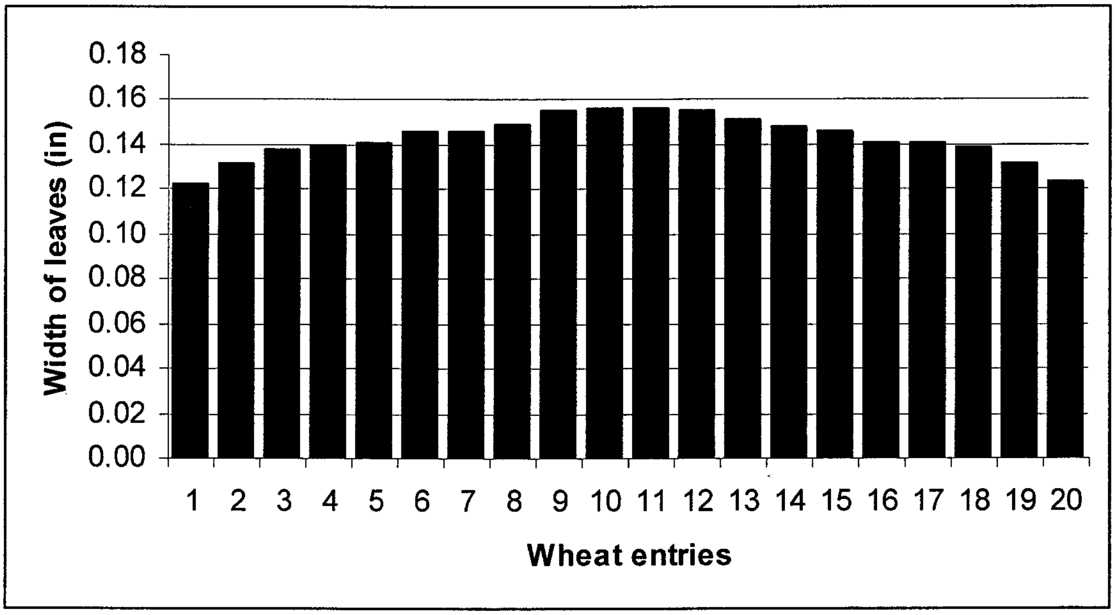
The lines with the longest coleoptile length (over 4.5 in) were the checks Edwin and Moro (wheat entries 13 and 14 in Fig. 1). Several breeding lines had coleoptile lengths over 3 in. For comparison, the checks Hiller, Tubbs, and Finch had lengths of 3.0, 3.0, and 3.5 in, respectively, and the nursery average was 3 in. The breeding lines seem to have few genetic differences affecting coleoptile length, and the varieties Edwin and Moro could be used in crosses to increase coleoptile length.

Figure 1. Coleoptile lengths of the Tall Late Nursery, Pendleton, OR, 2004



Leaf breadth testing (Fig. 2) results were similar to the coleoptile length tests. The range of leaf breadth measurements was small and the breeding nursery results shown in Figure 2 indicate a difference of .04 in (1 mm) between the widest and narrowest leaves of the 20 entries. These results also show the need for increased genetic variability in the club breeding lines.

Figure 2. Leaf breadth measurements of the Prelim 1 Nursery, Pendleton, OR, 2004



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GROWTH AND NUTRIENT UPTAKE OF WINTER CANOLA AT PENDLETON, OREGON

Don Wysocki, Nick Sirovatka, and Sandy Ott

Abstract

Winter canola (*Brassica napus)* is a broad-leaf, tap-rooted crop. Canola planted in late summer (September 1-20) establishes as a small rosette plant with 6 or more leaves. The plant over-winters in this stage and resumes rapid growth as soil and air temperatures warm in the spring. At the beginning of April, the plant begins vertical stem elongation (bolting). The plant grows rapidly from bolting through the end of bloom, producing more than 5 tons of dry matter during this period. Nutrient uptake by a canola crop precedes growth and dry matter accumulation. Nutrient concentrations in tissue are highest in young plants and become less as plants mature. As an example, nitrogen (N) tissue concentrations are 4 percent or higher at fall rosette and decline to about 1 percent at harvest. Total nutrient uptake, however, continues to increase through bloom. The corresponding N uptake at bloom for 2 consecutive years was 300 and 235 lb/acre respectively. Results for sulfur (S), phosphorus (P), and boron (B) follow the same trends. Maximum uptake levels for these fertilizer nutrients are about 40, 50, and less than 1 lb/acre, respectively. It is important to have adequate nutrition available at or prior to bolting because of very rapid growth during and after this stage.

Key Words

Canola, nutrient uptake, nutrients, nitrogen, sulfur, phosphorus

Introduction

Winter canola has been grown commercially in eastern dryland soils beginning in the early 1990's. Production peaked at about 15,000 acres, with yields ranging from between 1,800 to 3,700 lb/acre. Winter canola has typically been sown on summer fallow in early September. Agronomically, the greatest challenge in growing a winter canola crop is getting adequate stand establishment. Sowing this small-seeded crop into summer fallow requires the seed to be placed in moist soil with a maximum of 2 inches of soil cover. Sowing rate is typically 5-8 lbs of seed/acre. Canola seed will germinate quickly when gravimetric soil water content is at or above 15 percent and soil temperature is above 60°F. Winter canola yields best in eastern Oregon when sown before September 20th (Wysocki et al. 1991). Seeds sown into moist soil by this date emerge quickly and establish a multi-leafed plant known as a rosette before winter. When planted by this date, plants experience sufficient heat (growing degree days) for the rosette to grow six or more true leaves before winter.

Plants over-winter in the rosette stage. Severe freezing temperatures (<20^0 F) may damage or kill the outer leaf of the rosette over the winter months; however, plants remain viable if the crown is not injured. Winter canola sown early has cold tolerance similar to Stephens winter wheat. Rosettes will resume growth in the spring as temperatures increase. The plant will continue to grow as a rosette until late March or early April. At this point, the growing point rises above the crown and the plant begins rapid stem elongation. This crop stage is known as bolting. The plant grows rapidly from bolting through full bloom, a time interval of about 7 weeks. During this rapid growth period, the plant produces over 60 to 70 percent of its total dry matter. Lateral branches called racemes shoot from the main stem, with both bearing flowers. Flowering continues as long as temperature and water conditions are favorable and usually is complete in late May. At the completion of flowering growth slows. Crop dry matter is lost because of flower drop and senescence of lower leaves. Seed pods form at the base of flowers and begin to elongate. Pods grow to maturity and fill with seed. This stage is called pod filling and occurs mostly in June. Plants reach maturity in late June or early July. The crop is swathed when the lower third of the pod canopy has brown seed in the pods.

Winter canola is a new crop to eastern Oregon and it exhibits a unique growth habit different from cereals. The objective of our research was to gather information on growth and nutrient uptake of early planted winter canola.

Methods

Ceres winter canola was sown at the Columbia Basin Agricultural Research Center (CBARC) at 8 lb/acre in strip trials in the autumns of 1997 and 1998. Trials were sown on summer-fallowed Walla Walla silt loam soil (coarse silty, mixed, hyperactive, mesic, Typic Haploxerells) that was pre-irrigated with 0.075 in. of water, 5 days prior to planting. Seed was sown in a block of at least 80 by 100 ft. Eighty lb/acre N and 10 lb/acre S were applied in June prior to planting as anhydrous ammonia and nitrosol respectively. The block consisted of consecutive 5-ft drill passes of a Hege plot drill. Six drill strips in each block were selected for study. At each crop stage shown in Table 1, a 1-ft-long by 5-ft-wide sampling element (5 ft^2) in each drill strip was harvested to measure dry matter, nutrient concentration, and nutrient uptake. Plants in each element were cut off at the soil surface at each respective crop stage, washed, dried, weighed, and ground for analysis. Plant tissue was dried at 60°C for 48 hours. Dry matter/acre was determined from harvested tissue from each sampling element. At harvest a 5-ftby 20-ft strip was swathed with a Swift plot swather and combined with a Hege 140 plot combine with 8/64-inch round-hole sieve openings. Cylinder speed was 1000 RPM, fan speed 900 RPM, and concave clearance was set at 3/16 inch. Plant tissue was sent to Agri-Check Laboratory at Umatilla, Oregon for chemical analysis.

Results and Discussion

Table 1 shows the crop chronology, crop growth stage, dry matter, and nutrient content of winter canola crops for two consecutive growing seasons. All reported results are the average of the six sampling elements. Nutrient content is shown both as tissue concentration (percent or ppm) and total uptake (lb/acre). Dry matter accumulation at each crop stage is plotted in Figure 1. Dry matter reaches a peak at full bloom and then declines. The decline is due to flower drop, leaf senescence, our inability to completely collect all dry matter at

Table 1. Chronology, dry matter accumulation, and nitrogen, sulfur, phosphorus, and boron content of winter canola at various crop stages, Columbia Basin Agricultural Research Center.

Calendar date	Days after sowing	Crop stage	Dry matter	Nitrogen		Sulfur		Phosphorus		Boron	
			(lbs/acre)	%	(lbs/acre)	%	(lbs/acre)	%	(lbs/acre)	ppm	(lbs/acre)
			1997-1998								
September 17, 1997	0	Sowing	0	0	0	0	0	0	0	0	0
December 30, 1997	104	Winter rosette	2870	4.42	127	0.53	15	0.46	13	17	0.05
March 16, 1998	180	Spring rosette	3519	3.81	134	0.44	15	0.50	18	35	0.12
April 4, 1998	199	Bolting	6765	3.81	258	0.33	22	0.53	36	41	0.28
April 21, 1998	216	Early bloom	8454	3.51	297	0.26	22	0.48	41	45	0.38
May 19, 1998	244	Full bloom	13779	1.34	185	0.18	25	0.38	52	24	0.33
June 11, 1998	267	Pod fill	15810	0.99	156	0.15	24	0.34	53	24	0.37
June 29, 1998	285	Harvest straw	10289	0.55	56	0.21	22	0.18	19	23	0.23
		Harvest seed	3278	2.82	92	0.31	10	0.88	29	11	0.04
		Total at harvest	13567	1.10	149	0.23	32	0.35	48	20	0.27
			1998-1999								
September 11, 1998	0	Sowing	0	0	0	0	0	0	0	0	0
November 25, 1998	75	Winter rosette	2407	4.86	121	0.36	9	0.57	14	27	0.07
February 26, 1999	168	Spring rosette	2719	4.39	124	0.53	15	0.51	14	38	0.11
March 26, 1999	196	Bolting	4534	4.01	189	0.45	22	0.49	23	44	0.21
April 22, 1999	223	Early bloom	9470	2.38	236	0.33	33	0.40	39	44	0.43
May 12, 1999	243	Full bloom	12212	1.56	197	0.32	41	0.35	44	31	0.39
June 10, 1999	272	Pod fill	15376	1.10	175	0.29	47	0.28	44	31	0.50
July 9, 1999	301	Harvest straw	9219	0.56	51	0.30	28	0.09	8	33	0.30
		Harvest seed	3401	3.00	102	0.37	13	0.96	33	13	0.04
		Total at harvest	12620	1.21	153	0.32	40	0.32	41	28	0.35

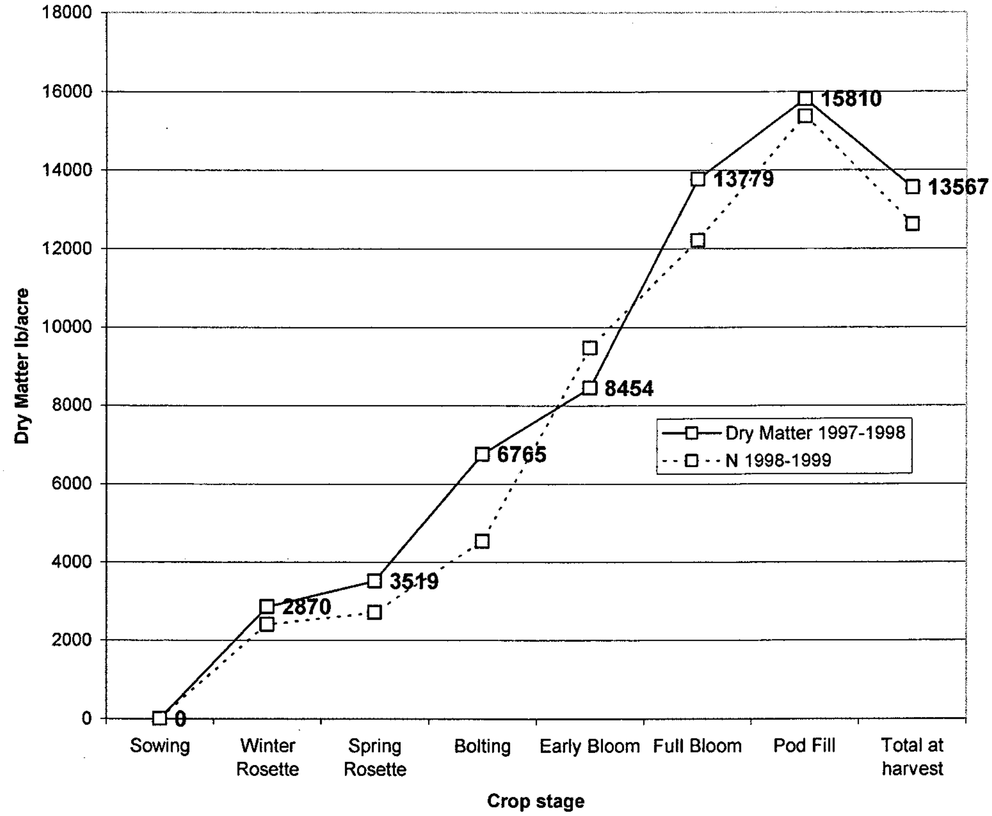

Figure 1. Dry matter accumulation, winter canola, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

later crop stages, and perhaps to partitioning of nutrients to below-ground dry matter. Dry matter and N uptake are plotted in Figure 2 which shows the relationship between nutrient uptake and dry matter accumulation. Nutrient uptake precedes dry matter accumulation (growth). Nitrogen, S, P, and B concentrations and plant uptake are shown in Figures 3-6. Plant tissue concentrations are highest in early crop stages and decline with advancing maturity. The decline in total uptake with advancing crop stage is most likely due to partitioning of nutrients to below-ground tissue, loss from flower drop and leaf senescence, our inability to completely collect all dry matter at later crop stages, and perhaps to volatile loss of N directly from plant tissue. Volatile N loss has been show to occur in wheat (Harper et al. 1987, Parton et al. 1988).

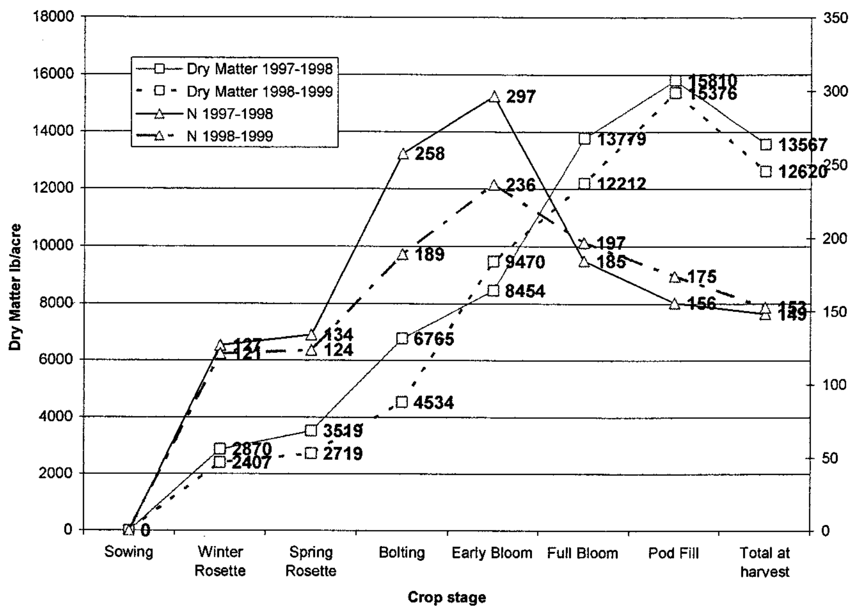

Figure 2. Dry matter accumulation and N uptake on winter canola, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

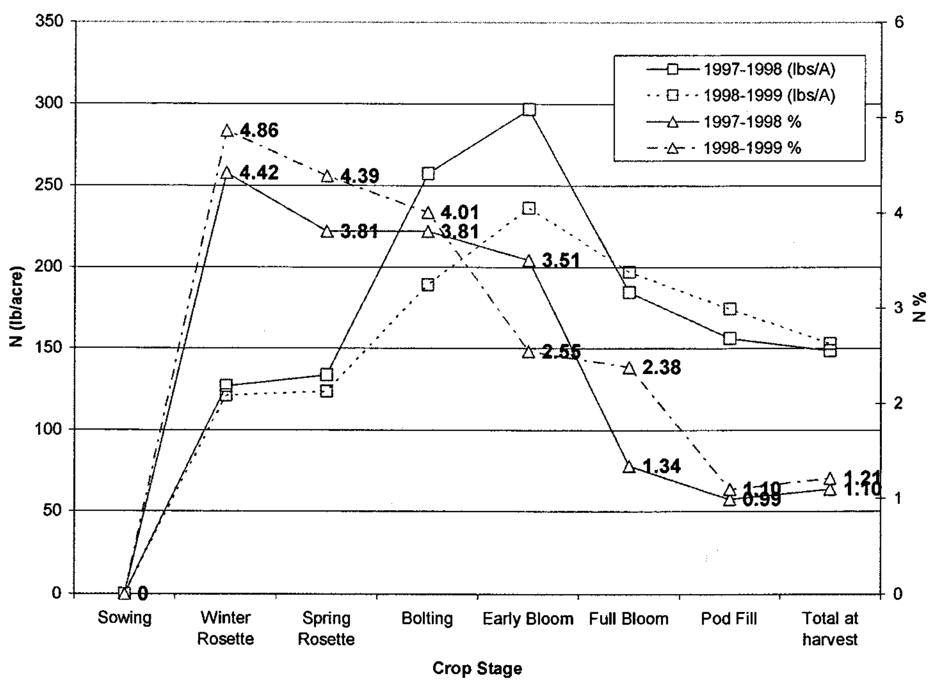

Figure 3. Nitrogen tissue concentration and plant uptake by winter canola, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

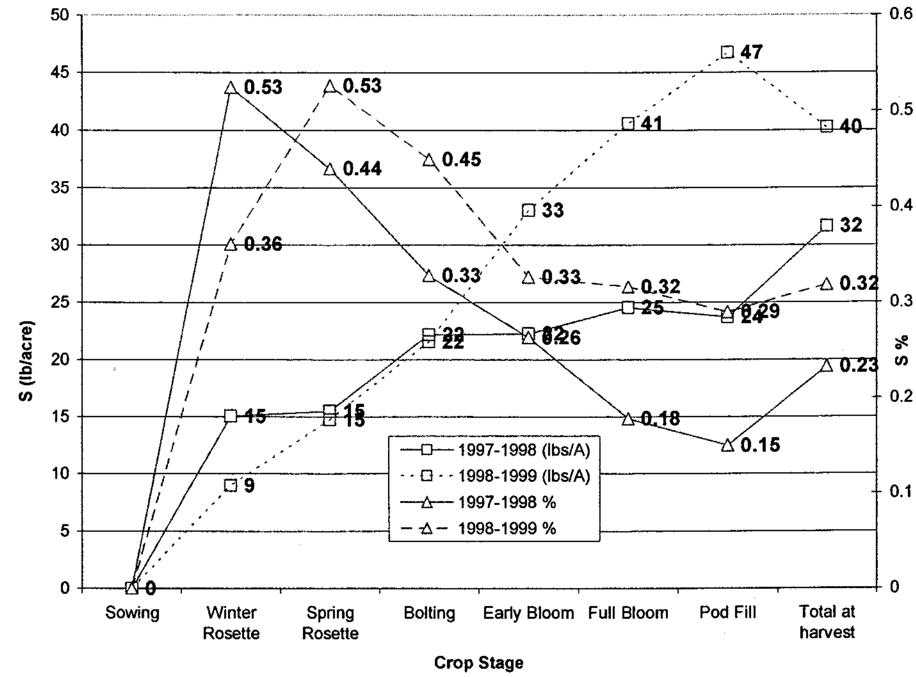

Figure 4. Sulfur tissue concentration and plant uptake by winter canola, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

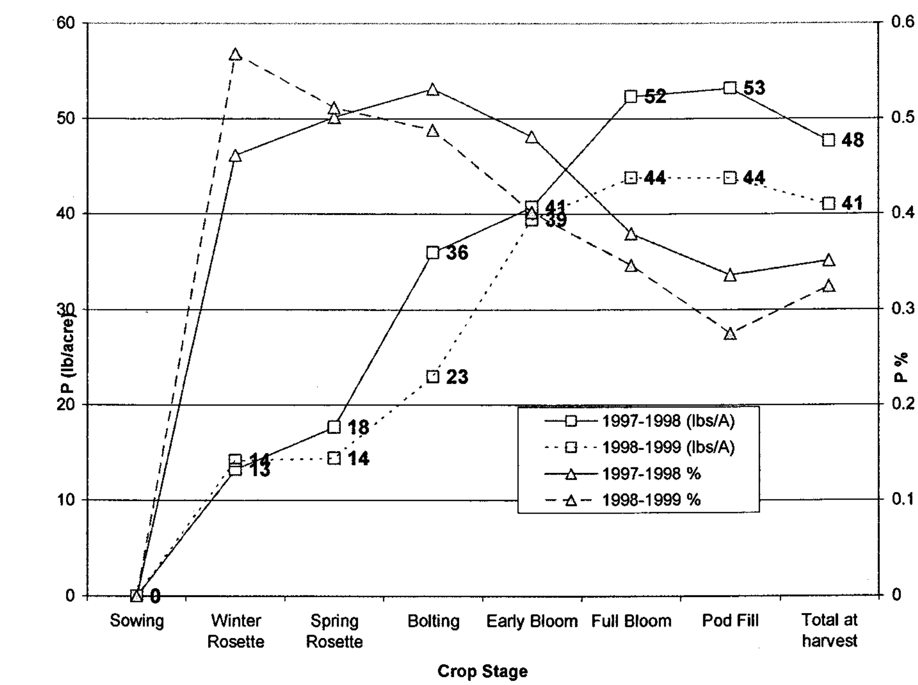

Figure 5. Phosphorus tissue concentration and plant uptake by winter canola, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

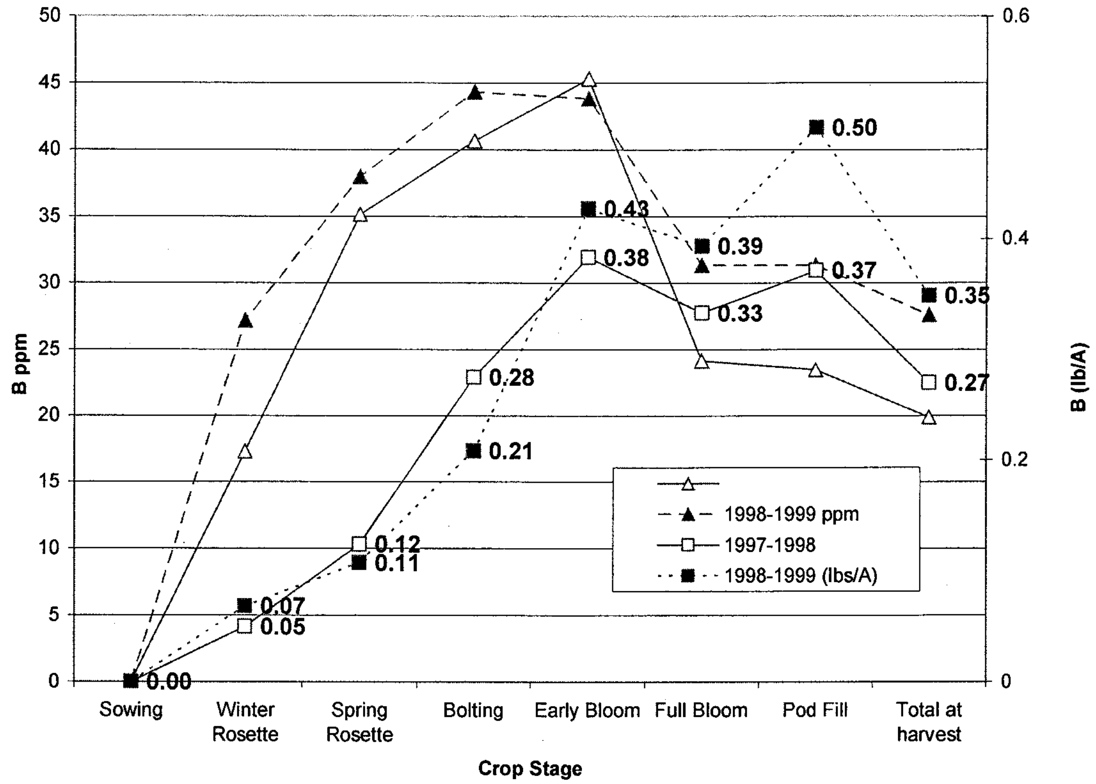

Figure 6. Boron tissue concentration and plant uptake by winter canola, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Dry matter production and nutrient content of seed and crop residue is plotted in Figure 7. Because of scale, dry matter is factored by 100. Seed is approximately one-third of the dry matter, but contains two-thirds of the N, one-third of the S, and three-fourths of the phosphorus taken up by the crop. Total crop year precipitation (September-August) for 1997-1998 and 1998-1999 was 15.57 and 18.35 inches, respectively. However, the spring growing season (March-June) precipitation for these seasons was 6.36 and 4.48 inches. The former was 0.41 inches above, while the latter was 1.47 inches below the spring average.

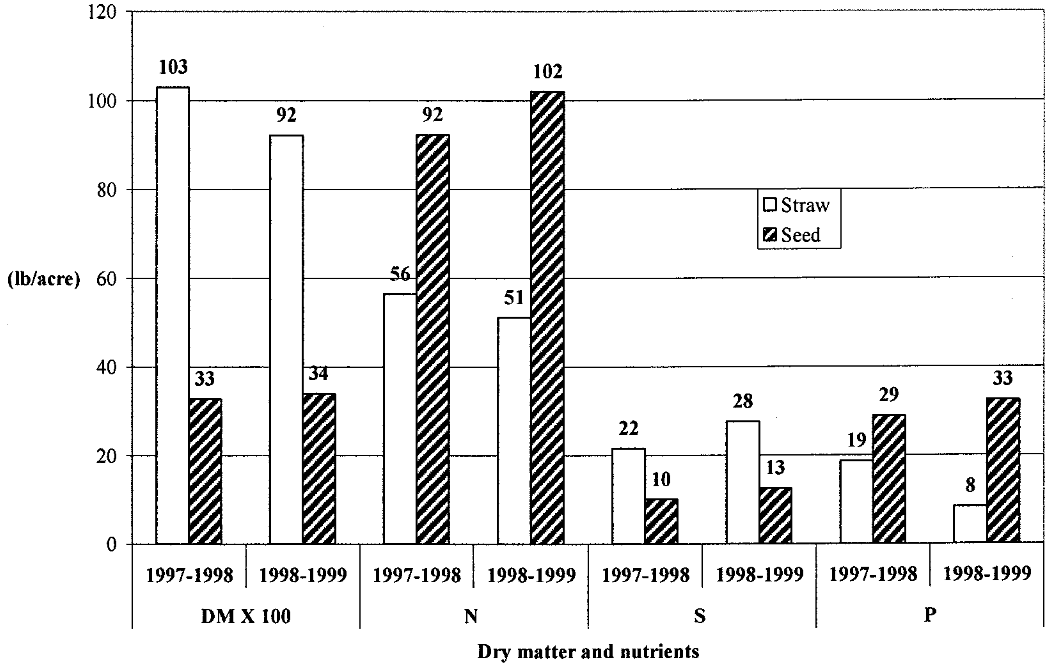

Figure 7. Dry matter and nutrient partitioning in canola residue and seed, Columbia Basin Agricultural Research Center, Pendleton, Oregon .

Conclusions

Canola has high initial N concentrations in the fall rosette growth stage (>4 percent). This accounts for about 50-100 lb/acre uptake in the fall. Plant nutrient concentrations decrease throughout the growth cycle. Maximum uptake is attained at flower and nutrients are lost from the system either by flower and leaf senescence, below-ground partitioning, or incomplete biomass retrieval of volatile nutrient loss from the tissue. When growing winter canola, fertilizer nutrient needs should be supplied in adequate amounts at or prior to bolting. Nutrients supplied after this crop growth stage are likely to be ineffective because it there will be distributed in the root zone for rapid uptake.

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ALTERNATIVE ROTATION CROPS: PEAS (*Pisum sativum*)

Stephen Machado, Brian Tuck, and Christopher Humphreys

Abstract

This article examines the yield potential of new pea varieties including winter types in eastern Oregon. Pea yields are influenced by seeding date, seeding rate, and location. Grain yields ranged from 500 to 3,500 lbs/acre. Winter peas can produce about 4,000 to 5,500 lbs/acre of biomass that can be used for either forage or increasing soil organic matter.

Key Words

Alernative crops, crop mixtures

Introduction

Field pea is the most widely grown cool-season pulse. It is an annual cool-season (55 to 65°F) legume, growing 2 to 5 ft tall. Field pea is adapted to temperate and subtropical environments and is currently produced in both western and eastern Oregon (Sattell 1998). It has a wide range of uses from dry pulses to succulent fresh peas to edible podded types. The production of field pea is increasing in Europe, Canada, and Oceania, where the crop is now being produced for animal feed. Domestic production of field pea is estimated at 344,087 acres and includes dry pea, processing pea, seed pea, and Austrian winter pea (NASS 2004).

Winter pea has been grown in northern Idaho for over 50 years, but increased disease and insect pressures threaten continued production. Commercial seed yields have varied from 1,120 to 3,808 lbs/acre during the past 10 years. Improved cultivars (Auld et al. 1983) and improved cultural management recommendations (Murray et al. 1984, Murray et al. 1987) have ensured continued production of winter peas in northern Idaho. Up to 174,100 acres of Austrian peas were grown in the United States in 2003 (NASS 2004).

Uses

Fall-planted legumes fix nitrogen (N) and provide winter cover to help reduce soil erosion (Murray et al. 1987). Winter peas can be harvested for seed, combined with winter cereals for silage production (Murray et al. 1985), grown for green manure to restore depleted soil organic matter (Auld et al. 1982, Sattell 1998), or combined with winter cereals for harvesting as a multiple seed crop (Murray and Swensen 1984).

Seeding date

Peas are seeded in the fall (winter type) or in the spring (spring type). They require 5, 2, or 1 week(s) to emerge at soil temperatures of 40, 50 or 60°F, respectively. Because spring peas have been grown for quite some time, growers have determined optimum seeding dates for their respective climatic zones. Winter pea is a new alternative crop and agronomic work is required to determine its optimum growing conditions. To this end we conducted seeding date, seeding rate, and variety experiments from the 2001-2002 to 2003-2004 crop-years. To determine the optimum seeding date and seeding rate for winter peas, two lines were grown at the Columbia Basin Agricultural Research Center (CBARC) in Pendleton (45°N, 118° West, elevation 1,440 ft) and at Moro (45°N, 121°West, elevation 1,835 ft). Soils at both stations are Walla Walla silt loams that are 4-6 ft deep. Moro received 8.42, 03, 8.82, and 11.2 inches of precipitation in the 2001-2002, 2002-2003, and 2003-2004 crop-years, respectively and Pendleton received 13.03, 15.4, and 20.2 inches of precipitation in the 2001-2002, 2002-2003, and 2003-2004 crop-years, respectively. The peas were grown at two planting dates and two seeding rates. Data obtained are presented below (Tables 1 and 2). Unfortunately the winter peas in the 2003-2004 crop-year at Pendleton could not be harvested because peas from different plots had grown so big and into each other; we could not distinguish the plots from each other.

There were significant interactions between site, planting date, and variety on grain yield at both sites in both crop-years (Tables 1 and 2). At Pendleton, grain yield of PS9530726 significantly increased when seeded in November while grain yield of PS9430706 was not influenced by seeding date in the 2002-2003 crop-year. The yield of PS9430706 was significantly higher than the yield of PS9530726 for both seeding dates. At Moro, there were no significant differences between the varieties for each seeding date and between the seeding dates. Similar results were obtained at Moro in the 2003-2004 crop-year (Table 2). Grain yields at Moro were, however, much higher during the 2003-2004 crop-year than yields in the previous crop-year. Both varieties appear to be adapted to eastern Oregon conditions. Further work is required.

Table 1 Grain yield of winter pea lines at the Columbia Basin Agricultural Research Center, Pendleton and Moro, OR, 2002-2003.

		Pendleton	Moro
Planting date	Breeders lines	Grain yield (lbs/acre)[a]	
October 15-16	PS9530726	1,241.4	1,140.2
	PS9430706	2,050.8	1,015.2
		1,497.6b	**1,030.1a**
November 11-14	PS9530726	1,623.7	896.5
	PS9430706	1,982.5	1,174.2
		1,773.4a	**899.0a**
$LSD_{0.05}$		319.5	461.4

[a]Means with same letters are not significantly different at the 0.05 probability level. LSD compares means of varieties.

Table 2. Grain yield of winter pea lines at the Columbia Basin Agricultural Research Center, Moro, OR, 2003-2004.

Planting date	Breeders lines	Grain yield (lbs/acre)[a]
October 15-16	PS9530726	1,787.7
	PS9430706	1,930.4
		1,859.1a
November 11-14	PS9530726	1,879.3
	PS9430706	1,606.1
		1,742.2a
$LSD_{0.05}$		425.3

[a]Means with same letters are not significantly different at the 0.05 probability level. LSD compares means of varieties.

Seeding rate, depth, and row spacing

Peas are normally seeded at 7 seeds/ft^2. Depending on variety, there are 1,400 to 3,500 seeds/lb and therefore seeding rates vary from 80 to 200 lbs/acre. For grain/pea mixtures, peas should be 60 to 66 percent of the mixture. We conducted seeding rate experiments at CBARC in Pendleton and Moro during the 2002-2003 and 2003-2004 crop-years. Peas were seeded at either 5 or 7 seeds/ft^2. On average, there was no significant difference in grain yield between the two seeding rates in the 2002-2003 crop-year (Table 3). However, yield of both varieties increased with increase in seeding rate. PS9430706 consistently produced higher yields than PS9530726 and this was significantly so at Pendleton. In the 2003-2004 crop-year, increasing seeding rates significantly increased the average grain yield at Moro (Table 4). There were no data obtained from Pendleton. Based on these results peas should be seeded at 7 seeds/ft^2. The effect of seeding rates higher than 7 seeds/ft^2 was not investigated. Peas are normally seeded in rows 6 to 7 inches apart at a depth of about 2.5 inches; hoe drills are preferred.

Table 3. Seeding rate effects on grain yield of winter pea lines at the Columbia Basin Agricultural Research Center, Pendleton and Moro, OR, 2002-2003.

		Pendleton	Moro
Seeding rate (seeds/ft^2)	Breeders lines	----------Grain yield (lbs/acre) [a]------	
5	PS9530726	1,242.8	848.4
	PS9430706	1,866.2	896.9
		1,554.5a	**872.6a**
7	PS9530726	1,432.5	1,018.4
	PS9430706	2,000.6	1,094.7
		1,716.5a	**1,056.5a**
$LSD_{0.05}$		338.12	292.5

[a]Means with same letters are not significantly different at the 0.05 probability level. LSD compares means of varieties.

Table 4. Seeding rate effects on grain yield of winter pea lines at the Columbia Basin Agricultural Research Center, Moro, OR, 2003-2004.

Seeding rate (seeds/ft^2)	Breeders lines	Grain yield (lbs/acre)[a]
5	PS9530726	1,705.7
	PS9430706	1,739.6
		1,722.7b
7	PS9530726	1,833.0
	PS9430706	1,768.3
		1,800.6a
$LSD_{0.05}$		302.5

[a]Means with same letters are not significantly different at the 0.05 probability level. LSD compares means of varieties.

Fertilizer rates

Like all legumes, peas should be inoculated prior to planting using appropriate bacteria (*Rhizobia*). Apply 20 to 40 lbs N/acre at seeding if the soil test is below 20 lbs N/acre. Phosphorus and potassium rates for peas are similar to small grains. Peas require a pH of 5.9 to 6.5 but can grow in soils with a pH of up to 7.5.

Disease control

Seed treatments using Thiram®, Captan®, or Apron® prevent diseases. Major diseases include seed rot, root rot, and blights of stems, leaves, and seeds caused by *Fusarium solani, Pythium spp,* and *Rhizoctonia solani.* A 4-year rotation is recommended. Peas are affected by *Aschocyta* blight, which causes purplish-black streaks or lesions on leaves, stems, or pods. Peas are also susceptible to pea mosaic virus, which is vectored by the pea aphid. Septoria blight, bacterial blight, powdery mildew, and downy mildew also affect peas.

Weeds

The latest varieties of winter pea grow so much biomass that weeds are smothered. Weed control is critical in early spring when pea plants are small. As temperatures increase, winter peas grow very rapidly and smother most weeds. Herbicides that are commonly used in peas are Pursuit®, Sencor®, Treflan®, and Sonalan®.

Insects

Pea leaf weevil and pea aphid are common insects that infest peas. Scouting methods, economic thresholds, and control measures are discussed in the **Pacific Northwest** Insect Management Handbook (2004).

Flowering and Maturity

Spring peas flower in about 60 days and mature in about 90 to 110 days. High temperatures during flowering may cause flowers to blast. The crop is at physiological maturity when all pods have turned yellow or tan.

Harvesting

Peas are directly combined when seed moisture is less than 20 percent (ideally 16 percent) or swathed before they are too dry. Lodging is common in peas; so swath or combine at a 90-degree angle to the direction of lodging. Use very low cylinder speeds (350-600 rpm) to reduce splitting, concave settings at 0.6 inches, lowered or removed if crop is very dry.

Yield potential

The yield potential of pea is influenced by site and environmental factors. Yields range from 500 to 3,500 lbs/acre. We evaluated 3 winter pea lines at CBARC in Moro in 2001-2002, 6 lines of winter peas at CBARC in Pendleton in the 2002-2003 crop-year, and 12 lines of spring peas at CBARC in Pendleton and in Moro in 2003. Commercial spring wheat varieties were also evaluated in 2002-2004 at Pendleton. Winter and spring peas were planted in October and March, respectively, at a seeding rate of 7 seeds/ft^2. The crops were grown after winter wheat at Pendleton and after fallow at Moro. At Pendleton, seedbed conditions were not ideal due to too much straw from the previous wheat crop, resulting in lower plant stands than at Moro (data not shown). Grain yields of the winter pea varieties ranged from 500 to 3,000 lbs/acre (Tables 5 and 6) and biomass produced by winter peas ranged from 4,000 to 5,500 lbs/acre (Table 5). Spring pea lines produced about 700 to 1,100 lbs/acre at Pendleton and 300 to 600 lbs/acre at Moro (Table 7). Winter pea lines yield 1,200 to 1,900 lbs/acre more than spring types.

The effect of precipitation is clearly demonstrated in Table 8. Grain yields of commercial spring varieties increased by 3 to 4 times in the 2003-2004 crop-year compared to yields in the previous years. Precipitation at Pendleton was 20 inches in the 2003-2004 crop-year compared to 15 inches and 13 inches in 2002-2003 and 2001-2002, respectively. Grain yields ranging from 2,700 to 3,200 lbs/acre were obtained in the 2003-2004 crop-year. The variety 'Universal' appears to yield well under both dry and wet years but the yield was not significantly different from 'Badminton' and 'Mozart' under dry or wet conditions. We therefore recommend all three varieties to growers.

Table 5. Biomass and grain yield of winter peas at the Columbia Basin Agricultural Research Center, Pendleton and Moro, 2001-2002 crop year.

Entry	Biomass (lbs/acre)[a]	Grain yield (lbs/acre)
PS9430706	5,684.3a	1,415.6a
PS9430726	4,640.8b	1,388.9a
PS9530645	4,747.9b	532.6b

[a]Means with similar letters are not significantly different at the 0.05 probability level.

Table 6. Grain yield and height of Elite winter pea lines evaluated in the 2003-2004 crop-year at the Columbia Basin Agricultural Research Center, Pendleton, OR.

Entry no.	Accession no.	Grain yield (lbs/acre)	Plant height (in)
1	PS-010	2,628.0	52.0
2	PS-431	1,902.4	42.8
3	PS-448	2,367.1	47.3
4	PS-358	2,859.3	33.5
5	PS-011	2,459.7	33.1
6	PS-009	3,136.8	45.8
$LSD_{0.05}$		1,183	11.0

Table 7. Grain yield and height of Western Regional dry pea lines evaluated at the Columbia Basin Agricultural Research Center, **Pendleton and Moro, OR** in 2003.

Entry no.	Accession no.	Pendleton		Moro	
		Grain yield (lbs/acre)	Plant height (in)	Grain yield (lbs/acre)	Plant height (in)
1	PS610152	1,162.8	9.6	475.1	8.1
2	PS710048	1,027.3	9.8	482.6	8.1
3	PS810162	735.5	9.8	370.4	7.5
4	PS810191	1,122.0	10.4	431.0	8.3
5	PS810240	1,243.8	9.4	718.8	7.0
6	PS9910346	1,001.7	9.8	574.1	7.9
7	PS9910592	977.0	9.9	431.0	8.3
8	PS710909	801.7	9.9	311.9	8.1
9	PS99101364	793.6	10.4	287.2	8.4
10	PS99101381	835.2	10.0	308.3	7.9
11	PS9910140	1,066.4	9.9	646.8	7.9
12	PS9910188	1,319.0	10.3	679.3	7.5
$LSD_{0.05}$		320.5	0.8	173.4	0.8

Table 8. Grain yield and height of commercial spring pea varieties in the 2002, 2003, and 2004 crop-years at the Columbia Basin Agricultural Research Center, Pendleton, OR.

	2002		2003		2004	
Variety	Grain yield (lbs/acre)	Plant height (in)	Grain yield (lbs/acre)	Plant height (in)	Grain yield (lbs/acre)	Plant height (in)
Jasmine	613.5	15.8	-	-	-	-
Badminton	779.7	12.3	797.2	13	2,736.1	33.0
Midas	670.7	14.3	-	-	-	-
Eiffel	779.2	16.5	-	-	-	-
Universal	858.0	14.3	767.4	17.8	3,267.5	42.8
Mozart	-	-	786.3	11.9	2,945.5	37.0
$LSD_{0.05}$	143.5	3.2	166.2		553.6	3.8

Rotation effects

Peas can be grown in a mixture with barley, oat, triticale, or wheat. Peas are an excellent N fixing crop (more than 100 lbs N/acre/year) (Heichel 1987) and have great potential as a green manure crop to replace fallow. Peas can return more than 80 lbs N/acre to the soil if killed in mid-season. The response of pea to moisture is similar to wheat.

Production costs and marketing

Price ranges from $5.50 to more than $11.00/cwt can result in potential gross returns of $82.50 to $165.00/1,500 lbs/acre.

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LONG-TERM EXPERIMENTS AT CBARC-PENDLETON, 2004

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Abstract

The Columbia Basin Agricultural Research Center (CBARC) is home to the oldest experiments in the Pacific Northwest (PNW). The perennial grassland, conventional-till continuous cereal, and crop residue management experiments were initiated in 1931, and the tillage-fertility, wheat-pea rotation experiments were initiated in 1940 and 1963. In 1998, a no-till continuous cereal was added to mirror the conventional-till continuous cereal. This article summarizes the results obtained in 2004. The *perennial grassland* serves as a baseline for comparisons with other systems. *Continuous cereal*: in both conventional and no-till cropping systems, spring barley produced the highest yield, followed by winter wheat and then spring wheat. Winter wheat, spring barley, and spring wheat produced higher yields under conventional tillage than under the no-till cropping system. *Crop residue*: highest yields were obtained when manure was applied, followed by 80-lb nitrogen (N) rates. Treatments involving field burning without N application and check treatments resulted in the lowest yields. *Wheat-pea rotation*: for wheat, highest yields were produced under no-till management. Spring plow, fall plow, and fall chisel treatments all had lower yields. For peas, highest yields were produced in the no-till and spring plow treatments. Fall plow and fall disk treatments had lower yields. *Tillage fertility*: tillage fertility plots were in fallow during 2004. *Continuous no-till winter wheat (USDA):* yields and test weights continue to be collected on this trial with a 7-year average yield of 70.9 bu/acre.

Key Words

Carbon sequestration, cropping systems, organic matter

Introduction

Long-term research guides future agricultural development by identifying the effects of crop rotation, variety development, fertilizer use, aerial and surface contamination, and organic amendments on soil productivity and other beneficial soil properties. Comprehension and evaluation of many changes often require 10-20 years to identify and quantify. Soil microflora and soil-borne plant pathogens require from 2 to 8 years in a new cropping sequence or tillage system to reach a stable equilibrium. To this end, long-term experimentation is required to understand interactions among soil, water, and plant factors for both agronomic and agricultural policy decisions. The oldest experiments in the PNW are at CBARC, Pendleton, in the intermediate rainfall zone (Table 1). Below is a brief description of these experiments and the results obtained in the 2004 crop year. The treatments have changed over the years and the descriptions below refer to current procedures. Detailed descriptions of the protocols and how they have changed over time have been compiled into a database located on our network server.

Description of Experiments

Table 1. Long-term experiments at Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Experiment	Treatments	Year initiated
Perennial grassland	None	1931
Conventional-till continuous cereal	Fertility, tillage	1931
Residue management	N, manure, burning, pea vine	1931
Tillage-fertility	Tillage, fertility	1940
Wheat-pea	Tillage, fertility	1963
No-till continuous cereal	Fertility, tillage	1998
Continuous no-till winter wheat (USDA)	None	1998

Perennial grassland

The perennial grassland site (150 ft wide by 360 ft long) contains no experimental variables but has been maintained since 1931. The site is intended to approximate a near-virgin grassland and serves as a baseline for evaluating changes in other cropping systems. It is periodically reseeded with introduced grass selections, occasionally fertilized, and infrequently irrigated. The dominant grass species are bluebunch wheatgrass (*Agropyron spicatum var. 'Secar'*) with lesser amounts of Idaho fescue (*Festuca idahoensis var. 'Joseph'*). Weeds, particularly witchgrass (*{Panicum capillare*), common mallow (*Malva neglecta*), and downy brome (*Bromus tectorum*), are controlled as needed. In 2004, prickly lettuce (*Lactuca serriala*) made an appearance in areas where the grass stand was thin. This stand was renovated and reseeded during 2002 and 2003. Broadleaf weeds were controlled in 2003 and 2004 with broadcast applications of dicamba/carfentrazone-ethyl and 2,4-D amine/MCPP mixtures and spot applications of MCPA. This site received limited grazing from 1931 to 1985. It has not been grazed since but vegetation is sometimes clipped during or after summer growth. Above-ground productivity was measured in 2004 for the first time since renovation. Species counts were initiated in 2004. A 10-year comprehensive soil sampling was begun in 2004.

Continuous cereal

The objectives of the various continuous cereal monocultures have varied over the years; however, the current objective is to determine the effects of annual mono-cropping on crop yield and soil productivity. Annual monoculture plots of winter and spring wheat and spring barley, using plow (inversion) tillage are maintained. In each plot there are fertilized and unfertilized blocks. Treatment histories for the tilled plots are shown in Table 2. A no-till (direct seeded) annual winter and spring wheat and spring barley companion plot was established in 1998 and the treatments are shown in Table 3. The plots are not replicated. The most practical, generally recommended methods and equipment available to growers are used. In 2004, a John Deere (JD) 8300 double disk drill on 6.8-inch spacing was used to seed all conventional-till monocultures. In 2004 a JD 1560 disk drill on 7.5-inch spacing was used to seed no-till spring barley and no-till spring wheat monocultures. A Conservapak (CP) hoe drill on 12-inch spacing was used to seed the no-till winter wheat monoculture. Spring barley plots were seeded to

'Baronesse', spring wheat plots were seeded to 'Zak', and winter wheat plots were seeded to 'Stephens'. Target seeding rates are contained in Table 4. All fertilized monocultures received the equivalent of 100 lbs/acre of 16-20-0-14 (nitrogen [N], phosphorus [P], potassium [K], sulfur [S]). In conventional-till spring plots this was applied as a plowdown dry product. In conventional-till winter wheat plots this was shank-applied after plowing. In no-till monocultures this was drill-applied at seeding either as a liquid or a dry product. In conventional-till spring plots the balance of the N was applied as plowdown urea granules. In the conventional-till winter wheat monoculture the balance of the N was shank-applied after plowing as urea ammonium nitrate solution. In no-till monocultures the balance of the N was drill-applied as urea granules in the no-till winter wheat plot or as urea ammonium nitrate solution in the spring no-till monocultures.

Glyphosate was applied to all monocultures before sowing or plowing. Bromoxynil was used to control broadleaf weeds in the winter wheat no-till monoculture. Bromoxynil and MCPA ester was used to control broadleaf weeds in all other monocultures. Downy brome was controlled in the conventional-till winter wheat monoculture with preplant incorporated diclofop-methyl and pre-emergence metribuzin applications. Downy brome was controlled in the no-till winter wheat monoculture with a preplant application of triallate and a preemergence application of metribuzin. Except for the conventionally tilled spring-sown mono-cultures, all unfertilized components of the other monocultures required a post-harvest treatment with glyphosate for post-harvest broadleaf control. Post-harvest treatment was not required in any of the fertilized components of this experiment.

Table 2. Treatment history of the tilled continuous cereal monocultures, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Period	Crop grown	Variables	N application
1932-1950	Winter wheat	Fertilizer rate and type	0-126
1951-1958	Winter wheat	None	0
1959-1976	Winter wheat	None	70
1977-1992	Winter wheat	None	80
1993-present	Winter wheat	Fertility	0,80
1932-1953	Spring wheat	Fertilizer rate and type	0-94
1954-1958	Spring wheat	None	0
1959-1976	Spring wheat	None	74
1977-1992	Spring wheat	None	80
1993-present	Spring wheat	Fertility	0,80
1982-1994	Spring barley	None	80
1994-present	Spring barley	Fertility	0,80

Table 3. Treatment history of the direct-seeded continuous cereal monocultures, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Period	Crop grown	Variable	N application
1998-present	Spring barley	N rate	0,90
1998-present	Spring wheat	N rate	0,90
1998-present	Winter wheat	N rate	0,100

Table 4. Target seeding rates and stand for fertilized continuous cereal monocultures, Columbia Basin Agricultural Research Center, Pendleton, Oregon, 2004.

Crop grown	System	Target seeding rate (seeds/ft^2)	Stand (plants/ ft^2)
Winter wheat	Conventional till	22	16
Winter wheat	No till	25	13
Spring barley	Conventional till	23	16
Spring barley	No till	26	22
Spring wheat	Conventional till	26	22
Spring wheat	No till	29	25

Table 5. Treatment history of the residue management (CR) experiment, Columbia Basin Agricultural Research Center, Pendleton, Oregon..

		1931-1966		1967-1978		1979 to present	
Trt No.	Organic N addition	RT[a]	N[b]	RT	N	RT	N
1	---[c]	--	--	--	--	--	--
2	---	FD	0	NB	40	SB	40
3	---	SD	0	NB	80	SB	80
4	---	NB	30	NB	40	NB	40
5	---	NB	30	NB	80	NB	80
6	---	FB	0	FB	0	FB	0
7	---	SB	0	SB	0	SB	0
8	Manure[d]	NB	0	NB	0	NB	0
9	Pea vines[e]	NB	0	NB	0	NB	0
10	---	NB	0	NB	0	NB	0

a Residue treatment: FD = fall disk, SD = spring disk, NB = no burn, FB = fall burn, SB = spring burn.
b N rate (lb/acre/crop); applied early October of crop year.
c 1 ton/acre/crop field weight alfalfa hay applied to plot 11 1939-1949 1-3 days prior to plowing.
d Manure = 10 tons/acre/crop wet weight; 47.5 percent dry matter; 1,404 lb C and 113 lb N/acre/crop; applied in April or May of plow year (1-3 days prior to plowing).
e Pea vines = 1 ton/acre/crop field weight; 88.4 percent dry matter; 733 lb C and 34 lb N/acre/crop; applied 1-3 days prior to plowing.

Crop residue management

The crop residue experiment is the most comprehensive of the long-term experiments at Pendleton. The objective of the experiment is to determine the effects of N application, burning, and pea vine and manure application on soil properties and productivity in a conventional moldboard plow, winter wheat-summer fallow production system. Treatment history is shown in Table 5. The experimental design is an ordered block consisting of 9 treatments (10 originally) and 2 replications. The experiment contains duplicate sets of treatments that are offset by 1 year so that data can be obtained annually. In 2004, plots were seeded to 'Stephens' using a JD 8300 double disk drill on 6.8-inch spacing. The target sowing rate was 22 seeds/ft^2.

Glyphosate was applied before plowing in the spring of 2003. Broadleaf weeds were controlled with bromoxynil and MCPA ester in the spring of 2004.

Tillage fertility

The objective of the tillage fertility experiment is to determine the effects of three tillage regimes and six N rates on soil properties and productivity in a tilled winter wheat-summer fallow production system. Treatments are shown in Table 6. The experimental design is a randomized block split-plot with three replications. Main plots consist of three primary tillage systems (moldboard plow, offset disk, and subsurface sweep) and subplots of six fertility levels. These plots were in fallow during 2004.

Table 6. Treatment history of the tillage-fertility (TF) experiment, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Primary treatment (tillage)		Tillage depth	Average residue cover
Symbol	Type	(inches)	at seeding (%)
MP	Moldboard plow	9	7
DI	Offset disk	6	34
SW	Subsurface Sweep	6	43

Subtreatment (fertility)		N rate (lb/acre/crop)[a]			
No.	Sulfur application	1941-1952	1953-1962	1963-1988	1989-present
1	No	0	0	40	0
2	Yes	10	30	40	40
3	No	0	0	80	80
4	Yes	10	30	80	80
5	Yes	10	30	120	120
6	Yes	10	30	160	160

[a]N applied 7-14 days prior to seeding as ammonium sulfate from 1941 to 1962, ammonium nitrate from 1963 to 1988, and urea-ammonium nitrate since 1989. N was broadcast from 1941 to 1988, and banded 6 inches deep with 12-inch row spacing since 1989.

Wheat/pea

The wheat/pea experiment was established in 1963. The objective of the experiment is to determine effects of four different tillage regimes on soils properties and productivity in a wheat/legume annual crop rotation. Treatments are shown in Table 7. Crop rotation is winter wheat/dry spring pea and the experimental design is a randomized block with four replications. Each replication contains eight plots (four treatments duplicated within each replication). Duplicate treatments, offset by 1 year, ensure yearly data collection for both wheat and peas. In 2004, all tilled plots were seeded using a JD 8300 double disk drill on 6.8-inch spacing. In 2004 no-till pea plots were sown with a JD 1560 drill on 7.5-inch spacing and no-till wheat plots were sown with a Great Plains double disk drill on 10-inch spacing. Target sowing rates were 22 seeds/ft^2 for winter wheat and 8 seeds/ft^2 for spring pea. 'Stephens' winter wheat and 'Universal' dry yellow pea were sown in 2004. All fertilizer was applied as preplant shank-applied liquid fertilizer. Tilled winter wheat plots received 80 lb N/acre and no-till winter wheat plots received 90 lb N/acre. All pea plots received 16 lb N/acre. Both peas and wheat received P and S along with the N application. Glyphosate was applied to both peas and wheat before sowing or tillage. Downy brome was controlled in the no-till wheat plots with a preplant application of triallate. This was followed with a spring postemergence application of metribuzin coupled with a bromoxynil treatment to control broadleaf weeds. Conventional-till wheat plots had a preemergence application of metribuzin to control downy brome and a spring application of bromoxynil and MCPA to control broadleaf weeds. Peas received a postplant incorporated application of metribuzin and imazethapyr for broadleaf control.

Continuous no-till winter wheat (USDA)

These plots were established as no-till in the fall of 1997. Prior to that year the plots were planted to conventionally tilled winter wheat each fall since 1931. Crop years 1998 and 1999 included two no-till drill treatments in addition to different fertilizer types, rates, and placement. From crop year 2000 to present, the drill used, fertilizer regime, and seeding rate have been relatively unchanged. A preseeding application of Round-up Ultra® (glyphosate) is made each fall at a rate of 24 oz/acre. The Conservapak drill is used to seed 'Stephens' winter wheat in mid- to late October at a target rate of 25 seeds/ft^2 or approximately 100 lb/acre. At seeding, the Conservapak delivers all fertilizer down the fertilizer shank below and to the side of the seed at rates of 105 lb/acre of 16-20-0 and 185 lb/acre of 46-0-0. A broadleaf herbicide application is made in the spring using Banvel® (dicamba) at 4 oz/acre and Bronate® (Bromoxynil plus MCPA ester) at 1.5 pt/acre. Clarity® (Dicamba) plus Salvo® (isooctyl ester of 2,4-D) was applied in April 2001. Flailing of standing stubble is done after harvest.

Table 7. Current treatments of the wheat/pea (WP) experiment, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

Treatment		Primary tillage	
No.	Identification	Wheat stubble	Pea vines
1	Max till	Disk (fall)	Chisel (fall)
2	Fall plow	Plow (fall)	Plow (fall)
3	Spring plow	Plow (spring)	Plow (fall)
4	No till	No till	No till

Efforts are being made to control cheatgrass using herbicides and changing varieties but cheatgrass is still a major problem in this experiment. Maverick® (Sulfosulfuron) was applied in March 1999. Fargo® (Triallate) was incorporated at seeding in October 2001. A Clearfield® wheat variety was planted in October 2002, with Beyond® (Imazamox) applied in March 2003. Maverick was applied again in March 2005. Hand weeding of goatgrass has been effective.

Results and Discussion

Precipitation and temperature

The Pendleton station received 118 percent of the 74-year average crop-year precipitation in 2004 (Table 8). Winter precipitation amounted to 114 percent of the 74-year average winter precipitation and spring precipitation was 126 percent of the 74-year average spring precipitation. Only the months of September, October, and November of 2003 and March of 2004 had below-average precipitation. Based on growing degree days (GDD), the crop-year, winter, and spring temperatures were slightly warmer than the 74-year average (Table 8). Only the months of November 2003 and January 2004 had below-normal temperature averages.

Managed perennial grassland

This perennial grassland serves as a baseline for comparisons with other systems. Usually scientists sample the area to obtain data to answer specific questions they are investigating at other sites. Above-ground biomass was measured for the first time since 1996. Species counts were done in the spring of 2004. A comprehensive 10-year sampling was done in 2004 to determine carbon status and other characteristics of this area.

Continuous cereal

Plant stand

In both conventional and no-till winter wheat plots, plant stands in the fertilized portion of each monoculture were equal to those of the unfertilized portion. Stands of all monocultures except for the no-till winter wheat monoculture equaled 71 to 86 percent of targeted sowing rates (Table 4).

Table 8. Precipitation and growing degree days (GDD) in the 2004 crop-year, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

	2004	74-year average
Fallow year precipitation (in)	15.65 (2003)	16.46
Crop-year precipitation (in) Sept 1-June 30	18.63	15.67
Two-year precipitation (in)	34.28 (2003-2004)	32.13
Winter season precipitation (in) Sept 1-Feb 28	11.09	9.71
Spring season precipitation (in) March 1-June 30	7.54	5.96
Crop-year GDD Sept 1-June 30	2,788.9	2,641.9
Winter season GDD Sept 1-Feb 28	1,287.8	1,230.0
Spring season GDD March 1-June 30	1,501.1	1,411.8

The stand in the no-till winter wheat monoculture was only 52 percent of the targeted sowing rate. In general, precipitation and temperatures were adequate in the fall of 2003 and the spring of 2004 to achieve adequate stands under most conditions. Percent residue cover, measured with a line-transect method, varied from 91 to 100 percent for all no-till monocultures and from 36 to 85 percent for all conventional-till monocultures.

Grain yield and yield components and other measurements

The continuous cereal cropping systems plots are not replicated and therefore combine yield cannot be statistically compared. However, it is statistically acceptable to compare the systems through t-tests conducted on four bundle samples obtained from each monoculture. Bundle grain yields were highly correlated to combine grain yields (r = 0.95, $P < 0.01$). Combine yields will be discussed in this paper. For brevity, only significant tests for combine grain yield will be shown (Table 10). In 2004 downy brome did not affect yield in any of the winter-sown monocultures (Table 9). Stripe rust (*Puccinia striiformis*) seriously affected all spring wheat monocultures that were sown to the variety 'Zak'. On June 18, 2004, 30 percent of the flag leaves had greater than 5 percent of their surface area covered. At this time the variety had 50 percent of its heads fully emerged from the boot. The extent of yield loss from stripe rust is not known. Other variables that were measured were combine grain yield, bundle grain yield, test weight, kernel weight, harvest index, percent protein, heads/ft^2, spikelets/head, and kernels/head.

Fertility effects

For all monocultures, fertilized plots produced significantly higher grain yields than unfertilized plots (Tables 9 and 10). Combined data indicate that unfertilized plots yielded 55 percent of fertilized plots. Fertilizer application in no-till winter wheat and no-till spring barley monocultures did not significantly affect test weight. Both in the no-till and conventional-till treatments of spring wheat and conventional-till spring barley monocultures, test weights were significantly reduced by fertilization. Fertilization with N significantly increased test weight in the conventionally tilled winter wheat monocultures. Kernel weights were significantly decreased by fertilizer application in all spring and winter wheat monocultures. In spring barley monocultures, kernel weight was increased by fertilization. Nitrogen fertilizer significantly increased percent protein in all monocultures. In no-till spring barley and spring wheat monocultures, fertilization increased the average percent protein by 2.9 percent. The number of heads/ft^2 was significantly increased by fertilization. The number of heads/ft^2 in unfertilized monocultures was about 61 percent of the heads/ft^2 in fertilized monocultures. Spikelets/head were significantly increased by fertilization in the conventional till spring wheat monoculture and the no-till winter wheat monoculture. Kernels/head were not significantly affected by fertilizer.

Conventional tillage

The t-test results for combine grain yield (Table 9) are shown in Table 10. Conventionally tilled fertilized winter wheat and spring barley yielded significantly more than spring wheat (Tables 9 and 10). Spring barley yields were not significantly different from winter wheat. Among the conventionally tilled unfertilized plots, spring barley produced significantly more grain yield than winter wheat and spring wheat. There was no significant difference in grain yield between unfertilized winter wheat and unfertilized spring wheat. High yield in unfertilized and fertilized spring barley was attributed to high numbers of heads/ft^2 and spikelets/head. Among the conventionally tilled fertilized plots, winter wheat produced significantly higher grain protein than spring wheat and spring barley. Among the conventionally tilled unfertilized plots, winter wheat produced significantly higher grain protein than spring barley but this was not significantly different from spring wheat grain protein.

No-till

The t-test results for combine grain yield (Table 9) are shown in Table 10. Among no-till fertilized monocultures, spring barley produced significantly higher yields than winter wheat and spring wheat. Winter wheat yields were significantly higher than spring wheat (Tables 9 and 10). Among no-till unfertilized monocultures, spring barley yields were significantly higher than spring wheat yields and spring wheat yields were significantly higher than winter wheat yields. High yield in unfertilized and fertilized spring barley was attributed to high numbers of heads/ft^2, spikelets/head, and kernel weight. Among no-till unfertilized monocultures, winter wheat had significantly higher grain protein than spring wheat and spring barley.

Conventional tillage v. no-till

Under both fertilized and unfertilized situations, conventional-till winter wheat yielded significantly more than no-till winter wheat. High yield in conventional-till winter wheat was attributed to high kernel weight and kernels/head in fertilized crops and to high kernel weight, heads/ft^2, spikelets/head and kernels/head in unfertilized plots (Table 9). Conventional-till spring wheat yielded significantly more than no-till spring wheat under fertilized conditions. No significant differences in yield were observed between unfertilized conventional-till and no-till spring wheat. High yield in conventional-till spring wheat was attributed to high kernel weight, spikelets/head, and kernels/head. There were no significant differences in yields of no-till spring barley and conventional-till spring barley under fertilized conditions but the no-till spring barley yielded significantly less than unfertilized conventional-till spring barley. High yield in unfertilized conventional-till spring barley was attributed to high kernel weight, heads/ft^2, and spikelets/head.

Crop residue management

Crop residue plots were seeded at a target rate of 22 seeds/ft^2. Treatment had no significant effect on resulting stand, which varied from 68 to 82 percent of target plants (Table 11). No downy brome was present in these plots and surface residue after seeding was insignificant. Combine grain yield and bundle grain yield were highly correlated ($r = 0.91$, $P < 0.0001$) and treatment significantly affected grain yield. Manure plots had the highest yields, followed by N treatments, spring burn N and pea vine treatments, and check; spring and fall burn treatments had the lowest yield. Both burn treatments yielded significantly less than treatment 1 (check). The yield of the 80-lb N spring burn treatment was significantly higher than the 40-lb N spring burn treatment. Grain yield was significantly correlated with plant stand ($r = -0.34$, $P < 0.05$), heads/ft^2 ($r = 0.61$, $P < 0.0001$), harvest index ($r = 0.73$, $P < 0.0001$), and grain protein ($r = 0.80$, $P < 0.0001$). Grain protein content was significantly affected by treatment and ranged from 6.5 percent in the fall burn treatment to 9.8 percent in the unburnt 80-lb fertilized treatment. Spring burning did not significantly reduce grain protein content. Grain protein content in manure plots was intermediate between 80-lb fertilized treatments and 40-lb fertilized treatments. The grain protein content of pea vine plots was similar to 40-lb fertilized treatments. Check plots had grain protein content significantly higher than both burn treatments.

Table 9. Comparisons of no-till and conventional-till monocultures with and without nitrogen (N) fertilizer, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

	CTCWW[a]		CTCSW		CTCSB		NTCWW		NTCSW		NTCSB	
N fertilizer	+ N	- N	+ N	- N	+ N	- N	+ N	- N	+ N	- N	+ N	- N
Stand count plants/ft^2	16.3	19.9	21.9	21.4	16.4	17.3	13.0	10.8	24.9	25.6	22.3	20.8
Combine yield bu/acre	85.0	35.7	62.4	41.5	104.7	60.4	68.4	24.6	46.2	40.2	106.4	44.8
Bundle yield bu/acre	95.4	60.8	66.0	48.9	103.1	65.8	76.5	31.7	49.9	43.7	112.8	59.8
Test weight lb/bu	58.5	59.1	57.2	60.3	53.8	53.0	57.5	58.8	53.1	59.5	52.6	52.1
1,000-kernel weight combine grain oz	1.63	1.85	1.11	1.51	1.51	1.44	1.40	1.67	0.78	1.43	1.44	1.38
1,000-kernel weight bundle grain oz	1.75	1.53	1.19	1.51	1.52	1.41	1.48	1.64	0.87	1.43	1.41	1.42
Percent grain protein	9.9	8.6	9.6	8.5	9.3	8.2	10.0	8.9	10.6	7.9	11.0	7.9
Harvest index	0.40	0.43	0.37	0.42	0.45	0.30	0.40	0.40	0.29	0.38	0.43	0.48
Heads/ft^2	44.2	30.4	45.1	28.4	65.7	46.9	43.3	24.7	55.8	31.7	85.1	44.2
Spikelets/head	15.2	17.2	16.7	14.2	21.2	20.8	15.7	14.1	15.7	12.9	20.4	18.8
Kernels/head	37.9	38.5	30.6	28.9	18.3	17.7	33.8	31.9	27.8	24.3	19.0	16.6
Downy brome plants/ft^2	0.2	0.4	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
Percent residue at seeding	36	44	85	46	39	25	100	100	95	93	99	91

[a]CTCWW: conventional-tillage continuous winter wheat.
CTCSW: conventional-tillage continuous spring wheat.
CTCSB: conventional-tillage continuous spring barley.
NTCWW: no-tillage continuous winter wheat.
NTCSW: no-tillage continuous spring wheat.
NTCSB: no-tillage continuous spring barley.

Table 10. T-test comparisons of mean bundle yield under different continuous cereal cropping systems in 2004 (Pr > t), Columbia Basin Agricultural Research Center, Pendleton, Oregon.

	ctcwwf[a]	ctcswf	ctcsbf	ctcwwnf	ctcswnf	ctcsbnf	ntcwwf	ntcswf	ntcsbf	ntcwwnf	ntcswnf
ctcswf	***[b]										
ctcsbf	ns[c]	**									
ctcwwnf	**	**	***								
ctcswnf	***	**	***	ns							
ctcsbnf	***	**	***	*	*						
ntcwwf	**	ns	**	**	****	**					
ntcswf	****	**	***	ns	ns	ns	***				
ntcsbf	ns	**	ns	****	**	**	*	**			
ntcwwnf	****	****	****	*	*	**	***	**	****		
ntcswnf	****	**	****	ns	ns	*	****	**	**	**	
ntcsbnf	****s	**	****	ns	*	**	****	**	**	*	*

[a]ctcwwf – conventional tillage, continuous winter wheat, fertilized.
ctcswf– conventional tillage, continuous spring wheat, fertilized.
ctcsbf– conventional tillage, continuous spring barley, fertilized.
ctcwwnf – conventional tillage, continuous winter wheat, no fertilizer.
ctcswnf– conventional tillage, continuous spring wheat, no fertilizer.
ctcsbnf– conventional tillage, continuous spring barley, no fertilizer.
ntcwwf – no tillage, continuous winter wheat, fertilized.
ntcswf – no tillage, continuous spring wheat, fertilized.
ntcsbf – no tillage, continuous spring barley, fertilized.
ntcwwnf – no tillage, continuous winter wheat, no fertilizer.
ntcswnf – no tillage, continuous spring wheat, no fertilizer.
ntcsbnf – no tillage, continuous spring barley, no fertilizer.

[b]*, **, ***, and ****: means significantly different at the 0.05, 0.01, 0.001, and 0.0001 levels of probability.

[c]ns–means not significantly different.

Table 11. Crop residue data for 2004, Columbia Basin Agricultural Research Center, Pendleton, Oregon.

	Check 1	Check 10	Spring burn 40 lb N/acre	Spring burn 80 lb N/acre	40 lb N/acre	80 lb N/acre	Fall burn	Spring burn	Manure	Pea vine
Treatment	1	10	2	3	4	5	6	7	8	9
Stand count plants/ft^2	18.6a[a]	17.0a	15.7a	15.6a	17.4a	15.1a	17.0a	18.6a	16.1a	17.0a
Combine yield bu/acre	58.0e	49.6f	71.2d	80.4c	82.6bc	88.5b	43.4f	46.0f	108.4a	79.7c
Bundle yield bu/acre	56.2d	51.8d	74.3c	91.3b	87.5b	82.4bc	48.4d	50.4d	109.4a	73.2c
Test weight lb/bu	58.7e	58.6	59.9cd	61.0a	60.2c	60.9ab	58.2f	58.8e	60.6b	59.8d
1,000-kernel weight combine grain oz	1.80e	1.84de	1.85cde	1.89abcd	1.89abc	1.92ab	1.82e	1.84cde	1.94a	1.86bcde
1,000-kernel weight bundle grain oz	1.86de	1.81e	1.91bcd	1.97abc	1.82bcd	1.98ab	1.86de	1.86de	2.02a	1.88cde
Percent grain protein	7.1ef	7.3e	8.4cd	9.6a	8.8bc	9.8a	6.5g	6.8fg	9.0b	7.9d
Harvest index	0.37c	0.36cd	0.39b	0.41ab	0.39b	0.42a	0.35d	0.36cd	0.43a	0.39b
Heads/ft^2	29.1c	31.0bc	32.5abc	38.3ab	37.4ab	33.8abc	27.4c	26.6c	40.0a	33.6abc
Spikelets/head	14.5ab	15.0ab	13.5b	14.2ab	13.8b	14.0ab	15.8a	15.0ab	15.8a	15.8a
Kernels/head	28.4a	30.5a	27.1a	30.4a	28.3a	31.8a	29.0a	34.4	36.9a	37.2a

[a] Means with the same letters are not significantly different at the 0.05 probability level.

Wheat/pea

Pea

In 2004 peas were seeded at a target rate of 8 seeds/ft^2. Stands were unaffected by treatment and ranged from 8.4 to 10.1 plants/ft^2 (Table 12). No downy brome was present in these plots. Combine and bundle yields were poorly correlated (r = 0.16). To this end, bundle yields, of which we are confident, are discussed below. No-till and spring plow treatments produced significantly higher yields than fall plow and disk treatments (Table 12). Standing stubble left over winter may have contributed to increased water storage over winter. High yields were significantly correlated with 1,000 kernel weight (r = 0.50, $P < 0.01$) and harvest index (r = 0.44, $P < 0.01$).

Wheat

Combine and bundle yields were poorly correlated (r = -0.01). To this end, bundle yields, of which we are confident, are discussed below. Wheat was seeded at a target rate of 22 seeds/ft^2 for tilled systems and 25 seeds/ft^2 for the no-till system. The chisel-after-pea treatment had significantly more plants/ft^2 than the no-till treatment (Table 12). However, plant stands were not significantly different between chisel-after-peas, spring plow, and fall plow treatments. Residue levels (determined by line transect method) that ranged from 100 percent for the no-till treatment to 20.5 percent for the spring plow treatment probably interfered with plant emergence under no-till. The reduction in plant stand, however, did not affect yields; there were no significant differences in grain yield between the treatments. There were no clear associations between grain and the yield components. Grain yields were not affected by downy brome infestation, although the number of brome plants was significantly higher in no-till than in other treatments. Fall plow and chisel treatments had significantly higher grain protein than spring plow and no-till treatments.

Insert table 12

Tillage fertility

Data from the tillage fertility experiment were obtained in alternate years. No data are available as plots were in fallow in 2004.

Continuous no-till winter wheat (USDA)

Yield and test weight data from 1998 to 2004 are shown in Table 13. Grain yield was positively correlated with spring precipitation (r = 0.86, $P < 0.05$).

Table 13. Yields and test weights of continuous no-till winter wheat trial (USDA), Columbia Basin Agricultural Research Center, Pendleton, Oregon, 1998-2004.

	Crop year						
	1998	1999	2000	2001	2002	2003[a]	2004
Planting date	Oct 24	Oct 15	Oct 15	Oct 18	Oct 25	Oct 28	Oct 27
Test weight (lb/bu)	60.0	59.9	61.0	58.5	56.5	57.2	55.7
Combine yield (bu/acre)	82.0	65.8	84.3	65.2	55.0	61.3	82.5
Crop-year precipitation (in)	15.0	16.9	18.7	15.7	12.6	15.2	15.0
Winter precipitation (in)	8.8	12.4	11.4	10.1	7.8	10.3	8.8
Spring precipitation (in)	6.3	4.4	7.3	5.7	4.9	4.9	6.3

[a] Clearfield winter wheat.

WINTER WHEAT RESPONSES TO NITROGEN FERTILIZATION IN A DIRECT-SEED, SUMMER-FALLOW MANAGEMENT SYSTEM

Steve L. Albrecht, Katherine W. Skirvin, and Dan S. Long

Abstract

The silt loam soils of the Columbia Plateau contain little organic matter and are easily eroded. Conservation tillage may decrease erosion on these soils; however, little is known about how the application of a conservation management system, such as direct-seed, will affect wheat production. A field experiment, utilizing direct-seed, summer- fallow management, was conducted from 1998 through 2004 at the Pendleton Experiment Station to study effects of tillage and of nitrogen (N) fertilization rates on winter wheat (*Triticum aestivum* L.) yields and soil properties. Wheat was grown without tillage (direct-seed) with fertilizer N rates of 0, 40, 80, 120, and 160 lb/acre. Conventional tillage (plow and rod-weeding) plots with fertilizer N rates of 0 and 120 lb/acre were established for comparison. Tillage, N fertilization, and precipitation all affected wheat yield. Based on the 7-year averages from 1998 to 2004, yields of wheat with no fertilizer N were 57 percent higher under conventional till than under direct-seed. However, wheat yields at the 120 lb/acre N fertilization rate produced only 7 percent higher yields with conventional tillage over 7 years. In direct-seed, 160 lb N/acre had the greatest grain yields. The 7-year average yield for plots with a more recent transition into direct-seed was 91 bu/acre, whereas the longer-established plots, begun 16 years earlier, yielded 87/acre. After conversion from a conventional system to a direct-seed management system, grain yields, although slightly lower than in a conventionally tilled system, did not decrease over time. Grain yields from direct-seed plots with adequate fertilizer N were 95 percent of yields from conventionally managed plots with equivalent N levels.

Key Words

Direct-seed, grain yield, nitrogen, summer-fallow, wheat

Introduction

Information is limited about the impact of N fertilization on wheat production in direct-seed management systems on the Columbia Plateau. Large areas of this region will likely convert to some form of conservation tillage or direct-seed agriculture in the near future, either to comply with governmental requirements for improved soil conservation and possibly for carbon sequestration, or to reduce inputs.

These soils require fertilizer N to achieve and sustain optimal wheat yields (Rasmussen et al. 1989, Brown et al. 2005). It is especially desirable to manage N efficiently on these soils because of concerns about N leaching and the substantial costs of fertilizer and application.

To provide information on N management, a long-term field experiment was established at the Pendleton Experiment Station in 1997. This experiment also provides the opportunity to evaluate changes over time in soil characteristics, such as microbial activity and water infiltration rates, with direct-seed management and compare any changes with both a longer established direct-seed system and a conventional system. The objectives of this study are to define the N response curve of winter wheat in a direct-seed, summer-fallow management system and to estimate soil contribution to N supply.

Materials and Methods

The long-term experiments are located at the Pendleton Experiment Station, about 10 miles northeast of Pendleton, Oregon. The elevation is 1,495 ft, and the annual precipitation averages 16.5 inches, which falls mainly as rain during the winter months. The average daily temperature is 50°F, ranging from 31°F in January to 70°F in July. The soil is a Walla Walla silt loam (coarse-silty, mixed, superactive, mesic Typic Haploxeroll) put into agricultural production in the 1880's.

A direct-seed, summer-fallow experiment (NTA) was established in the southeastern corner of the Pendleton Experiment Station in 1982. In 1997 a second set of direct-seed, summer-fallow plots (NTB) and a set of conventionally tilled, summer-fallow plots (CT) were added to the experiment. The addition of the NTB plots allows comparisons with longer-established direct-seed (NTA) plots.

Weeds in the NTA and NTB plots are controlled by herbicide applications. The CT plots are moldboard plowed in the spring and weeds are controlled by rod-weeding during the summer. In both the NTA and NTB plots there are five N treatments (0, 40, 80, 120, and 160 lb/acre) with four replications in a randomized, complete block design, whereas in the CT plots there are two N levels (0 and 120 lb/acre) with a similar experimental design. The cropping system alternates summer fallow and winter wheat, so that within every replication, each N treatment is duplicated with planting offset by one year (i.e., one cropped, one fallow), thus providing experimental data on an annual basis. Individual plots are 8 by 110 ft. Stephens winter wheat is planted in the fall, generally the second week in October. Fertilizer N is applied as Uran 32 (is this a trade name? if so it will need the correct symbol ® or © and the manufacturer's name) solution. Grain is machine harvested from 2 6- by 40-ft passes from the center of each plot, weighed, and used to calculate yield and test weight. Results are reported here for 7 crop years (1998-2004).

Results and Discussion

The best 7-year average grain yield, regardless of N treatment, for the direct-seed, summer-fallow wheat was 91 bu/acre at 160 lb N/acre (Table 1). At 120 lb N the best 7-year average grain yield for direct-seed was 89 bu/acre (NTB) while the maximum grain yield for the conventional tillage was slightly greater at 94 bu/acre. During this experiment, the maximum direct-seed grain yields, at 160 lb N/acre fertilization, ranged from 63 to 120 bu/acre. Grain yields among years for the direct-seed system, at 120 lb N/acre, were slightly less, from 60 to 119 bu/acre in the established system (NTA) and from 67 to 111 bu/acre in the newer system (NTB). Grain yields for conventional tillage for the same period, also at 120 lbs N/acre, ranged from 73 to 117 bu/acre. These results compare favorably with results commonly obtained in dryland, summer-fallow farming in the Columbia Plateau (Machado et al. 2004).

Table 1. Grain yield for 7 crop years, 1998 to 2004, Pendleton, OR.

Tillage year estab.[a]	N	1998	1999	2000	2001	2002	2003	2004	7-year mean[b]
	(lb/acre)	(bu/acre)							
NTA[c]	0	38	43	42	42	38	37	42	40 ± 2
1982	40	71	60	68	61	58	62	66	64 ± 5
	80	92	68	99	80	71	82	92	83 ± 11
	120	94	60	119	85	62	75	112	86 ± 22
	160	86	63	112	86	63	82	115	87 ± 21
NTB[d]	0	57	54	48	47	45	42	43	48 ± 6
1997	40	83	71	71	68	61	65	62	69 ± 7
	80	93	73	102	76	73	73	88	82 ± 11
	120	96	72	111	88	67	82	106	89 ± 16
	160	99	67	120	85	66	86	117	91 ± 22
CT[e]	0	66	72	62	72	61	59	62	65 ± 5
1997	120	79	83	115	96	73	94	117	94 ± 17

[a] Year experiment established
[b] Means ± standard deviation
[c] NTA = Established direct-seed plots
[d] NTB = New direct-seed plots
[e] CT = Conventional tillage

Average grain yields increased linearly in the direct-seed system with N fertilization up to 80 lb N/acre for the crop years 1998 to 2004 (Fig. 1). A regression equation ($y = 0.48x + 45$) for the lowest N additions of 0, 40, and 80 lb/acre, suggests that this management system will generate almost half a bushel of grain for each pound of N fertilizer and that the soil will contribute sufficient N from mineralization to produce 45 bu of grain. Although grain yields varied among years, the 7-year average grain production in both direct-seed systems showed a slight increase in yield that was consistent with increased N fertilization for the plots that received the 80, 120,. and 160 lb N/acre (Fig. 1). This suggests that, under these experimental conditions, a substantial increase in N fertilizer may bring only marginal yield benefits.

Seven-year average grain yields in the NTB plots were slightly greater than in the longer established plots (NTA), with the exception of the 80 lb/acre rate. On a yearly basis, grain production was similar for the NTA and NTB; however, in the early years of the experiment, 1998 and 1999, grain yields were generally greater in the NTB plots, especially at the 0 and 40 lb/acre N fertilization rates. This suggests that more N was available for the wheat during development in those years. Less residue is produced at the low fertilization rates, which means that less N may be bound in the residue. Tillage and N rate did not appreciably compromise or improve grain test weights (data not shown), although test weights did decrease somewhat in both direct-seed and conventional tillage, with increased N fertilization.

Figure 1. Winter wheat grain yields for two direct-seed management systems (data combined) at five levels of applied N (0, 40, 80, 120, and 160 lb/acre). Yield averages for 7 years, 1998-2004, at the Pendleton Experiment Station, OR. Regression based on first three data points.

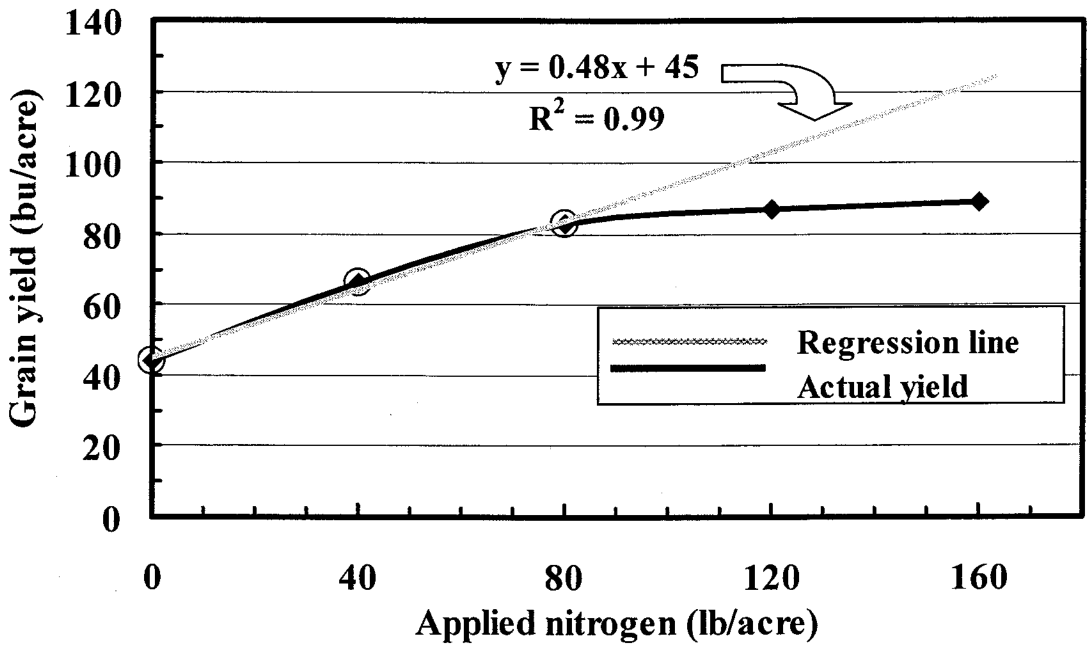
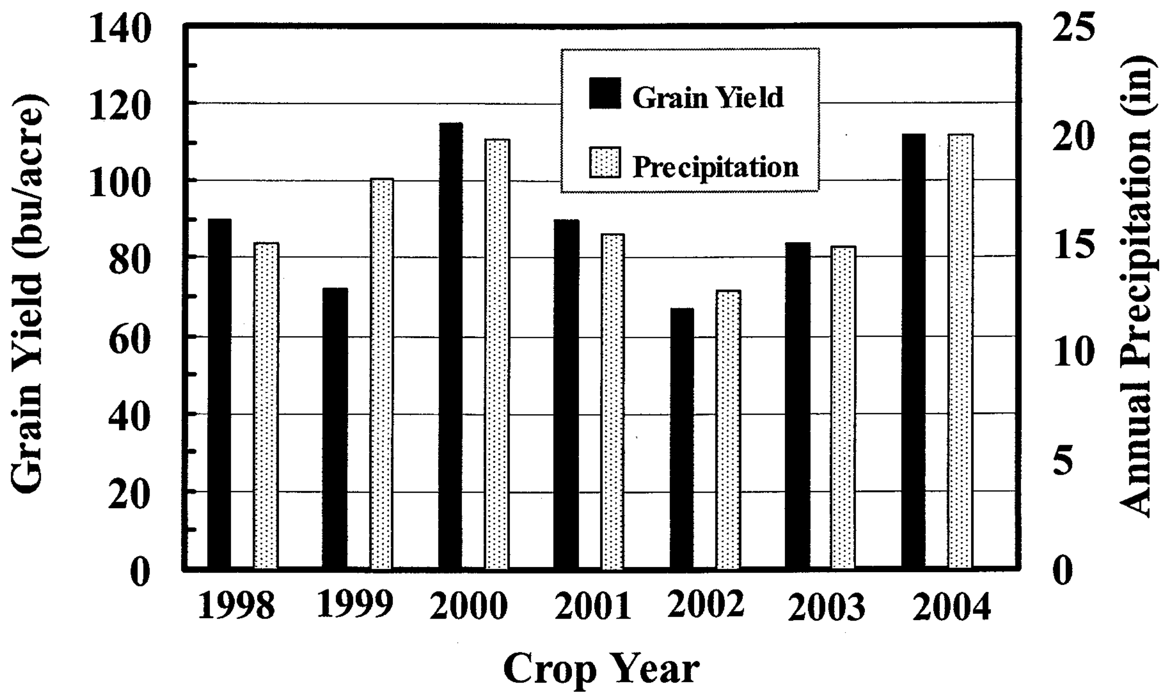


Figure 2. Winter wheat grain yields in two direct-seed management experiments and total annual precipitation for 7 crop years, 1998-2004, at the Pendleton Experiment Station, OR.



Except for 1999, there is a consistent relationship between grain yield and precipitation for the crop years 1998 to 2004 (Fig. 2). The grain yield is directly proportional to precipitation and, presumably, potential soil moisture. The direct link of yield to precipitation, regardless of tillage or N fertilization, emphasizes the importance of water to wheat production in the dryland, cereal-producing regions of the Columbia Plateau. A linear regression can be derived for the relationship of grain yield to precipitation over all years of the experiment. If the results for 1999 are considered as aberrant and not included in the regression computations, the relationship becomes even more evident. The regression equation is y = 5.7x, and the regression coefficient is 0.99, indicating a very strong relationship between wheat yield and precipitation. During the experiment, 1 inch of rain was required to produce 5.7 bu of wheat. At this time, the poor grain production in 1999 is not understood; however, the relatively poor yield may be related to the seedlings experiencing colder-than-normal temperatures in December and January.

In summary, wheat yields from two direct-seed, summer-fallow systems, although slightly less than yields from a conventional tillage system, were similar. However, grain yields following conversion to direct seed from conventional tillage decreased slightly for about 2 years after the transition. In this direct-seed system, N additions beyond 80 lb/acre increased grain yield, but they did so at a rate less than additions up to 80 lb/acre. In addition, this study reinforces the idea that rainfall, and presumably soil moisture, is crucial for wheat production in the light, silt loam soils of the Columbia Basin (Rasmussen et al. 1989).

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BIOLOGY OF RATTAIL FESCUE AND ITS MANAGEMENT IN DIRECT-SEEDED WINTER WHEAT AND CHEMICAL FALLOW

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Abstract

In a 1-year study of weed control in chemical fallow, glyphosate provided the most consistent control of rattail fescue across locations and provided the greatest overall reduction in late-season rattail fescue panicle density and subsequent seed production. Split applications of glyphosate were more effective than paraquat + diuron or than a single application of glyphosate. In a study of rattail fescue control in winter wheat, minor crop injury was seen with treatments containing imazamox at both sites and with treatments containing flufenacet at only one site. Control of rattail fescue in wheat was generally marginal from single herbicide applications, but excellent from multiple herbicide treatments. Rattail fescue biomass was greatly reduced from these multiple applications in wheat. Crop yield varied among sites. Results of two seed dormancy studies indicated that a temperature of 20°C improved germination of freshly harvested to 1-year-old rattail fescue seed, but was not needed for aged (2- to 3-year-old) seed. A prechill treatment of 5 days at 5°C was needed to promote germination of freshly harvested to 1-year-old rattail fescue seed, but was not needed for aged seed. Thermogradient temperature plate results indicated that optimum rattail fescue seed germination occurred at a constant day/night temperature (20/20°C). Results of a seed longevity study indicated that very little germination occurred after burial for 6 months, possibly due to seed dormancy cycles. Germination occurred at all sites after 1 year of burial, but dropped after 2 years of burial. Seed germination increased with burial depth after 2 years at the Summerville site. A vernalization study indicated that rattail fescue plants required vernalization to produce spikes and germinable seeds. The presence of a vernalization response in this study supports the classification of rattail fescue as a true winter annual.

Key Words

Chemical fallow, CLEARFIELD™ wheat, direct-seed, rattail fescue

Introduction

Control of rattail fescue (*Vulpia myuros*), a winter annual grass weed, has been difficult in chemical fallow or prior to establishment of direct-seeded spring or winter cereals. Although rattail fescue is not a new weed species in the Pacific Northwest (PNW), its incidence is expanding in circumstances where soil disturbances are minimized, such as in direct-seed systems. Very little information exists on the biology of this grass weed. Options for effective control without tillage in fallow and in cereal crops have not been adequately investigated and are needed for dryland crop producing areas of the PNW.

Information is currently lacking on the longevity of seed viability in the soil, the presence (or absence) of seed dormancy, vernalization requirements, and the optimum environmental conditions for seed germination and establishment under field conditions. Rattail fescue does not usually persist under high levels of tillage, but can tolerate the application rates of glyphosate typically used during chemical fallow periods in direct-seed systems. This leads to increasing infestation levels of rattail fescue in chemical fallow and subsequent direct-seeded cereal crops. Preliminary research in Oregon indicates that high rates of glyphosate applied in the spring may be insufficient to completely eliminate seed head production. More research is needed to determine optimum rates and timing for herbicide applications during fallow periods under a range of PNW agronomic zones.

Herbicide efficacy trials conducted in irrigated winter wheat indicate that potential treatments exist for control of rattail fescue. However, few treatments are currently registered for rattail fescue control, and no work has specifically been conducted under dryland winter wheat cropping conditions. Determining the effectiveness of various herbicide treatments for control of rattail fescue in dryland, direct-seed winter wheat systems is needed to secure appropriate herbicide registrations in the PNW.

In this study the specific objectives included: 1) determine basic biological characteristics for seed of rattail fescue, including optimum seed germination temperatures, occurrence and characteristics of seed dormancy, seed longevity under field conditions, and whole plant vernalization requirements; 2) coordinate and conduct herbicide trials to determine optimum treatment rates and timings for control of rattail fescue in chemical fallow systems; and 3) coordinate and conduct herbicide trials to determine optimum treatment rates and timings for control of rattail fescue in direct-seed winter wheat.

Materials and Methods

Seed dormancy

In 2003 and 2004, germination of aged rattail fescue seed, supplied by Riverside Seed Co., was compared to freshly collected rattail fescue seed from Mission, Oregon. The aged seed was collected in 1999 and dry stored at 21°C prior to, and for the duration of, the experiment. The fresh seed was hand collected each year, hand thrashed, sorted, and open-air dried for 5 days prior to initiating the experiment. All seeds were rinsed with a 5 percent solution of bleach, a surface sterilant, for 5 to 10 seconds and then rinsed with deionized water three times to ensure removal of bleach from the seed coat. Germination experiments were conducted 10 days after harvest (DAH) and subsequently at 30 DAH, 90 DAH, 180 DAH, and 365 DAH in petri dishes with two pieces of Watman blue blotter paper. A series of treatments were used to determine the effect of afterripening, prechilling, germination temperature, and potassium nitrate on dormancy breaking of rattail fescue. The treatments applied to the five levels of afterripening were a prechill for 5 days at 5°C versus no prechill; germination solution of 2.5 percent potassium nitrate (KNO_3) versus deionized water (H_2O); and a constant germination temperature of 20°C versus 30°C. Prechilled treatments received one of the germination solutions at the time they went into the prechill chamber. Although no photoperiod was used, the seeds were exposed to ambient light during germination counts. Each treatment consisted of 50 seeds and was replicated four times in a completely randomized design. The four replicates were placed in a slightly open plastic bag to reduce evaporation. Germination counts were made at 3, 7, 14, and 21 days. Seeds were considered germinated when 2 mm of the coleoptile had grown and a radicle was present. At day 21, the remaining ungerminated seeds were counted and recorded. Results were analyzed using ANOVA and presented as average percent germination values.

Optimal germination temperature

In 2004, a two-way thermogradient plate (Larsen 1971) was used to determine the effect of various temperature combinations on rattail fescue germination following dormancy breaking. Seeds were supplied by Riverside Seed Co. and stored at 21°C for 12 months to ensure adequate afterripening. All seeds were surface sterilized using the procedures described above. Germination experiments were carried out in petri dishes with two pieces of Watman blue blotter paper and deionized water. Temperatures ranged from approximately 5°C to 40°C (95 percent confidence interval of $\pm$2°C) and were set on a 14-hour-day/10-hour-night cycle. The thermogradient plate required approximately 2 hours of heating and cooling to the specific temperature. The germination boxes were randomly placed on each square of the thermogradient plate, resulting in 64 daytime/nighttime temperature combinations of approximately: 5/5, 5/10, 5/15, 5/20, 5/25, 5/30, 5/35, 5/40, 10/5, 10/10, 10/15, 10/20, 10/25, 10/30, 10/35, 10/40, 15/5, 15/10, 15/15, 15/20, 15/25, 15/30, 15/35, 15/40, 20/5, 20/10, 20/15, 20/20, 20/25, 20/30, 20/35, 20/40, 25/5, 25/10, 25/15, 25/20, 25/25, 25/30, 25/35, 25/40, 30/5, 30/10, 30/15, 30/20, 30/25, 30/30, 30/35, 30/40, 35/5, 35/10, 35/15, 35/20, 35/25, 35/30, 35/35, 35/40, 40/5, 40/10, 40/15, 40/20, 40/25, 40/30, 40/35, and 40/40°C. Each temperature combination received 50 seeds, and germinated seeds were counted on day 3, 6, 9, 12, 15, and 18. On day 18, all remaining ungerminated seeds were counted and recorded. Average germination at day 18 was analyzed by ANOVA and is presented using ArcMap v8.2™ (ESRI 2002).

Longevity of rattail fescue seed in soil

In June 2002, a 3-year study was initiated at three locations to assess seed longevity of rattail fescue under dryland conditions and with varying burial depths. During the course of this study, buried seed will be exhumed at 1-year intervals over the 3-year period. One study was located on a silt loam (21.2 percent sand, 65.4 percent silt, 13.4 percent clay, 3.5 percent organic matter [OM], 6.4 pH, with CEC 31.2) soil on the Blue Mountain Seeds, Inc. research field near Summerville, Oregon. The second site was located on a silt loam (25.6 percent sand, 62.6 percent silt, 11.8 percent clay, 2.7 percent OM, 8.6 pH, with CEC of 30.0) soil near La Grande, Oregon. The third site was located on a silt loam (28 percent sand, 63.6 percent silt, 8.4 percent clay, 1.8 percent OM, 6.9 pH, with CEC of 17.8) soil on the Columbia Basin Agricultural Research Center (CBARC) near Pendleton, Oregon.

Four replicate seed packets were buried 2.5, 5.0, 10.0, 15.0, and 20.0 cm deep for each exhumation time and at each of the three locations. Seed for the study was collected June 26, 2002, from a fallow field near Mission, Oregon. Seed was hand thrashed and cleaned. One hundred seeds were counted and placed in a 2.5- by 2.5-cm, 200-micron, nylon mesh screen packet, sewn closed with nylon-coated monofilament thread. The soil surface at the site was maintained vegetation-free using glyphosate applications when needed and hand weeding. Packets were buried September 16, 10, and 11, 2002 at Pendleton, La Grande, and Summerville, respectively.

This report represents data collected from the 0.5-, 1-, and 2-year seed exhumation periods. The study will continue, collecting the third year's seed packets in 2005. The 0.5-year packets were exhumed March 10, 2003, 1-year packets were exhumed September 10, 2003, and the 2-year packets were exhumed September 10, 2004. The seeds for all retrieval dates were air dried and the number of remaining seeds counted.

A growth chamber germination test was conducted using dry stored seed as a control against the buried seed. Both the dry stored and buried seeds were surface sterilized using the procedure described above and placed into petri dishes lined with germination paper (50 seeds/dish when possible). Both buried seeds and control seeds were germinated in deionized water after a prechill treatment of 5 days at 5°C with no photoperiod. The seeds were placed in an unlit, continuous 20°C germination chamber. Germination counts were taken at 3, 7, 14, and 21 days. Viability of the 1-year dry stored seed was tested using standard tetrazolium procedures (Peters 2000). Results are presented as mean percent germination values at 21days.

Rattail fescue vernalization requirements

Two Oregon locations were chosen in 2003 to test for the presence of a vernalization requirement in rattail fescue. The sites were the CBARC station near Pendleton, Oregon and the Lewis Brown research farm near Corvallis, Oregon. Starting in October of 2003, rattail fescue seeds representing two biotypes (eastern and western) were sown 2 cm deep into 2-m rows, spaced 40 cm apart. The eastern biotype seed was supplied by Riverside Seed Co., the western biotype seed was hand collected in the Willamette Valley. Six monthly planting dates were established at both sites. At both sites, the planting dates spanning 2003 to 2004 were October 20, November 17, December 16, January 28, February 24, and March 18 at Pendleton, and October 15, November 12, December 15, January 22, February 28, and March 29 at Corvallis. Each planting was replicated three times at each site in a randomized complete block design. On July 12 and July 17, 2004 the plots were assessed at Pendleton and Corvallis, respectively for the presence/absence of spikes. The spikes were harvested, seeds cleaned, and tested for germination using standard procedures. The number of germinated seeds was counted 14 days after incubation and then converted to a percentage of the total seed number and analyzed using ANOVA procedures.

Rattail fescue control in chemical fallow

Two studies were established in dryland winter wheat in 2004, one at CBARC, near Pendleton, Oregon, and the other near Mission, Oregon. The study objectives were to evaluate control of rattail fescue in a wheat stubble/chemical fallow system. At each site, 17 treatments consisted of different glyphosate or Surefire® application rates and timings. Rattail fescue seed was surface broadcast sown onto 9- by 30-ft plots arranged in a randomized complete block design with four replicates on November 4, 2003. Soil at the CBARC site was a Walla Walla silt loam (25 percent sand, 61 percent silt, 14 percent clay, 2.3 percent OM, 5.7 pH, and CEC of 16.7 meq/100g). Soil at the Mission site was a silt loam (20 percent sand, 64.2 percent silt, 15.8 percent clay, 2.4 percent OM, 6.5 pH, and CEC of 18 meq/100g). Herbicide treatments were applied using a 9-ft hand-held boom, CO_2-pressured sprayer delivering 10 gal/acre at 30 psi. Early postemergence (EPOST) treatments were applied March 29, 2004 at both sites when rattail fescue was at the 3- to 5-leaf stage of development. Late postemergence (LPOST) treatments were applied at the CBARC site on April 30, 2004, when rattail fescue was at the 5- to 6-leaf stage of development, and at the Mission site April 19, 2004 when rattail fescue was at the 3-inch to head stage of growth. Percent control of rattail fescue was visually evaluated at the CBARC site on June 4, 2004 and at the Mission site May 19, 2004. Panicles were collected from a 1-m^2 area per plot on July 9, 2004 at the CBARC site. Panicles were counted on June 11, 2004 at the Mission site after which this study was terminated. The panicles were harvested, seeds cleaned, and tested for number of germinable seeds/m^2. Data are presented as percent control and number of seeds produced per treatment.

Rattail fescue control in CLEARFIELD™ winter wheat

Two studies were established in winter wheat to investigate the response of rattail fescue to a variety of herbicides and timings at CBARC, near Pendleton, Oregon, and Hyslop Farm, near Corvallis, Oregon. Plots were 9 by 30 ft arranged in a randomized complete block design with four replications. Soil at the Pendleton site was a silt loam, with 2.4 percent OM, 5.7 pH, and CEC of 15.8 (meq/100g). Soil at the Corvallis site was also a silt loam, with 2.4 percent OM, 5.6 pH, and CEC of 13.9 (meq/100g). Herbicide treatments were applied using a hand-held boom sprayer delivering 10 gal/acre at 20 to 30 psi. Winter wheat var. 'Clearfirst' was seeded on October 14 and October 16, 2003 in Corvallis and Pendleton, respectively. Preemergence (PRE) treatments were applied at the time of planting. Early postemergence treatments were applied December 10 and March 29, 2004 in Corvallis and Pendleton, respectively, when wheat was at the 5- to 7-leaf stage and rattail fescue at the 6- to 8-leaf stage. Control of rattail fescue was visually evaluated on March 15 and May 27, 2004 at Corvallis and Pendleton, respectively. Crop injury was visually evaluated on March 15 and April 20, 2004 at Corvallis and Pendleton, respectively. On June 10 and June 24, 2004 rattail fescue biomass was sampled from a 1-m^2 area of each plot from the Corvallis and Pendleton sites, respectively. Biomass was oven dried at 60°C for 48 hours. The crop was harvested July 22 and July 27, 2004 at Corvallis and Pendleton, respectively, with a small plot combine and yields weighed and converted to bu/acre. Treatments in this trial are not registered for use and are being evaluated on an experimental basis only. Mention of products used in this trial should not be considered to be a recommendation for commercial use.

Results

Rattail fescue seed dormancy

First study. Results support three germination trends. A temperature of 20°C promoted germination of freshly harvested to 1-year-old rattail fescue seed compared to a 30 °C germination temperature, but had a less pronounced effect on aged seed (Table 1). A prechill treatment of 5 days at 5°C promoted germination of freshly harvested to 1-year-old rattail fescue seed, but had less effect on aged seed (Table 1). Fresh and aged rattail fescue seed had a negligible response to a germination-promoting KNO_3 treatment at 6 months of afterripening (Table 2).

Second study. A second study, using only fresh rattail fescue seed collected at Mission, Oregon in 2003 was conducted to validate findings of the first dormancy study. Results indicated that newly harvested 2003 rattail fescue seed responded to treatments similarly to the newly harvested seed in the first study. A temperature of 20°C promoted germination of freshly harvested to 1-year-old seed (Table 3). The prechill treatment of 5 days at 5°C promoted germination of freshly harvested to 1-year-old rattail fescue seed (Table 3). At 20°C, KNO_3 had no effect on germination of 2003 rattail fescue (Table 4).

Table 1. Effect of dry storage time, germination temperature, and prechilling on rattail fescue seed germination after 21 days.

		Storage time									
		Fresh		1 month		3 months		6 months		1 year	
Temperature	Chill	New[a]	Aged	New	Aged	New	Aged	New	Aged	New	Aged
		%									
20	Chill	9	89	84	90	97	91	97	91	98	88
20	No chill	0	91	28	89	69	89	98	92	99	85
30	Chill	0	83	12	87	36	84	62	82	96	79
30	No chill	0	74	0	71	0	68	18	84	68	85
Tukey (0.05)		4	15	15	13	20	16	20	26	10	12

[a]New – seed from Mission, Oregon collected in 2002. Aged – seed from Riverview Seed Co. collected in 1999.

Table 2. Effect of dry storage time, germination temperature, and potassium nitrate (KNO_3) on rattail fescue seed germination after 21 days.

		Storage time									
		Fresh		1 month		3 months		6 months		1 year	
Temperature	Fluid	New[a]	Aged	New	Aged	New	Aged	New	Aged	New	Aged
		%									
20	H_2O	3	87	54	89	83	91	96	90	97	88
20	KNO_3	6	92	59	91	83	88	98	94	99	86
30	H_2O	0	79	8	78	25	77	32	86	78	80
30	KNO_3	0	78	4	81	11	75	48	80	85	84
Tukey (0.05)		4	15	15	13	20	16	20	26	10	12

[a]New – seed from Mission, Oregon collected in 2002. Aged – seed from Riverview Seed Co. collected in 1999.

Table 3. Effect of dry storage time, germination temperature, and prechilling on Mission, Oregon 2003 rattail fescue seed germination after 21 days.

		Storage time				
Temperature	Chill	Fresh	1 month	3 month	6 month	1 year
20	Chill	89	90	96	87	97
20	No chill	85	85	92	95	99
30	Chill	31	49	74	81	94
30	No chill	0	0	3	10	53
Tukey (0.05)		13	14	12	21	11

Table 4. Effect of dry storage time, germination temperature, and potassium nitrate (KNO_3) on Mission, Oregon 2003 rattail fescue seed germination after 21 days.

		Storage time				
Temperature	Fluid	Fresh	1 month	3 month	6 month	1 year
20	H_2O	80	81	91	86	97
20	KNO_3	94	93	96	96	100
30	H_2O	14	21	37	38	70
30	KNO_3	17	28	40	52	77
Tukey (0.05)		13	14	NS	21	11

Optimal germination temperature
Thermogradient plate results indicated that optimum germination occurred in one temperature regime in all three replications (20/25°C). Images of germination over time were created using a Kriging interpolation technique through ArcGIS™ software (Fig. 1).

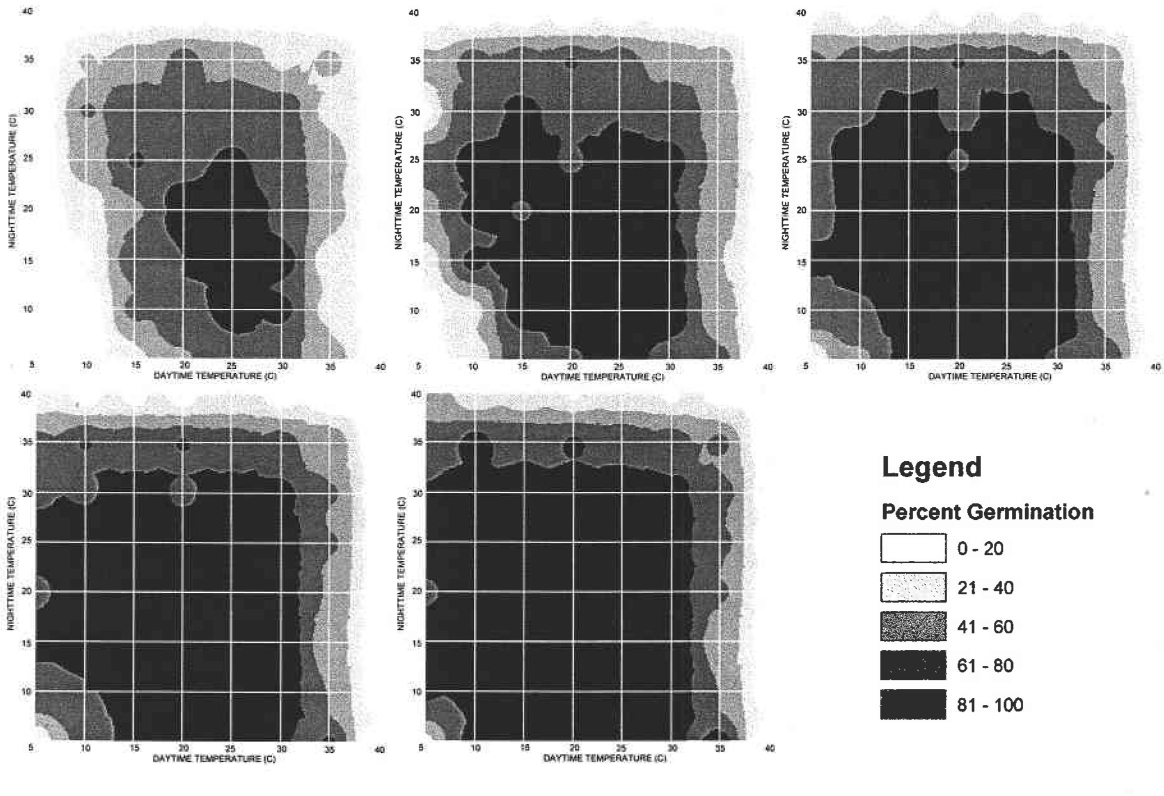

Figure 1. Percent germination of rattail fescue at 3, 6, 9, 12, 15, and 18 days (left to right, top to bottom) on a two-way thermogradient plate.

Longevity of rattail fescue seed in soil

Germination results indicate that at least 6 months are required under all three site conditions prior to the initiation of germination at any depth (Table 5). At 1 year burial, germination occurred at every depth at every site; however, germination was greatest at the Summerville site. At Pendleton, germination increased with burial depth, whereas in Summerville germination decreased with depth. There was no germination pattern related to burial depth in LaGrande. Tetrazolium viability test results indicated that for the Pendleton and La Grande sites, the majority of the seeds that did not germinate were indeed nonviable, whereas the Summerville site had viable seeds that did not germinate, possibly due to dormancy (Table 5). After 2 years of burial, only Summerville seed germinated in significant numbers, and germination increased with burial depth.

Rattail fescue vernalization requirements

Results indicated that rattail fescue plants require a vernalization period to produce spikes and subsequent germinable seed (Table 6). Plants derived from seeds sown on or after February 24 and January 22 at Pendleton and Corvallis, respectively, did not complete their life cycle by July 12. Winter temperatures at Corvallis were warmer than temperatures at Pendleton, and were therefore not sufficient to vernalize plants derived from seeds sown on January 22. There were no differences in vernalization between the eastern and western biotypes. Although no significant difference existed in subsequent seed germination from the early versus late planted seed source in Pendleton, there was a marked difference in the percent germination of seeds from the October planting in Corvallis from any of the later planting dates. The presence of a vernalization response in this study supports the classification of rattail fescue as a true winter annual.

Table 5. Rattail fescue germination and viability response to seed burial time at three locations.

	6 months			1 year			Viability at 1 year by TZ			2 years		
Depth	Pend[a]	Sum	LaGr	Pend	Sum	LaGr	Pend	Sum	LaGr	Pend	Sum	LaGr
(cm)	----------------------%----------------------						-------% viable------			----------%------------		
2.5	0	0	0	3	25	2	2	17	4	0	5	0
5		1	0	5	25	1	1	21	1	1	2	0
10	0	1	0	7	22	3	1	16	3	1	7	1
15	0	3	0	12	31	3	2	24	2	5	11	0
20	1	1	0	24	17	1	2	14	1	2	9	0
Control	97	97	97	97	97	97	--	--	--	99	99	99
LSD (.05)	--	--	--	--	--	--	NS	NS	NS	--	--	--

[a] Seed buried at Pendleton, Oregon (Pend), Summerville, Oregon (Sum), or LaGrande, Oregon (LaGr).

Table 6. Summary of heading and germination for two biotypes of rattail fescue grown at Pendleton and Corvallis, Oregon, 2003-2004.

Location	Planting date	Eastern biotype		Western biotype	
		Spikes present	Germination (% ± se)	Spikes present	Germination (% ± se)
Pendleton	Oct. 20	Y	64.5 ± 4.8	Y	42.1 ± 4.8
	Nov. 17	Y	36.3 ± 6.8	Y	Not estimable
	Dec. 16	Y	49.2 ± 5.0	Y	41.0 ± 5.0
	Jan. 28	Y	32.6 ± 5.3	Y	42.0 ± 5.3
	Feb. 24	N	0	N	0
	Mar. 18	N	0	N	0
Corvallis	Oct. 15	Y	95.5 ± 5.6	Y	82.3 ± 3.5
	Nov. 12	Y	12.4 ± 5.6	Y	6.3 ± 6.2
	Dec. 15	Y	30.0 ± 9.6	Y	22.8 ± 6.2
	Jan. 22	N	0	N	0
	Feb. 28	N	0	N	0
	Mar. 29	N	0	N	0

Rattail fescue control in chemical fallow

Results indicate that LPOST timings provided better overall control at Pendleton. Control at Mission was more rate dependent than timing dependent (Table 7). As expected, higher rates generally provided a higher level of control. Split applications of glyphosate provided the most consistent control across locations and provided the greatest overall reduction in late-season rattail fescue panicle density and subsequent seed production (Table 7). In general, split treatments of glyphosate were more consistently effective at controlling rattail fescue than Surefire, but control with Surefire, when used as a split application with glyphosate, provided acceptable control. The low rates of glyphosate appear to have promoted seed and panicle production at the Pendleton site. This is likely due to glyphosate control of other weeds such as mustards, downy brome, and volunteer wheat. Although the untreated check had low seed germination, the high panicle density lends suspect to the loss of seeds during harvest. The Mission study was terminated after panicle counts were made.

Rattail fescue control in CLEARFIELD™ winter wheat

In winter wheat, minor crop injury was observed from treatments containing imazamox (Table 8). Other herbicide treatments produced minor to negligible crop injury. At the Corvallis site, treatments containing Define® produced moderate, early crop injury. The reason for this injury has not been determined at this time. Control of rattail fescue was only moderately effective with single applications, but multiple treatments that consisted of a PRE treatment followed by an EPOST treatment resulted in excellent control and reductions in overall biomass (Table 8). Crop yield varied across sites, primarily due to differences in growing season precipitation and temperatures. Within site yield differences due to herbicide treatment were also evident (Table 8).

Table 7. Rattail fescue response in chemical fallow in Oregon, 2004.

			Weed control		Panicle count		Seed germination
			Pendleton	Mission	Pendleton	Mission	Pendleton
Treatment	Rate	Timing	6/4/04	5/19/04	7/9/04	6/11/04	7/9/04
	fl oz /acre		---------%---------		---------------no./m^2	---------------	
Untreated check	--	--	0	0	2,730	4,280	64,440
glyphosate	13	EPOST	33	58	3,160	1,860	141,880
glyphosate	19	EPOST	30	65	3,750	3,740	371,810
glyphosate	26	EPOST	40	69	2,970	2,730	212,950
glyphosate	32	EPOST	55	75	2,060	1,950	154,730
Surefire	32	EPOST	28	48	2,040	2,950	144,720
glyphosate	13	LPOST	85	49	1,370	4,040	24,190
glyphosate	19	LPOST	90	64	400	2,960	7,700
glyphosate	26	LPOST	94	73	200	2,210	2,820
glyphosate	32	LPOST	97	78	160	3,800	3,310
Surefire	32	LPOST	70	74	2,120	1,760	49,780
glyphosate / glyphosate	13 / 13	EPOST/ LPOST	89	76	760	2,970	16,420
glyphosate / glyphosate	19 / 13	EPOST/ LPOST	95	78	120	3,280	3,610
glyphosate / glyphosate	13 / 19	EPOST/ LPOST	98	80	150	2,210	11,350
glyphosate / glyphosate	19 / 19	EPOST/ LPOST	99	84	80	3,230	6,010
glyphosate / glyphosate	19 / 26	EPOST/ LPOST	99	83	20	1,250	1,510
glyphosate / Surefire	13 / 31	EPOST/ LPOST	86	90	970	1,140	54,030
Surefire / glyphosate	32 / 13	EPOST/ LPOST	89	73	770	2,700	20,880
LSD (0.05)			6	10	630	1,830	141,780

Glyphosate treatments received AMS at 8.5 lb/100 gal. Surefire treatments received R-11 at 0.25 percent v/v. Applications were applied in 10 gal/acre water. EPOST= 3- to 5-leaf rattail fescue, LPOST= 5- to 6-leaf rattail fescue. Product formulations included: glyphosate = Roundup UltraMax® (3.8 lb/gal); Surefire® = paraquat + diuron.

Table 8. Influence of herbicide treatments on CLEARFIELD ™ winter wheat in Oregon, 2004.

Treatment	Rate	Timing	Crop injury		Rattail fescue control		Rattail fescue biomass		Crop yield	
			Pendleton 4/20/04	Corvallis 3/15/04	Pendleton 5/27/04	Corvallis 3/15/04	Pendleton 6/24/04	Corvallis 6/10/04	Pendleton 7/22/04	Corvallis 7/22/04
	Prod/acre		------------------------ % ------------------------				-------- g/m^2 --------		--------- bu/acre ------	
Untreated check	--	--	0	0	0	0	25	365	44	92
Prowl H_20	25.3 oz	PRE	0	2	81	69	6	239	47	101
Define	9.6 oz	PRE	0	12	97	100	1	0	54	122
Define + R-11	9.6 oz	EPOST	0	0	48	100	17	0	43	119
Maverick + R-11 + Soln 32	0.67 oz	EPOST	4	2	35	95	18	9	59	117
Osprey + R-11 + Soln 32	4.75 oz	EPOST	3	9	33	85	19	80	60	116
Karmex (80% DF)	1.25 lb	EPOST	0	0	25	76	7	108	43	113
Beyond + R-11 + Soln 32	6 oz	EPOST	20	16	58	80	15	96	69	106
Define/Maverick + R-11 + Soln 32	9.6 oz/0.67 oz	PRE/EPOST	5	11	100	100	0	0	77	120
Define/Osprey + R-11 + Soln 32	9.6 oz/4.75 oz	PRE/EPOST	4	15	100	100	1	0	73	123
Define/Karmex	9.6 oz/1.5 lb	PRE/EPOST	0	14	100	100	0	0	64	119
Define/Beyond + R-11 + Soln 32	9.6 oz/5 oz	PRE/EPOST	19	18	100	100	0	0	75	111
Prowl H_20/Define + R-11	25.3 oz/9.6 oz	PRE/EPOST	1	0	97	100	0	0	44	118
Prowl H_20/Maverick + R-11 +Soln 32	25.3 oz/0.67 oz	PRE/EPOST	1	0	96	100	0	1	68	119
Prowl H_20/Osprey + R-11 + Soln 32	25.3 oz/4.75 oz	PRE/EPOST	6	3	98	97	2	10	58	117
Prowl H_20/Karmex	25.3 oz/1.25 lb	PRE/EPOST	1	4	93	91	0	49	49	117
Prowl H_20/Beyond + R-11 + Soln 32	25.3 oz/6 oz	PRE/EPOST	24	4	81	99	5	5	66	113
LSD (0.05)			8	5	10	7	12	44	10	7

PRE – Preemergence treatments applied immediately after seeding, but before crop emergence. EPOST – early postemergence applied to rattail fescue in the 6- to 8-leaf stage of growth. All EPOST treatments, except for diuron, received a non-ionic surfactant at 0.5 percent v/v. In addition, sulfosulfuron, mesosulfuron, and imazamox EPOST treatments received Soln 32 (UAN) at 2.5 percent v/v. Treatments were applied at 10 gal/acre at 20 or 30 psi. Product formulations included: pendimethalin = Prowl H_2O®; flufenacet = Define®; sulfosulfuron = Maverick®; mesosulfuron = Osprey®; diuron = Karmex®; imazamox = Beyond®.

References

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PRECIPITATION SUMMARY - PENDLETON

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

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
75 Year Average	**.73**	**1.37**	**2.07**	**2.06**	**1.97**	**1.55**	**1.72**	**1.53**	**1.49**	**1.22**	**.34**	**.48**	**16.53**
1984-85	.98	1.18	3.43	1.96	.69	1.49	1.33	.65	.89	1.42	.05	.98	15.05
1985-86	1.54	1.34	2.66	1.27	2.38	3.04	1.94	.83	1.79	.09	.61	.19	17.68
1986-87	1.87	.91	3.41	.95	2.08	1.31	1.85	.83	1.63	.62	.47	.06	15.99
1987-88	.04	0	1.44	1.61	2.60	.32	1.65	2.59	1.79	.94	0	0	12.98
1988-89	.40	.08	3.65	1.10	2.86	1.55	2.95	1.94	2.19	.33	.15	1.19	18.39
1989-90	.24	1.00	1.65	.49	1.43	.63	1.89	1.77	2.14	.70	.37	.76	13.07
1990-91	0	1.37	1.73	1.18	1.15	.86	1.71	1.01	4.73	2.22	.15	.24	16.35
1991-92	.03	.89	4.18	.97	.96	1.34	.85	1.29	.20	.90	1.74	.78	14.13
1992-93	.58	1.70	2.61	1.30	2.43	1.04	2.32	2.67	1.58	2.01	.47	2.60	21.31
1993-94	0	.30	.49	1.91	2.38	1.67	.52	1.18	2.88	.75	.33	.07	12.48
1994-95	.76	1.44	3.77	1.83	2.75	1.15	2.35	2.92	1.56	1.73	.22	.41	20.89
1995-96	.93	1.35	2.95	2.37	2.79	2.45	1.49	2.33	2.00	.39	0	.05	19.10
1996-97	.66	1.99	3.05	4.23	2.74	1.60	3.00	2.46	.46	1.10	.36	.02	21.67
1997-98	.88	1.34	1.59	1.41	2.84	.87	1.43	1.30	3.12	..51	.18	.10	15.57
1998-99	1.24	.40	4.71	2.96	1.18	2.16	1.23	.99	1.65	.61	.04	1.18	18.35
1999-00	0	1.75	2.17	1.88	2.39	3.35	3.39	.65	1.98	1.39	.31	0	19.26
2000-01	1.75	3.84	1.61	.84	1.29	.89	1.42	2.13	.75	1.47	.55	0	16.54
2001-02	.36	1.91	1.88	1.02	1.36	1.33	1.41	1.12	1.02	1.39	.23	0	13.03
2002-03	.24	.61	1.09	3.06	3.25	2.18	2.20	1.78	1.01	0	0	.23	15.65
2003-04	.70	.68	1.68	3.33	2.77	2.29	.85	2.03	2.78	1.88	.12	.91	20.02
2004-05	.54	.75	2.09	1.08	.53	.33	1.76	1.41					
20 Year Average	**.66**	**1.20**	**2.49**	**1.78**	**2.12**	**1.58**	**1.79**	**1.62**	**1.81**	**1.02**	**.32**	**.49**	**16.88**

PRECIPITATION SUMMARY - MORO

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

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
95 Year Average	**.57**	**.92**	**1.68**	**1.64**	**1.62**	**1.17**	**.97**	**.79**	**.82**	**.67**	**.22**	**.29**	**11.36**
1984-85	.53	.86	3.18	.41	.27	.97	.44	.14	.63	.92	.05	.14	8.54
1985-86	1.11	1.09	1.19	1.12	1.84	2.39	.98	.34	.35	.06	.54	.07	11.08
1986-87	1.52	.45	1.53	.78	1.68	1.10	1.54	.28	.99	.29	.78	.11	11.05
1987-88	.07	.01	.66	3.23	1.60	.21	1.25	2.21	.55	1.02	.04	0	10.85
1988-89	.56	.02	2.51	.22	1.33	.77	1.91	.84	.91	.08	.11	.50	9.76
1989-90	.07	.59	.96	.48	1.91	.17	.76	.79	1.36	.39	.15	1.43	9.06
1990-91	.29	1.27	.61	.74	.87	.60	1.43	.40	.77	1.27	.33	.16	8.74
1991-92	0	1.40	2.57	1.02	.47	1.64	.64	2.38	.04	.28	.81	.02	11.27
1992-93	.68	.85	1.50	1.68	1.42	1.47	1.68	1.22	1.42	.87	.39	.30	13.48
1993-94	.02	.09	.41	.68	1.40	.90	.55	.40	.62	.61	.11	.07	5.86
1994-95	.19	2.27	1.79	.90	3.67	1.18	1.14	1.95	.97	1.45	1.10	.17	16.78
1995-96	1.02	.64	3.20	2.20	1.86	2.43	.65	1.57	1.44	.36	.15	.03	15.55
1996-97	.55	1.56	2.63	4.18	1.57	.84	1.28	1.26	.55	.56	.13	.57	15.68
1997-98	.46	1.61	.66	.29	2.49	1.30	1.02	.66	3.15	.26	.26	.06	12.22
1998-99	.38	.16	2.57	1.34	1.34	1.00	.51	.06	.56	.11	.09	.23	8.35
1999-00	0	.83	1.62	.62	1.77	2.43	.76	.44	.48	.20	0	0	9.15
2000-01	.30	1.39	.60	.35	.43	.53	.81	.71	.34	.50	.02	.23	6.21
2001-02	.53	1.03	2.02	1.17	.68	.65	.42	.38	.66	.85	.04	0	8.43
2002-03	.02	.27	.59	2.65	1.92	1.26	.90	1.00	.21	0	0	.47	9.29
2003-04	.25	.65	.73	2.44	1.58	1.47	.61	.79	.93	1.11	.29	1.06	11.91
2004-05	.47	.79	.32	1.55	.42	.12	.77	.75					
20 Year Average	**.43**	**.85**	**1.58**	**1.32**	**1.50**	**1.17**	**.96**	**.89**	**.85**	**.56**	**.27**	**.28**	**10.66**

AVERAGE MAXIMUM TEMPERATURE SUMMARY - PENDLETON

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

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	MAX
75 Year Average	**78**	**65**	**49**	**42**	**40**	**46**	**54**	**62**	**70**	**79**	**89**	**88**	**115**
1984-85	75	62	50	37	30	43	53	66	72	80	95	83	105
1985-86	70	62	35	26	43	46	59	61	69	85	83	93	104
1986-87	72	68	49	37	38	47	56	68	74	82	85	87	104
1987-88	83	72	52	41	40	50	56	64	69	77	90	88	102
1988-89	79	74	52	41	45	33	52	64	69	81	88	83	101
1989-90	80	65	54	40	44	46	57	68	68	78	92	87	108
1990-91	85	64	55	35	40	55	52	62	66	73	89	91	100
1991-92	82	67	48	43	44	51	59	65	76	86	86	89	104
1992-93	76	67	46	40	33	36	50	61	74	76	79	83	98
1993-94	81	68	46	41	49	42	58	65	72	78	92	88	107
1994-95	82	63	46	43	41	52	55	60	70	75	88	84	98
1995-96	81	63	54	40	43	42	52	63	65	78	92	89	107
1996-97	75	64	48	44	41	45	55	60	74	77	86	90	102
1997-98	79	65	50	41	47	53	55	61	67	78	95	92	111
1998-99	83	66	53	44	50	51	55	61	68	78	88	89	103
1999-00	80	66	56	45	42	47	53	67	70	78	88	89	105
2000-01	75	63	44	38	39	44	58	60	75	77	87	91	102
2001-02	83	65	52	44	46	51	49	62	69	81	93	86	110
2002-03	80	64	52	45	46	49	58	61	70	84	94	90	107
2003-04	83	71	49	44	34	48	61	66	67	78	91	89	103
2004-05	77	67	53	47	44	51	61	64					
20 Year Average	**79**	**66**	**50**	**40**	**42**	**47**	**55**	**63**	**70**	**79**	**89**	**88**	**111**

AVERAGE MINIMUM TEMPERATURE SUMMARY - PENDLETON

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

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	MIN
75 Year Average	**43**	**35**	**31**	**27**	**24**	**29**	**32**	**36**	**42**	**47**	**51**	**50**	**-30**
1984-85	43	34	33	22	21	21	31	38	42	47	54	49	-16
1985-86	40	35	17	13	28	31	38	35	43	50	49	53	-21
1986-87	42	34	35	27	21	31	35	38	44	47	52	47	-3
1987-88	43	29	32	25	24	26	31	39	42	48	51	47	3
1988-89	42	39	35	27	28	15	33	39	42	48	49	52	-18
1989-90	41	35	34	26	31	26	31	38	42	49	54	53	-4
1990-91	45	36	35	14	23	34	31	36	42	46	51	53	-26
1991-92	42	33	34	30	33	34	32	39	41	51	53	52	11
1992-93	43	37	34	24	16	21	31	38	47	49	51	50	-12
1993-94	42	37	19	30	32	26	32	40	45	47	53	51	-4
1994-95	44	34	32	28	28	31	32	36	42	47	54	47	-5
1995-96	47	36	36	29	27	22	33	38	41	45	53	51	-21
1996-97	42	37	31	28	24	30	35	36	44	48	51	53	-3
1997-98	47	35	34	28	29	33	33	35	43	48	57	52	3
1998-99	49	33	36	26	32	32	33	32	39	47	49	54	-5
1999-00	38	32	36	32	29	32	31	37	44	46	51	48	19
2000-01	45	37	27	27	28	27	32	36	42	47	52	52	16
2001-02	45	34	34	28	28	29	30	34	40	50	54	48	18
2002-03	42	29	30	32	34	29	37	37	43	47	53	51	9
2003-04	46	40	26	29	21	30	34	35	43	48	52	55	-20
2004-05	44	38	31	30	26	22	32	36					11
20 Year Average	**43**	**35**	**31**	**26**	**27**	**28**	**33**	**37**	**42**	**48**	**52**	**51**	**-26**

AVERAGE MAXIMUM TEMPERATURE SUMMARY - MORO

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

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	MAX
75 Year Average	**75**	**62**	**47**	**39**	**37**	**43**	**51**	**59**	**67**	**74**	**83**	**82**	**111**
1984-85	70	57	45	35	29	40	50	61	67	75	89	78	99
1985-86	66	59	33	24	39	43	55	56	67	80	75	87	101
1986-87	67	65	48	34	36	44	51	63	70	78	78	82	98
1987-88	78	68	49	36	35	47	52	59	63	70	83	81	100
1988-89	74	71	49	39	44	32	48	62	66	76	78	77	99
1989-90	76	61	51	40	43	45	54	63	64	73	87	82	106
1990-91	80	60	52	34	39	51	49	58	62	68	83	86	98
1991-92	78	64	46	40	43	48	57	61	72	81	82	84	103
1992-93	71	62	46	37	30	35	47	57	71	71	73	80	95
1993-94	78	66	45	38	48	41	57	62	69	73	88	82	106
1994-95	80	62	45	42	37	49	52	57	68	71	81	78	96
1995-96	78	61	53	38	42	40	50	59	61	73	88	84	103
1996-97	72	61	47	42	40	45	53	57	71	73	80	85	99
1997-98	76	61	49	41	42	47	52	58	63	73	88	85	106
1998-99	81	62	50	41	47	48	52	57	64	71	81	83	100
1999-00	76	62	51	42	37	42	51	62	64	74	80	81	97
2000-01	72	60	41	36	36	42	54	57	71	72	81	85	100
2001-02	78	61	49	40	42	47	48	58	65	76	84	81	104
2002-03	76	61	49	40	43	47	56	57	66	78	88	84	102
2003-04	78	67	44	38	33	43	57	63	67	77	85	84	100
2004-05	72	63	51	44	40	48	57	59					
20 Year Average	**75**	**62**	**47**	**38**	**39**	**44**	**52**	**59**	**66**	**74**	**83**	**82**	**106**

AVERAGE MINIMUM TEMPERATURE SUMMARY - MORO

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

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	MIN
75 Year Average	**46**	**38**	**31**	**27**	**24**	**28**	**32**	**36**	**42**	**48**	**54**	**53**	**-24**
1984-85	44	34	31	22	21	22	30	38	42	48	58	50	-7
1985-86	41	36	19	13	26	29	37	35	45	52	51	57	-15
1986-87	44	39	34	25	23	31	34	40	46	50	54	52	7
1987-88	49	38	32	25	25	29	33	39	41	48	52	50	4
1988-89	45	42	34	27	29	16	31	38	43	49	53	53	-15
1989-90	46	37	34	26	31	26	32	39	41	48	56	55	13
1990-91	49	37	35	17	22	33	30	36	41	46	54	56	-16
1991-92	47	37	33	30	31	35	35	40	45	53	55	54	12
1992-93	45	39	33	22	17	20	31	36	46	49	50	51	-3
1993-94	46	40	22	28	32	25	33	39	45	48	56	54	-3
1994-95	48	36	30	28	25	32	31	36	45	49	55	50	-2
1995-96	49	38	36	28	27	23	32	37	40	47	55	52	-15
1996-97	44	38	31	27	26	29	34	36	45	48	53	56	7
1997-98	49	38	33	28	27	32	33	36	43	48	57	54	2
1998-99	50	34	35	25	30	30	30	34	39	47	51	56	-2
1999-00	44	35	35	30	25	29	33	38	42	46	52	52	13
2000-01	52	38	27	25	26	26	32	35	43	47	54	56	10
2001-02	49	36	33	29	29	28	29	35	41	51	55	51	3
2002-03	45	33	27	33	33	29	35	35	42	50	57	56	7
2003-04	49	42	27	28	22	29	36	37	44	49	56	58	-6
2004-05	47	40	31	29	25	26	33	36					6
20 Year Average	**47**	**37**	**31**	**26**	**26**	**28**	**33**	**37**	**43**	**49**	**54**	**54**	**-16**