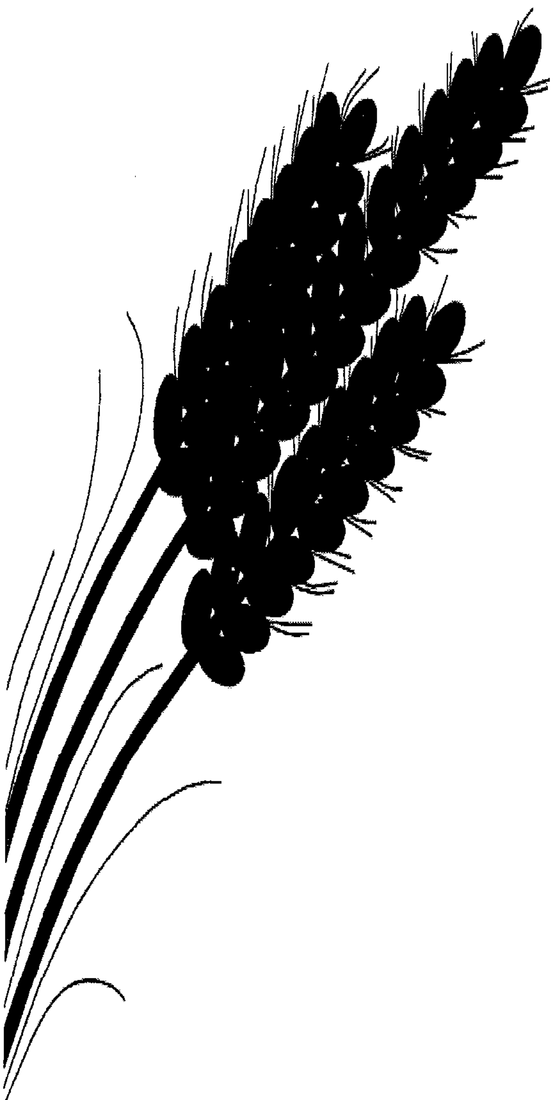
Special Report 999
May 1999

1999 Columbia Basin Agricultural Research Center Annual Report



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Oregon State University

in cooperation with
Columbia Plateau Conservation Research Center
USDA-Agricultural Research Service

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CONTENTS

INTRODUCTION

Staffs of the Columbia Basin Agricultural Research Center (CBARC, Oregon State University, Pendleton and Sherman Stations) and the Columbia Plateau Conservation Research Center (CPCRC, USDA-Agricultural Research Service, Pendleton) are proud to present results of their research. This bulletin represents a sample of the work in progress at these Centers. A collection of bulletins over a three-year period offer a more complete, ongoing assessment of the productivity and applicability of this research and education. Changes in staffing, programming, and facilities at these Centers during the past year are summarized below.

Promotions and Awards

Neither promotions nor awards were presented to staff of Oregon State University during the reporting period. Among USDA staff, certificates of merit and cash awards were given to Dr. Stephen Albrecht for strong leadership in team research to evaluate and oversee long-term, no-till experiments; to Dr. John Williams for creative, multiagency, research on the Umatilla River Watershed and for development of a unique rainfall simulator; to Paul Rasmussen for outstanding work in technology transfer; to Richard Greenwalt for suggesting, purchasing, and installing computer software that linked Pendleton to the Corvallis administrative office and also for installing and administering the new telephone system; to Patricia Frank for her work in Civil Rights training; to Kim Miller for her outstanding work ethic and overall quality of output during last summer's wheat harvest; and to Robert Correa for developing a unique switching system to activate runoff and sediment samplers.

Staff Changes

Many changes occurred in OSU staff during 1998–1999. Dr. Rolando Descalzo served as a Research Associate in the Plant Pathology Program from March until July 1998. Ms. Lisa Patterson resumed employment in the Plant Pathology Program. Dr. GuangLong Feng served as a Research Scholar in the Cropping Systems Program directed by Dr. Bill Payne. Dr. Feng is an Associate Professor at the Yucheng Comprehensive Experimental Station in Beijing, Peoples Republic of China. His credentials in plant-water relations aided in the cropping systems research at Pendleton. Ms. Connie Schrandt served as a Faculty Research Assistant in the Dryland Cropping Systems Agronomy Program directed by Dr. Don Wysocki. Ms. Schrandt arrived in May and departed in September to accept a position with the Oregon Department of Environmental Quality. Mr. John Muth terminated employment as the Trades Maintenance Worker 2 at Pendleton; the functional title for this position is OSU Facilities and Equipment Manager. Mr. Paul Thorgersen became employed in this position during May; Mr. Thorgersen brought into this position an extensive experience with the farm equipment repair industry in Umatilla County. Ms. Karen Morrow, who resigned as Biological Research Technician III during October, had the functional title of Cereals Breeding Coordinator and had managed the Pendleton Station's contracts with the OSU Statewide Cereal Testing Program and the USDA-ARS Regional Club Wheat Breeding and Genetics Program. Mr. Scott McDonald was employed into the Cereal Breeding Coordinator position. Mr. McDonald is a native of Summerville, OR and received the M.S. degree in Plant Breeding at Washington State University. Mr. Darrin Walenta resigned his position as Senior Faculty Research Assistant in the Weed Science research program during August. Mr. Walenta entered an M.S. degree program at Washington State University. Mr. Greg Harris was employed into the technical position in the weed science program. Mr. Harris, a native of eastern Washington, is a graduate of Eastern Oregon University and brought into the program his work experience in commercial agriculture. Temporary employees in OSU programs during the reporting period included Sandra Alderman, Timothy Alderman, Alec Bailey, Charlene Clemmens, Brian Currin, Renee Foden, Jared Frank, Mark Easley, Andrea Haley, Bryce Herinckx, Kyle Grogan, Kevin Johnson, Jodi Justus, Brandon Kellogg, Matthew Millar, Russell Montgomery, Keely Moon, Justin Richards, Bryan Rodriguez, Nick Sirovatka, Kari Snyder, Bill Thurman, Sascha Usenko, Wenxin Wang, Amy Wasson, Lori Wasson, and Jacquelyn Zollner.

There were several additions and changes in USDA staff during 1998–1999. Melissa Wood accepted a 180-day appointment as an Engineering Technician to work for Dr. Dale Wilkins in April 1998. Virginia Bramlett accepted a 90-day appointment as a Biological Science Aid to work for Dr. Stewart Wuest in April 1998; her position was extended until November 1998. Judy Elliott filled the part-time Office Automation Assistant position and Stephen Osborn filled the Physical Science Technician position in June 1998. Dan Durr was employed on a 180-day appointment to design a system that more accurately characterizes the release of carbon dioxide from soil during tillage. In May 1998, Eric Nicita resigned as Hydrologic Technician to accept a position with the Forest Service. Joy Matthews, a 180-day appointee, filled the Hydrologic Technician position in November 1998. Katherine Skirvin, Biological Science Technician Plants, went from part-time to full-time status in September 1998. Kevin Collins, Sarah Fife, Mishelle Freston, Sarah Heidt, Kate Holsapple, Jennifer Kirby, Staci Loiland, Jason Meunier, Kim Miller, Leslie Pollard and Byron Wysocki worked as temporary employees during the summer and school vacations. Dr. Mark Siemens accepted an Agricultural Engineering position in January 1999. Paul Rasmussen, Soil Scientist, retired 1 January 1999 with 38 years of Federal service.

New Projects

Modern procedures for the diagnosis of plant pathogens and diseases are being introduced into the Plant Pathology Laboratory. Equipment purchased by the Oregon Wheat Commission was installed to increase the precision and speed for identifying pathogens in root disease complexes and for bolstering wheat seedling screening procedures to identify sources of genetic resistance to Fusarium foot rot and Rhizoctonia root rot. This activity will be used to create further linkages between the pathology and wheat breeding programs.

ARS Headquarters granted the Columbia Plateau Conservation Research Center a two-year, post-doctoral position in agricultural economics to investigate financial aspects of agricultural sustainability in the Pacific Northwest, including reduced tillage and conservation tillage systems. A project was started to develop a carbon sequestration model that will compute the decomposition rate and soil carbon residence time based on antecedent organic matter, crop residues, crop roots, and organic carbon containing amendments such as compost, manure, or sewage sludge.

Facilities and Equipment

Several ongoing improvements were made to OSU facilities and equipment and vehicle inventories. The most noticeable change involved an extensive improvement in the landscaping at Pendleton. Trees were removed to address safety and tree-health concerns, and the windbreak and shrubs near buildings were pruned to improve maintenance efficiency and appearance. A new roof was installed on the automotive shed, and a new office was constructed in the OSU shop to improve operational efficiency. Efforts are currently underway to design and construct a water treatment facility to correct high nitrate concentrations and coliform bacteria contamination in the OSU water supply. Equipment added to the OSU program included a new 1-ton truck, John Deere 7300 no-till drill, customized John Deere 880T swather, Kubota 3410 tractor, and John Deere G20 tandem disk.

A committee led by Tami Johlke designed and ordered the new sign that now perches on the front lawn. Two laboratory incubators were purchased for the microbiology laboratory. Several maintenance and repair projects were undertaken this year. The inside of the main office building was painted, metal shop bay was insulated, exterior doors were replaced with ADA compliant doors, the 26-year old air conditioner compressor was replaced, and electrical surge protectors for the well pump, air conditioner compressor and air handling fan motor were installed. A Conserva Pak no-till seeder with capabilities to accurately place seed and fertilizer was added to our line of field equipment.

Training

OSU staff continued to maintain training requirements for pesticide application licenses, first aid, and cardiopulmonary resuscitation. Gloria Eidam travelled to Corvallis for training with the OSU Human Resources system, Judy Elliott received additional training in computer technology, and Paul Thorgersen was trained in safety and regulations for public water systems.

All USDA staff licensed to apply pesticides completed recertification training. All staff received updates on cardiopulmonary resuscitation, first aid, ethics, and civil rights training. Dr. Steve Albrecht, Dr. Dale Wilkins, Dr. Clyde Douglas, Paul Rasmussen, and Dr. Ron Rickman received training in statistics from Linda Whitehand, ARS Regional Statistician. Patricia Frank, Judy Elliott, and Bob Correa attended a one-day course on "Microsoft Office." Stephen Osborn attended a weeklong training session on global positioning systems. Dr. John Williams attended two seminars, entitled "Project Management" and "Team Leadership." Bob Correa, Tami Johlke, Daryl Haasch, Roger Goller, and Dr. Dale Wilkins attended a seminar, entitled "Safety Stewardship." Patricia Frank attended two, one-day seminars, entitled "PowerPoint Presentations" and "Business Writing." Dr. John Williams and Dr. Ron Rickman attended an NRCS training session on AGNPS, a model for estimating the distribution and source of agricultural nonpoint source pollution, in Portland. Dr. Dale Wilkins attended a training session on ground-penetrating radar.

Visitors

The Center hosted several special events, including an OSU Cereal Research Review; NRCS Research Review; staff enrichment training sessions (first aid, CPR); OSU administrator's participation in the Pendleton Roundup; temporary employee orientation; Umatilla County Smoke

Management Task Force hearing; STEEP's Technical, Grower, and Administrative Coordinating Committees; and numerous research and planning meetings.

Distinguished visitors hosted by the staff at the enter included: Dr. Antoinette Betschart, Area Director, USDA-ARS-Pacific West Area, Albany, CA; Darrel Temple, USDA-ARS, Stillwater, OK; Linda Whitehand, ARS Regional Statistician, Albany, CA; Jeri Berc, Special Assistant to the Deputy Chief for Soil Survey and Resource Assessment, NRCS, Washington, D.C.; Tony Ingersoll, NRCS, Pullman, WA; Sowgi Ral Rubal, Chiboub Taouak, Ben-Sghayer Laafif and other members of a wheat industry delegation from Tunisia; a thirty-member team of Japanese wheat purchasing agents and export representatives from Portland-based shippers, Richard Fritz and Wendy Kam of the Oregon Wheat League, and Daren Coppock, Oregon Wheat Growers League; Shigeto Nakashima and Zen Bakuren, members of Kinichiro Katoh, All Japan Barley Processors Association, Tokyo; Mark Rhodes, Soft-Slick Custom Computing, Hermiston, OR; Tommy Mitoma and Kerji Ohno of the Mitsubishi Corporation, Tokyo, Japan; Carlos Queueir and Encio Hidelgo of Ecuagran, and Felipe Vergara of Grupo Superior, Quito, Ecuador; and Pablo Malvenda, U.S. Wheat Associates, Santiago, Chile.

Seminars

The 1997 OSU/ARS Seminar Series at the Center was coordinated by John Williams. Seminars included the following speakers and subjects:

Understanding Connections between Management Practice and System Function: The Key to Successful Conservation Cropping Systems; Dr. Dave Huggins, Soil Scientist, USDA-ARS, Pullman, WA; 18 March.

Wheat Breeding and Genetics for Improving Wheat Quality and Production in the Pacific Northwest. Dr. C. James Peterson; 21 May.

Introduction to Flora I.D. Northwest Software; Bruce S. Barnes, Pendleton, OR; 14 July.

Root Shoot Interrelationships at Whole Plant Level; Dr. GuangLong Feng, Associate Professor at the Yucheng Comprehensive Experimental Station in Beijing, Peoples Republic of China; 22 September.

Cable Drawn Farming: System Analysis and Control Development; Dr Mark Siemens, Agricultural Engineer, Tifton, GA; 9 October.

No-Till in the Pacific Northwest and in Chile; Dr. David Bezdicek, Professor, Crop and Soil Science, Washington State University, Pullman, WA; 13 October.

The New ARS/NRCS Partnership Management Team; Dr. Jim Bonta, Research Hydraulic Engineer, USDA-ARS, North Appalachian Experimental Watershed, Coshocton, OH; 12 November.

Discussion of Wheat Breeding Philosophies and Future Research and Marketing Needs for the Pacific Northwest; Dr. Jack Brown, Associate Professor and Brassica Breeder, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow, ID; 24 November.

Breeding Wheat for Improvement of Starch Quality; Dr. Fred Stoddard, Australia National Cooperative Research Center for Quality Wheat, University of Sydney, Australia; 4 December.

Evaluations of Barley for Reaction to Fusarium graminearum; Dr. C. Kent Evans, Postdoctoral Research Associate, Department of Plant Pathology, University of Minnesota, St. Paul; 7 December.

Breeding Soft Red Winter Wheat for Resistance to Fusarium Head Blight and Product Quality; Dr. Kim Campbell, Wheat Breeder, Ohio Agricultural Research and Develop. Center, Wooster, OH; 8 December.

Bacterial Ring Rot: Alternative Strategies for Disease Management; Garreth Redgrave, Crop Production Specialist, Cenex/Land O'Lakes, Inc., Chinook, MT; 11 December.

Documenting Soil Quality Changes in the Transition to No-Till: 16 Years versus First Year No-Till and conventional tillage Near Pendleton, Oregon; Dr. Stewart Wuest, Soil Scientist, USDA-ARS, Pendleton, OR; 23 December.

Factors Affecting Colonization of Soybean Roots by Calonectria ilicicola and Development of Red Crown Rot Disease; Dr. Pali Kuruppu, Postdoctoral Scientist, Department of Plant Pathology, Louisiana State University, Baton Rouge, LA; 3 March.

A Look at Some Aspects on Fusarium Ear Rot and Septoria tritici Blotch; Dr. Chibwe Chungu, Postdoctoral Scientist, Winnipeg Research Center, Agriculture and Agri-Food Canada, Winnipeg, Manitoba; 5 March.

Topics of Importance in Higher Education and Agriculture; Dr. Lyla Houglum, Dean of Extended Education and Director of the Oregon Extension Service, Oregon State University, Corvallis, OR; 8 March.

Molecular and Cultural Analysis of Bacterial Diversity Associated with Ectomycorrhizae of True-Fir Seedlings Following Wildfire in Central Interior British Columbia; Dr. Madhukar Khetmalas, Postdoctoral Scientist, Natural Resources and Environmental Studies Program, University of Northern British Columbia, Prince George, B.C.; 9 March.

Coat Protein-Mediated Resistance to Wheat Streak Mosaic Virus in Soft White Winter Wheat; Dr. Paul McCarthy, Postdoctoral Research Associate, Department of Plant, Soil and Entomological Sciences, University of Idaho, Moscow, ID; 17 March.

Topics of Importance in Higher Education and Agriculture; Dr. Jim Zuiches, Dean of the College of Agriculture and Home Economics, Washington State University, Pullman, WA; 22 March.

Molecular Detection of Plant Pathogens and Disease Control; Dr. Dara Melanson, Senior Research Scientist, Molecular Plant Pathology and Tissue Culture Laboratory, South Australian Research and Development Institute, Adelaide, Australia; 26 March.

Topics of Importance in Higher Education and Agriculture; Dr. Paul Risser, President, Oregon State University, Corvallis, OR; 29 March.

Liaison Committees

The Pendleton and Sherman Station Liaison Committees have region-wide representation and provide guidance in decisions on staffing, programming and facilities and equipment improvement at the stations. Membership is appointed by the Director of the Oregon Agricultural

Experiment Station and also, at Pendleton, by the Director of the Pacific West Area, USDA-ARS. These committees provide primary communication links among growers, industry, research staff, and their parent institutions. The Committee Chairs and OSU and USDA administrators encourage and welcome your concerns and suggestions for improvements needed in any aspect of the research centers or their staffs.

The Pendleton Station Liaison Committee is coordinated by Chairwoman Kay Simpson (Pendleton: 541-276-3507) and the Sherman Station Liaison Committee is coordinated by Chairman Ernie Moore (Moro: 503-565-3202).

Acknowledgements

The staff expresses their appreciation to individuals, associations and corporations who have given special assistance for the operation of experiments on or associated with the Center during 1998–1999. The Oregon Wheat Commission continued to provide the critical support upon which the Center's OSU projects are founded. Thanks are also given to those who donated additional equipment, funds, labor, seed, and/or chemicals (*Dr. Betty Klepper, Leroy and Cathie Martin, American Cyanamid Co., BASF Corp., Bayer Corp., Novartis, E. I. duPont de Nemours, Marsh Aviation, Zeneca, Umatilla-Morrow Community Corrections Work-Release Program*) or loaned equipment, services, or facilities (*Richard Lieuallen, Earl Brown, Mid-Columbia Producers*).

We express our appreciation and thanks to those who donated labor, supplies, equipment or funding for the Pendleton Station Field Day: *American Cyanamid Co., BASF Corp., Bayer Corp., E. I. du Pont de Nemours & Co., Farm Credit Services, Farm Equipment Headquarters, Gustafson Inc., Huntington-Price, Inland Chemical Service, Inland Empire Bank, Novartis Crop Protection, Novartis Seed Treatment, Pendleton Main Street Cowboys, Monsanto Co., Pendleton Bus Co., Pendleton Flour Mills, Pendleton Grain Growers, Rohm and Haas Co., Smith Frozen Foods, The McGregor Co., Umatilla County Wheat Growers League, Walla Walla Farmers Coop., Western Farm Service, Western States Equipment, Wheatland Insurance, and Wilbur-Ellis Co.*

We also appreciate and thank donors who provided buses, meals, and other services for the Sherman Station Field Day at Moro: *Cascade Ranchers, Columbia River Bank, Farm Credit Services, Gustafson Inc., Klamath First Federal Bank, Klickitat Valley Grain Growers, Mid-Columbia Bus Co., Monsanto Co., Morrow County Grain Growers, Novartis Crop Protection, Richelderfer Air Service, Safeway, Sherman Aviation, Sherman County Fair, The Halton Co., UAP Pacific, United Sewerage Agency, Wasco Electric Coop., Western Tillage Equipment Co., and Wilbur-Ellis Co.*

Cooperative research plots at the Center were operated by Warren Kronstad, Patrick Hayes, Chris Mundt, Dan Sullivan, and Russ Karow. Additionally, we are very thankful for the ever-present assistance from the Extension Service personnel in all counties of the region, and especially from the following counties: Umatilla (*Mary Corp, Tom Darnell, and Jeff McMorran*), Union/Baker/Wallowa (*Gordon Cook*), Morrow (*Kathryn Kettel*), Sherman and Wasco (*Sandy Macnab*), and Gilliam (*Jordan Maley*) counties in Oregon; and Columbia (*Roland Schirman*), Adams/Lincoln (*Bill Schillinger*), Walla Walla (*Walt Gary*), and Whitman (*John Burns*) counties in Washington.

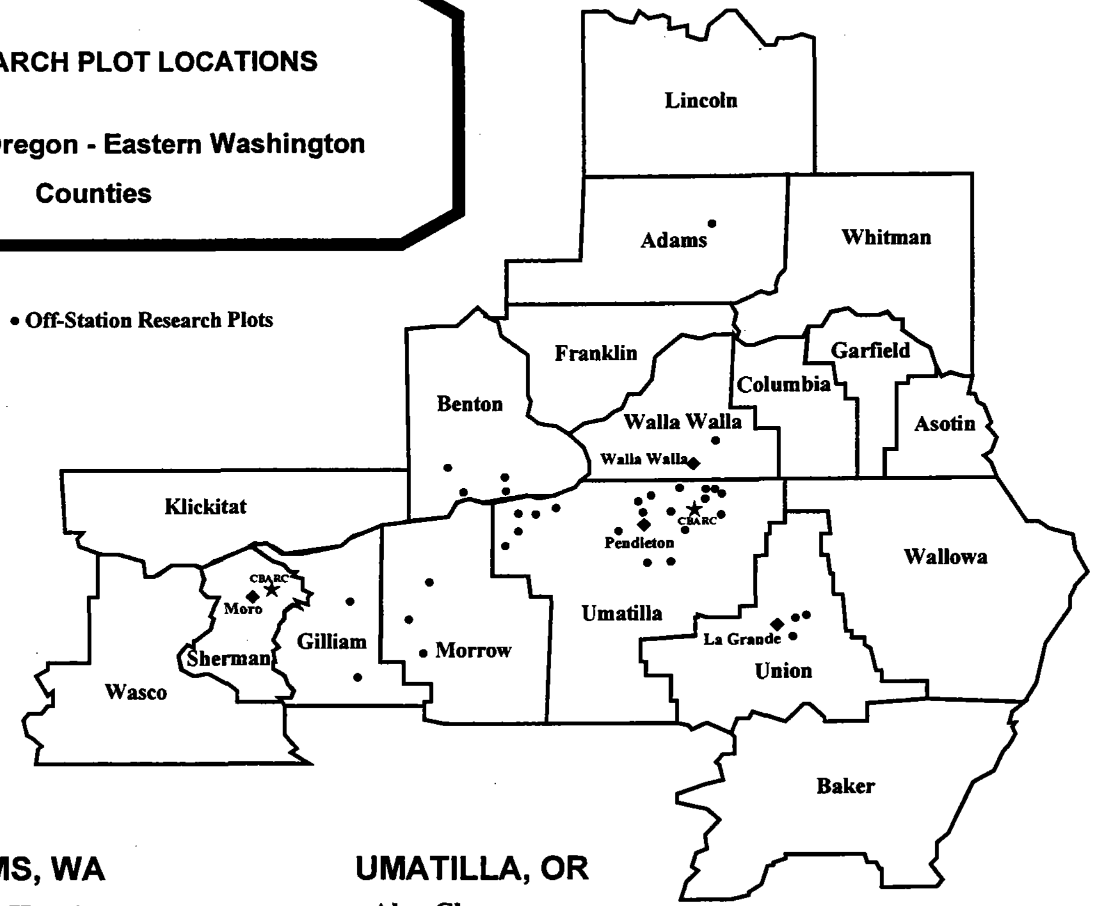
We also wish to thank the 30 farmers who have allowed us to work on their properties during the past year. They have performed field operations, loaned equipment, donated chemicals, forfeited yield, and adjusted their practices to accommodate our experiments. The locations of these off-station plot sites are shown on the map that follows.

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

Richard Smiley	Dale Wilkins
Superintendent	Research Leader
OSU-CBARC	USDA-ARS-CPCRC

RESEARCH PLOT LOCATIONS

Eastern Oregon - Eastern Washington Counties



ADAMS, WA

Curtis Hennings

BENTON, WA

Clyde Bybee
Doug Powell
Sandpiper Farms
Watts Brothers Farms

GILLIAM, OR

Van Rietman
Jim Rucker

MORROW, OR

Doug Drake
William Jepsen
Chris Raush

UMATILLA, OR

Alan Cleaver
Ted Gilliland
Greg Goud
Maurice Johns
Robert Johns
Don Lieuallen
Frank Mader
Arthur Pryor
Duff Farms
Dennis Rea
Tremayne Rea
Clint Reeder
Paul Reeder
Leon Reese
Shannon Rust
Tim Rust
Jeff Shaw
Steve Townsend
Larry Williams
Hermiston Experiment Station
Pendleton Experiment Station

SHERMAN, OR

Moro Experiment Station

UNION, OR

Rob Beck
Roger Davis
John Cuthbert

WALLA WALLA, WA

Bob Buchanan

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CARBON SEQUESTRATION BY AGRICULTURAL SOILS

Stephan L. Albrecht, Clyde L. Douglas, Jr. and Ron W. Rickman

The Greenhouse Effect

Some gases in the atmosphere absorb heat and prevent long-wave radiation from reflecting back into space. This condition is similar to properties of glass in a greenhouse, hence the name "Greenhouse Effect." These gases, often referred to as "greenhouse gases," can be both natural and synthetic. The natural gases include carbon dioxide (CO_2), methane or marsh gas (CH_4), and many oxides of nitrogen, for example, nitrous oxide or laughing gas (N_2O).

Carbon dioxide in the atmosphere has increased from 280 parts per million (ppm) before 1850 to about 360 ppm today (IPCC, 1994). Burning of fossil fuels and changes in land use have contributed to this increase. As the CO_2 concentration increases, so does the possibility that the atmospheric temperature will also increase, causing a change in global climate (King et al., 1997; Schmandt and Clarkson, 1992; Schneider, 1989). Some scientists argue the atmosphere is so well buffered that the atmospheric CO_2 will not change (Anonymous, 1998). Another argument is that as air temperature increases, cloud cover will increase and more of the sun's energy will be reflected, resulting in no climate change (Anonymous, 1998). Although exact predictions can not be made at this time, there is agreement among most scientists that, if greenhouse gases continue to increase, climate will change. While the unusually warm summer of 1998 and the recent effects of El Niño might not be a product of a change in climate, they have increased the concern about possible global climate change.

Policy Concerns

Recently, the international community has been discussing ways to reduce greenhouse gases in the atmosphere. A straightforward, if not easy, approach would be to reduce the man-made production of these gases. Unfortunately, greenhouse-gas production is linked to industrial output or energy production, and any reduction will most certainly impact living standards. On November 11, 1998, the United States announced that it had signed the Kyoto Protocol, which provides legally binding commitments to the reduction of greenhouse gases. If ratified with the advice and consent of the U.S. Senate, the Kyoto Protocol binds United States to reduce greenhouse-gas emissions to seven percent below 1990 levels by the year 2012.

An effective strategy to comply with this protocol could be accomplished through flexible mechanisms such as carbon emission trading, tax incentives for new technology, encouragement of voluntary reductions, and providing a larger role for agriculture in emissions reductions through soil carbon sinks (Glasener and Nipp, 1999). However, some oppose the Kyoto agreement because they believe implementation of the agreement will put the U.S. at a comparative disadvantage to less-developed countries (Global Climate Coalition, 1999).

Some critics question the science supporting projections that global warming is a serious environmental threat, and have voiced objections that developing countries are exempt from reducing emissions of CO_2 and other greenhouse gases. The concerns raised by the critics are being examined by ongoing atmospheric research conducted by several government agencies, including USDA-ARS and USDI-NOAA and many university scientists. As with many issues of this scale, it will take time to produce definitive answers.

At this time there are a number of solutions that might be used to meet our international commitment. One possibility is that industrial emitters of CO_2 could possibly purchase "credits" from farmers who sequester carbon in their soils. Also, government programs could be developed to provide incentives to encourage producers to sequester carbon in agroecosystems. Carbon sequestration would not only provide carbon credits, but would protect soils from erosion by wind or water. Thus, carbon sequestration would not only increase farm income; it would encourage agricultural practices that promote soil quality.

Soil Organic Matter and Carbon Sequestration

Preliminary estimates of overall CO_2 sources and sinks indicate that current agricultural activities constitute a net sink. Currently, the Kyoto Protocol recognizes forests as sinks but not agricultural croplands and grasslands. Two roles are distinguished for forests: the process of biomass build-up, e.g., fixation of atmospheric CO_2 into biomass, and carbon storage in wood and other biomass to be used as sinks. Increasing carbon sequestration in agricultural soils is a possible strategy in slowing or stopping the current increase in atmospheric CO_2 concentrations. Lal et al. (1998) estimate that U.S. cropland could potentially sequester 120-270 million metric tons of carbon per year. This potential sequestration could be accomplished through increasing productivity, decreasing tillage, and conversion of other land usage to agricultural production (Paustian et al., 1997).

The Intergovernmental Panel on Climate Change (IPCC, 1994) has estimated that in the next 50 to 100 years, between 40 and 80 gigatons of carbon might be absorbed in agricultural soils by using existing, generally accepted management practices. These practices involve reduced tillage or direct seeding, use of legumes in rotations, reduction of summer-fallow, and returning animal wastes or sewage sludge to the soil. When croplands are planted to perennial grasses, under the Conservation Reserve Program, or formerly cultivated land is planted to a biomass crop such as trees, between 0.5 and 1.5 tons per hectare of carbon are added to the soil annually.

Soil can be both a source and sink for carbon and nutrients. Soil organic matter (SOM) represents a major pool of carbon within the biosphere and is estimated to be roughly twice that in the atmosphere. Changes in land use and climate can change the amount of carbon held in soils and affect CO_2 fluxes between the atmosphere and the soil. Some agricultural management practices will lead to a net carbon sequestration in soils. Regional estimates of the carbon sequestration potential of these practices are crucial if policymakers are to plan future land use changes to reduce CO_2 emissions.

Pacific Northwest soils have a great potential to increase their carbon contents and contribute to carbon sequestration. Best management practices to sequester carbon may include reducing summer-fallow, increasing green manure use, improving erosion control, shifting from conventional tillage to minimal and no-tillage, reducing crop residue burning, and ensuring adequate fertilization. The reduction of summer-fallow by conversion to annual cropping may be the more important management change to increase carbon sequestration.

In Europe, soil-carbon sequestration potential has been estimated using several mathematical models and data from the Global Change and Terrestrial Ecosystems Soil Organic Matter Network (Smith et al., 1997). Relationships between management practices and yearly changes in soil organic carbon were developed and used to estimate changes in the total carbon in European soils. At the Columbia Plateau Conservation Research Center in Pendleton, the residue decomposition model, D3R (Douglas and Rickman, 1992) is being modified to predict carbon sequestration (Rickman et al., this issue). The information generated from this carbon sequestration model could be used to assist producers in the Pacific Northwest as well as in other locations in their efforts to increase the carbon concentration in their soils. Also, this data could be incorporated into geographical information systems for use by producers or other agencies.

Conclusions

While the international controversy over carbon sequestration continues to be debated, and many policy decisions in this area are yet to be made, practical and economically viable agronomic reasons exist to increase the carbon content of soils. However, research is needed to develop methods that increase the soil carbon sequestration rate and the quantities that can ultimately be stored. Agriculture has a tremendous opportunity to contribute to the mitigation through improved practices that also provide other environmental and conservation benefits.

It is currently possible to monitor changes in soil-carbon content. However, data collection is expensive and results can be extremely variable. There is an urgent need to develop reliable, accepted methods that are economically viable to estimate soil C. There is also a need for continuous and direct measurements of CO_2 exchange between the atmosphere and terrestrial ecosystems.

Agriculture can play an important role in carbon sequestration. Initial equipment costs and reluctance to adopt reduced tillage technologies could impede widespread adoption of soil carbon sequestration practices. Developing technologies have the potential to increase the ability of agriculture to sequester carbon. Many producers are already implementing these technologies, not specifically for carbon sequestration but for increasing crop yields, agronomic sustainability and improved soil quality.

Acknowledgements

We thank Katherine Skirvin for editorial assistance.

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DECOMPOSITION OF WHEAT AND THISTLE RESIDUE

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Introduction

Winter wheat (*Triticum aestivum* L.) grain yields are often low in the traditional wheat summer-fallow areas of agronomic zones 4 and 5 (Douglas et al., 1990). Sometimes there is insufficient residue left after seeding to control wind and water erosion and to meet the conservation tillage requirement of 30 percent residue cover. Weeds are serious problems in these two zones, and occasionally there is more Russian thistle (*Salsola iberica* Sennen) (Whitson et al., 1991) residue than wheat residue (Schillinger et al., 1999). Russian thistle residue can provide cover that will contribute to erosion control. However, we need to know the decomposition rate of Russian thistle to be able to estimate the amount of residue left after a summer-fallow season.

The objectives of this project were to evaluate the effect of winter wheat straw size on decomposition rate and to compare decomposition rates of winter wheat and Russian thistle left on the soil surface.

Materials and Methods

Winter wheat and Russian thistle stems were put into fiberglass cloth bags. Bags were placed on the surface of a Walla Walla silt loam (coarse-silty, mixed, mesic Typic Haploxeroll) soil located at the Columbia Plateau Conservation Research Center near Pendleton, OR. Treatments, replicated four times, were wheat straw length (one, two, and three inches), wheat straw split lengthwise, and thistle straw. Winter wheat residue was placed on the soil surface on October 3, 1994, and samples were retrieved on December 21, 1994, March 27, 1995, and July 10, 1995. Russian thistle residue was placed on the soil surface on November 17, 1994, and samples were retrieved on January 26, March 27, and June 21, 1995. Residue samples were taken from bags, washed carefully by hand to remove all soil, dried, and weighed to evaluate mass loss with time. Total precipitation from September 1994 through July 1995 was 4.27 inches greater than the 67-year average (Anonymous, 1996b). Total cumulative degree days for this same period was approximately 50 more than the 65-year average (Anonymous, 1996a).

Results and Discussion

Decomposition rate was independent of wheat straw length (p α 0.10) (Figure 1).

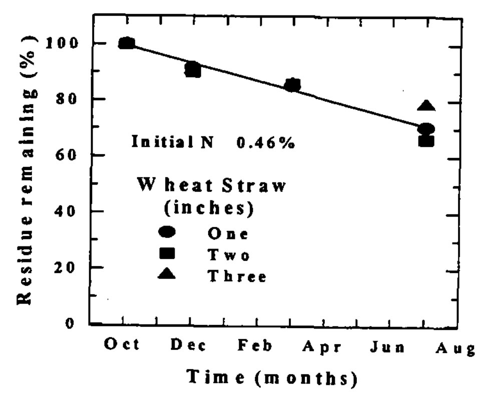

Figure 1 Decomposition of wheat straw as a function of straw length. 1994. Columbia Plateau Conservation Research Center.

Splitting wheat straws did not increase decomposition rate over not splitting straws (data not shown). Residue-decomposition rate can be increased by increasing the straw surface area available to the microorganisms that decompose the residue. Cutting residue into one-inch lengths did not increase the surface area enough to change the decomposition rate.

Initial N content of Russian thistle residue was approximately the same as N content of wheat straw. Decomposition rates of thistle residue (0.07 g/d) and wheat residue (0.10 g/d) (Figure 2) were not significantly different (p α 0.10). Russian thistle residue, left on the soil surface after wheat harvest, will decompose at approximately the same rate as wheat straw and be available the same length of time as wheat residue, to help control wind and water erosion.

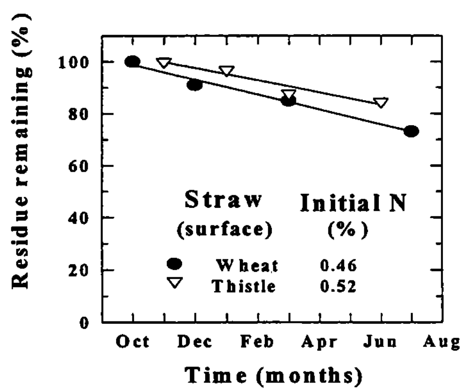

Figure 2. Decomposition of winter wheat and thistle straw. Columbia Plateau Conservation Research Center. Pendleton, OR

Average winter wheat yields and straw to grain ratios in zone 4 are 35 bu/acre and 1.69, and in zone 5, they are 50 bu/acre and 1.48, respectively (Douglas et al., 1999). Thus, residues (straw) left after harvest average 3550 (35 bu/acre × 60 lb/bu × 1.69 straw/grain ratio = 3550 lb/acre) to 4440 lb/acre across these two zones. Winter wheat residue decomposition (Figure 1), assuming no tillage, would leave approximately 2130 lb residue/acre [3550 lb residue/acre × 0.60 (estimated fraction decomposed by October) = 2130] in zone 4 and 2660 lb residue/acre in zone 5 at seeding time in October. This amount would correspond to greater than 50 percent surface cover (Renard et al., 1997). However, grain yields in some areas of zones 4 and 5 may be around 20 bu/acre. Twenty bu/acre × 1.69 (straw/grain ratio) would equal approximately 2030 lb residue/acre after harvest. If all residues were left on the soil surface, there would be only 1220 lb/acre of wheat straw on the surface at seeding the next fall.

When residue is buried by tillage, it is difficult to leave enough on the soil surface to help control erosion. As an example, consider a tillage system that is used in some dryland areas: chisel and sweep in the fall, sweep and fertilize in the spring, rodweed three times during the summer, and seed with a deep furrow drill in the fall (W.F. Schillinger, personal communication, 1999). Residue left on the soil surface as a result of this tillage system can be estimated from residue burial tables published by The Conservation Tillage Information Center (CTIC) (1992). Burial by tillage, plus loss from decomposition, would reduce the residue from 2030, 3550, and 4440 lb residue/acre left after harvest to an estimated 290, 510, and 630 lb residue/acre after fall seeding. Renard et al. (1997) indicates it takes approximately 550 lb wheat residue to equal 30 percent ground cover. Only the 50-bu/acre-wheat yield (4440 lb at harvest and 630 lb residue/acre at seeding) meets the 30 percent ground cover requirement.

If 2000 lb thistle residue/acre and 2030 lb wheat residue/acre were on the soil surface in the fall after wheat harvest, and if the same tillage sequence as above was used, there would be approximately 350 lb thistle and 290 lb wheat residue, a total of 640 lb residue/acre, left on the soil surface after seeding. This amount of residue would meet the 30 percent requirement and help control soil erosion by wind and/or water.

Conclusions

Straw length did not effect decomposition rate of winter wheat residue. Thistle residue decomposed similarly to winter wheat residue when left on the soil surface, and should be as effective as wheat residue in helping control wind and water erosion.

Acknowledgements

We thank Melissa Hedman and Sarah Heidt for laboratory assistance.

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STATEWIDE CEREAL VARIETY TESTING PROGRAM

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Introduction

This article reports results from cereal variety trials conducted in the Columbia Basin during 1998. These trials were conducted as part of an Oregon statewide testing program initiated in 1992 to provide growers with local data on performance of cereal varieties. The statewide program is coordinated by Russ Karow, Extension Cereals Specialist and Ernie Marx, Research Assistant, Department of Crop and Soil Science, both of Oregon State University. Karen Morrow was the trial coordinator for the Columbia Basin sites. Seed was packaged in Corvallis and distributed to trial coordinators. Coordinators planted, managed, and harvested trials on the station or in cooperation with growers. Information on trial locations, coordinators, and grower-cooperators is given in Table 1. The Corvallis research team processed harvested grain, analyzed results, and provided summary data to extension agents, seed dealers, agricultural field representatives, and growers across the state and region.

Winter and spring barleys, triticales, and wheats of several market classes were tested at ten sites statewide, including five in the Columbia Basin. When the program began in 1992, five Columbia Basin sites were selected to represent a range of growing conditions found in the region. Pendleton, Moro, and Heppner are dryland sites. The Pendleton site has the highest rainfall (17 in) and relatively moderate temperature extremes. The Moro site represents the low-rainfall (12 in) areas of the region. Heppner has shallow soils and a cool season. Irrigated trials are conducted at Hermiston and La Grande. Hermiston is an early season site with sandy soils. La Grande is at a higher elevation with cold winters that sometimes cause crop damage, and it has a long, cool growing season.

This article reports data on yield for the Columbia Basin. More complete data, including test weights and protein, can be found on the Internet (**www.css.orst.edu/cereals/**) or in *Winter cereal varieties for 1999* (Special Report 775R, Oregon State University Extension Service) and *Spring grain varieties for 1999* (Special Report 986, Oregon State University Extension Service).

The statewide variety testing program is a grower-driven program. If you have ideas about varieties to be included in your area or have suggestions for program improvement, contact Russ Karow, OSU Extension Cereals Specialist (541-737-5857).

Materials and Methods

Dryland plots (5 ft × 20 ft) at Heppner, Pendleton, and Moro were seeded at 20 seeds/ft^2. Irrigated plots (5 ft × 20 ft) at LaGrande and Hermiston were seeded at 30 seeds/ft^2. Seeding rates for dryland plots ranged from 68 to 134 lb/acre, depending on variety, to attain the desired rate of 20 seeds/ft^2. Irrigated plot seeding rates ranged from 98 to 201 lb/acre. All trials were arranged in a randomized complete block design with three replications. Plots were seeded using small plot drills. Seeding, harvest, and production practices were typical for each location. Spring grain trials at Heppner were lost in 1998.

Harvested grain was cleaned with a Pelz rub-bar cleaner. Plot yield, test weight, protein, and moisture were determined on cleaned grain samples. Yields are reported on a 10% moisture basis and in 60-lb per bushel for wheat and triticale and in pounds per acre for barley. Protein is reported on a 12% moisture basis and was determined using a Tecator Infratec 1225 whole grain analyzer.

In addition to small-plot variety trials, large-scale winter wheat drill-strip trials have been conducted across the state for the past five years. Cooperating growers were provided with 50 to 80 lb seed of each variety to be tested. The seed for 1998 trials was donated by Eric and Marnie Anderson and Pendleton Grain Growers. Cooperators, often with assistance of local county agents, established single-replicate drill-strip plots on their farms. These drill strips were managed and harvested by the cooperating grower with standard field equipment. Weigh wagons or weigh pads were used to obtain yield data. Two-quart grain samples were saved from some plots and used for test weight and protein analyses. Yield data for 1998 drill-strip trials is listed in Table 2.

Results and Discussion

The tables at the end of this report contain yield information from 1998 trials as well as compilations of data from 1996–1998. Because year-to-year variability is often high, conclusions should not be made from a single year's data. Three-year averages are a better indication of how well a variety is suited to a location. For newer lines that have not been tested multiple years, the 1998 data may help identify lines to watch in the future.

Winter Trials

Winter wheat (soft white common) (Tables 3 and 5). Stephens, Madsen, and Rod continue to be among the highest yielding varieties. Weatherford (OR898120) is a new release that has yielded as well as current varieties during the past two years of trials. Weatherford is later maturing than Stephens, with a heading date similar to Madsen. It is slightly taller than most widely grown varieties. Weatherford is resistant to moderately resistant to stripe rust, leaf rust, common bunt, powdery mildew, *Septoria tritici*, foot rot, and eyespot. It appears to have tolerance to Cephalosporium stripe. Winter hardiness is similar to Stephens. Grain quality is similar to current varieties for most attributes. Foundation seed for Weatherford will be available in fall 1999.

Brundage, released by Idaho in 1997, is another new line that has performed well in the Columbia Basin. Brundage is earlier than Stephens and tends to have slightly lower protein. Seed is available in Idaho.

Winter wheat (club) (Tables 3 and 5). Coda, Hiller, and Temple are three new club lines that have performed well for three years. Yields for these varieties have consistently matched or exceeded yields of Rely and Rohde. The new lines have stripe rust and foot rot resistance. Hiller has been the most consistent in our trials and may be the most widely adapted of the three. There is still some concern about Hiller not grading as club wheat, but trial samples have consistently graded as club.

Winter barley (Tables 4 and 6). Strider and Kold continue to be the recommended winter barleys in the Columbia Basin. Both varieties have barley stripe rust resistance. Foundation seed of Strider and Kold will be available in fall 1999. Registered and certified seed is available for Kold. Scio has had above average yields at many sites, but tends to have lower test weights. Scio is also susceptible to scald and barley stripe rust.

Steptoe has had below average yields and is susceptible to barley stripe rust.

Spring Trials

Spring wheat (Tables 7 and 9). Spring wheat yields at most Columbia Basin sites were lower in 1998 than 1996 and 1997, but were similar to long term averages observed since the statewide variety trials began in 1992. Rankings of soft white wheats remained similar, with Alpowa, Penawawa, and Pomerelle performing well. Several new lines had high yields in 1998, including IDO505 and IDO506 from Idaho and WA7850 from WSU. Additional years of data are needed to make final evaluations of these newer lines.

Relative yields of hard white spring variety IDO377S were down in 1998, but the three year average shows IDO377S yielding as well as or better than most soft white varieties. The grower cooperative Pro-Mar holds an exclusive license to production and should be contacted by interested growers.

Winsome is a new hard white spring release from Oregon State University. Heading date for Winsome is several days later than IDO377S and yields are similar to slightly lower. The Wheat Marketing Center's 1995 collaborative foreign testing teams identified Winsome as a superior cultivar for Asian noodle production. Seed for Winsome production should be available in 2001.

Among hard red spring wheats, Jefferson (IDO462) is a recent release which has performed well at dryland sites over a three-year period. Jefferson is slightly taller and more likely to lodge than WPB936. Idaho breeders intended Jefferson for dryland sites. It has performed well at Pendleton and Moro in our trials. Jefferson has also yielded well at the irrigated Hermiston site. Protein levels are comparable to existing hard red varieties. Foundation seed is available for Jefferson.

Spring barley (Tables 8 and 10). Baronesse continues to be a top performer at all sites except La Grande where yields are near average. The small number of varieties that have been grown in the spring barley trials for at least three years reflects a change in direction of spring barley breeding programs. Barley stripe rust (BSR) resistance has become a primary focus of breeding programs in the Pacific Northwest. Many BSR resistant lines have been developed and have been in the statewide trials for two years (1997 and 1998). Orca (2RF/M) and Montana's Chinook (2RM) are among the more promising BSR resistant spring varieties. These lines will appear in the three-year summaries next year, after data for the 1999 trials data is collected.

Seed Treatments

Imidacloprid (marketed by Gustafson as Gaucho) is an insecticidal seed treatment used to control aphids and Hessian fly in wheat. Stephens soft white winter and Alpowa soft white spring wheats were grown with and without imidacloprid treatments for three consecutive years. There was no apparent advantage to using the insecticide in the winter trials. For the spring trials, seed treatment increased yields by about 6 bu/acre. The difference between the winter and spring responses may be explained by the length of the growing season. During the long winter season the effectiveness of the insecticide dissipates. During the shorter spring season, the insecticide remains effective for a greater portion of the plant life cycle. Different pest populations in the two seasons could also contribute to the different yield responses. Currently, Gaucho treatment costs approximately $12 to $15/100 lb seed. Novartis is developing a similar insecticidal seed treatment.

Conclusions

While many varieties may excel in a given location in a given year, differences between widely grown varieties are often negligible when data from multiple years is examined. When selecting a variety, growers should consider disease resistance, hardiness, or other factors pertinent to the site where the crop is grown. Before switching to a new variety, small acreages should be grown for comparison to old varieties, preferably for more than one year, before making shifts in large acreages.

Acknowledgements

We thank Charlie Anderson, John Cuthbert, Norm Goetze, and Carl Haugerud for their donations of land, time, and effort to the statewide variety testing program. Without their contribution of resources, this program would not be possible. Cash funding for the statewide variety testing program is provided by the OSU Agricultural Experiment Station, Oregon Wheat Commission, and Oregon Grains Commission. The OSU Extension Service provided the project coordinator's salary and the clerical support funding. Without the support of these organizations, this program would not be feasible.

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Table 1. Oregon statewide cereal variety testing program, trial locations, site coordinators, and grower-cooperators, 1998.

Trial name	Trial type	Trial location	Trial coordinator	Grower cooperator
Corvallis	all grains—dryland	Hyslop Farm	Russ Karow, Ernie Marx	
Morrow Co. (Heppner)	all grains—dryland	Anderson Farm	Karen Morrow	Charlie Anderson
Hermiston	all grains—irrigated	Hermiston Exp. Stn.	Karen Morrow	
Klamath Falls	all grains—irrigated	Klamath Exp. Stn.	Randy Dovel	
LaGrande	all grains—irrigated	Cuthbert Farm	Karen Morrow	John Cuthbert
Madras	all grains—irrigated	Central OR Exp. Stn.	Steve James, Mylen Bohle	
Moro	all grains—dryland	Sherman Exp. Stn.	Karen Morrow	
North Valley (Cornelius)	winter grains—dryland	Goetze Farm	Russ Karow, Ernie Marx	Norm Goetze
North Valley (Scio)	spring grains—dryland	Haugerud Farm	Russ Karow, Ernie Marx	Carl Haugerud
Ontario	all grains—irrigated	Malheur Exp. Stn.	Clint Shock, Eric Eldredge	
Pendleton	all grains—dryland	Pendleton Exp. Stn.	Karen Morrow	

Table 2. Grower drill-strip, winter wheat variety tests across Oregon and southeast Washington, 1998. Sites are listed in order of descending average yield.

Variety	Kaseberg Wasco	Newtson S. Reservation	Miller Dufur	Nichols Dayton, WA	Hales Midway	Starvation Farms Lexington	Buether Kent	Reeder Pendleton	Rietmann Condon	Stonebrink Enterprise	Klages Joseph	Hoeft Spring Hollow	Average
	Yield (bu/acre)												
Gene	126	86	94	95	89	75	60	61	61	54	71	42	76
MacVicar	96	85	88	92	78	77	60	60	50	47	35	46	68
Madsen	105	85	93	82	80	73	65	—	56	46	72	31	72
Madsen/Stephens	107	95	84	84	81	67	62	—	66	52	67	40	73
Rod	100	89	88	76	73	76	68	53	48	64	43	47	69
Rohde	81	87	78	72	66	77	56	63	62	51	35	40	64
Stephens	95	98	94	82	78	75	59	64	63	61	50	35	71
7 way mix	108	—	—	—	—	—	—	—	—	—	—	—	—
Connie	—	—	—	—	64	—	—	—	—	—	—	—	—
Crew/Hyak	—	—	79	—	—	—	—	—	—	—	—	—	—
Eltan	—	83	—	—	88	—	—	59	—	54	38	38	—
Hiller	—	95	87	—	81	73	59	64	—	—	—	42	—
ID 485	—	83	—	—	57	61	—	62	64	—	—	42	—
Mac 1	—	87	—	—	67	70	—	53	63	—	—	35	—
MacVicar (high seed rate)	—	—	—	—	—	—	56	—	—	—	—	—	—
Madsen control	—	—	—	—	—	—	—	60	—	—	—	—	—
Madsen w/treatment	—	—	—	—	—	—	—	62	—	—	—	—	—
Madsen/Rod	—	—	90	—	—	—	—	—	—	—	—	—	—
Rod & Madsen	—	89	—	—	—	—	—	—	—	—	—	—	—
WB 470	—	95	—	—	66	—	—	—	—	—	—	41	—
WB 471	—	—	—	—	—	—	—	62	—	—	—	—	—
WB 472	—	—	—	93	—	—	—	—	—	—	—	—	—
Average	102	89	87	85	74	72	60	60	59	53	51	40	72

Table 3. Oregon statewide variety testing program, winter wheat yield data across five Columbia Basin locations, 1998.

Variety or line†	Market class	Heppner	Hermiston	LaGrande	Moro	Pendleton	5-site average	5-site percent of average‡
Winter wheat		Yield (60 lb bu/acre; 10% moisture)						
Brundage (ID14502B)	SW	62	90	99	80	95	85	105
Coda (WA7752)	Club	60	95	86	71	83	79	98
Eltan	SW	48	108	82	56	66	72	89
Foote (OR880172)	SW	47	80	58	50	97	66	82
Gene	SW	55	117	82	66	89	82	101
Hiller	Club	61	106	81	75	93	83	103
Hybritech 1017	SW	61	103	82	62	100	81	101
Hybritech 1019	SW	63	100	97	82	102	89	110
ID467	HR	64	100	80	67	74	77	95
ID86-10420A	SW	50	95	85	63	96	78	96
Ivory (OR850513)	HW	66	96	77	64	104	81	100
Lambert	SW	49	101	92	64	105	82	102
MacVicar	SW	54	99	93	73	80	80	99
Madsen	SW	81	102	90	76	106	91	112
Madsen+Stephens	SW	65	101	95	86	103	90	111
OR939515	SW	62	108	88	73	112	89	109
PureSeed Durum	Durum	53	67	75	55	71	64	79
Rely	Club	54	95	76	70	91	77	95
Rod	SW	55	117	78	67	80	79	98
Rohde	Club	65	104	70	66	85	78	97
Stephens-Dividend+Gaucho	SW	78	118	89	86	102	95	117
Stephens-Raxil+Gaucho	SW	60	111	83	80	85	84	104
Stephens-Vitavax+Gaucho	SW	65	113	83	82	97	88	109
Stephens-Vitavax, no Gaucho	SW	56	105	95	83	92	86	106
Temple (ORCL0054)	Club	68	95	85	71	92	82	102
WA7834	Club	36	89	54	61	50	58	71
Weatherford (OR898120)	SW	73	92	77	80	107	86	106
Average		60	100	83	71	91	81	—
PLSD (5%)		15	15	16	14	11	—	—
PLSD (10%)		13	12	13	11	9	—	—
CV		16	9	12	12	8	—	—
P-value		0.00	0.00	0.00	0.00	0.00	—	—

†All seed was treated with fungicide and Gaucho insecticidal seed treatment unless otherwise noted.

‡Percent of average is the average yield of each variety as a percentage of the average yield of all varieties (in this case, 81 bu/acre).

Table 4. Oregon statewide variety testing program, winter barley yield data across five Columbia Basin locations, 1998.

Variety or line†	Market class	Heppner	Hermiston	LaGrande	Moro	Pendleton	5-site average	5-site percent of average‡
Winter barley		Yield (lb/acre; 10% moisture)						
Kold	6RF	5807	4754	4841	5904	5972	5456	107
OR1957369	6RF	6870	5148	5106	4450	5416	5398	106
ORW10	6RF/M	5296	3221	4775	4201	4570	4413	86
ORW11	6RF/M	6137	5500	4672	5721	5909	5588	109
Scio	6RF	5893	5402	4199	5444	5241	5236	103
Steptoe	6RF	4204	4320	4729	4375	2867	4099	80
Strider	6RF	5565	4654	5906	5793	5866	5557	109
Average		5682	4714	4890	5127	5120	5107	—
PLSD (5%)		653	1312	NS	1105	1230	—	—
PLSD (10%)		534	1073	NS	904	1006	—	—
CV		6	16	13	12	14	—	—
P-value		0.00	0.03	0.14	0.01	0.00	—	—

†All seed was treated with fungicide and Gaucho insecticidal seed treatment unless otherwise noted.
‡Percent of average is the average yield of each variety as a percentage of the average yield of all varieties.

Table 5. Oregon statewide variety testing program, winter wheat yield data across five Columbia Basin locations, 1996–1998.

Variety/line	Market class	Heppner	Hermiston†	LaGrande‡	Moro	Pendleton	All sites Average
1996		Yield (60 lb bu/acre; 10% moisture)					
Brundage (ID8614502B)	SW	52	90	36	67	84	66
Coda (WA7752)	Club	54	97	23	63	92	66
Gene	SW	37	86	11	76	86	59
Hiller	Club	58	93	20	75	89	67
ID467	HR	49	86	36	59	84	63
MacVicar	SW	38	95	34	74	72	63
Madsen	SW	57	93	51	70	81	70
Madsen+Stephens	SW	49	99	34	69	76	65
Rely	Club	51	90	40	59	78	64
Rod	SW	57	108	63	79	89	79
Rohde	Club	55	94	19	67	71	61
Stephens-Dividend	SW	43	89	43	73	78	65
Stephens-Raxil	SW	43	90	35	82	76	65
Stephens-Vitavax+Gaucho	SW	45	97	36	77	76	66
Stephens-Vitavax, no Gaucho	SW	46	100	36	76	75	66
Temple (ORCL0054)	Club	55	68	16	61	70	54
1996 trial average (bu/acre)		**53**	**97**	**36**	**67**	**80**	**66**
1997							
Brundage (ID8614502B)	SW	68	77	—	94	71	—
Coda (WA7752)	Club	74	93	136	81	94	96
Gene	SW	49	96	103	81	61	78
Hiller	Club	60	103	135	93	79	94
ID467	HR	—	—	—	—	—	—
MacVicar	SW	58	94	135	70	40	79
Madsen	SW	61	88	128	78	76	86
Madsen+Stephens	SW	58	86	116	82	70	82
Rely	Club	58	95	127	81	79	88
Rod	SW	58	97	125	81	76	87
Rohde	Club	57	85	124	83	73	84
Stephens-Dividend	SW	62	83	120	87	64	83
Stephens-Raxil	SW	62	87	121	90	65	85
Stephens-Vitavax+Gaucho	SW	54	80	137	78	63	83
Stephens-Vitavax, no Gaucho	SW	58	86	126	71	62	81
Temple (ORCL0054)	Club	61	90	135	83	90	92
1997 trial average (bu/acre)		**57**	**89**	**126**	**79**	**70**	**84**

Table 5 (continued). Oregon statewide variety testing program, winter wheat yield data across five Columbia Basin locations, 1996–1998.

Variety/line	Market class	Heppner	Hermiston	LaGrande	Moro	Pendleton	All sites Average
		Yield (60 lb bu/a; 10% moisture)					
1998							
Brundage (ID8614502B)	SW	62	90	99	80	95	85
Coda (WA7752)	Club	60	95	86	71	83	79
Gene	SW	55	117	82	66	89	82
Hiller	Club	61	106	81	75	93	83
ID467	HR	64	100	80	67	74	77
MacVicar	SW	54	99	93	73	80	80
Madsen	SW	81	102	90	76	106	91
Madsen+Stephens	SW	65	101	95	86	103	90
Rely	Club	54	95	76	70	91	77
Rod	SW	55	117	78	67	80	79
Rohde	Club	65	104	70	66	85	78
Stephens-Dividend	SW	78	118	89	86	102	95
Stephens-Raxil	SW	60	111	83	80	85	84
Stephens-Vitavax+Gaucho	SW	65	113	83	82	97	88
Stephens-Vitavax, no Gaucho	SW	56	105	95	83	92	86
Temple (ORCL0054)	Club	68	95	85	71	92	82
1998 trial average (bu/acre)		**60**	**100**	**83**	**71**	**91**	**81**
1996–1998 average							
Brundage (ID8614502B)	SW	60	86	—	80	83	—
Coda (WA7752)	Club	63	95	82	72	89	80
Gene	SW	47	100	65	74	79	73
Hiller	Club	60	101	79	81	87	81
ID467	HR	—	—	—	—	—	—
MacVicar	SW	50	96	87	72	64	74
Madsen	SW	66	94	90	74	87	82
Madsen+Stephens	SW	57	95	82	79	83	79
Rely	Club	54	94	81	70	83	76
Rod	SW	57	107	89	75	82	82
Rohde	Club	59	95	71	72	76	75
Stephens-Dividend	SW	61	96	84	82	81	81
Stephens-Raxil	SW	55	96	80	84	76	78
Stephens-Vitavax+Gaucho	SW	55	97	86	79	79	79
Stephens-Vitavax, no Gaucho	SW	53	97	86	76	76	78
Temple (ORCL0054)	Club	61	85	79	72	84	76
Average yield (1996–1998)		**57**	**95**	**82**	**72**	**80**	77

Table 5 (continued). Oregon-wide variety testing program, winter wheat yield data across five Columbia Basin locations, 1996–1998.

Variety/line	Market class	Heppner	Hermiston†	LaGrande‡	Moro	Pendleton	All sites Average
		---Percent of average---					
1996–1998 percent of trial average							
Brundage (ID8614502B)	SW	107	90	—	111	104	—
Coda (WA7752)	Club	111	100	100	99	112	104
Gene	SW	83	105	80	103	98	94
Hiller	Club	105	106	97	112	109	106
ID467	HR	—	—	—	—	—	—
MacVicar	SW	89	101	107	100	80	95
Madsen	SW	117	99	110	103	109	107
Madsen+Stephens	SW	101	100	100	109	103	103
Rely	Club	96	99	99	96	103	99
Rod	SW	100	113	109	104	102	106
Rohde	Club	105	99	87	100	95	97
Stephens-Dividend	SW	107	101	103	113	101	105
Stephens-Raxil	SW	97	101	98	116	94	101
Stephens-Vitavax+Gaucho	SW	96	102	105	109	98	102
Stephens-Vitavax, no Gaucho	SW	94	102	105	105	95	100
Temple (ORCL0054)	Club	108	89	96	99	104	99

†Hermiston had hail damage in 1996.
‡LaGrande had frost damage in 1996.

Table 6. Oregon statewide variety testing program, barley yield data across five Columbia Basin locations, 1996–1998.

Variety	Market class	Heppner	Hermiston†	LaGrande‡	Moro	Pendleton	All sites average
		Yield (lb/acre; 10% moisture)					
1996							
Kold	6RF	5470	5186	4153	4357	5940	5021
Scio	6RF	5180	4715	2599	4575	5131	4440
Steptoe	6RF	5226	3456	2080	3486	4492	3748
Strider	6RF/M	4928	4990	3272	3623	6252	4613
1996 trial average (lb/acre)		**5350**	**4088**	**2881**	**4186**	**5417**	**4384**
1997							
Kold	6RF	4271	4052	7564	3683	4067	4728
Scio	6RF	4507	4980	8980	4232	3860	5312
Steptoe	6RF	2378	5227	4858	3976	3285	3945
Strider	6RF/M	5003	5424	8470	4659	3717	5454
1997 trial average (lb/acre)		**3961**	**4518**	**7138**	**3942**	**3802**	**4672**
1998							
Kold	6RF	5807	4754	4841	5904	5972	5456
Scio	6RF	5893	5402	4199	5444	5241	5236
Steptoe	6RF	4204	4320	4729	4375	2867	4099
Strider	6RF/M	5565	4654	5906	5793	5866	5557
1998 trial average (lb/acre)		**5682**	**4714**	**4890**	**5127**	**5120**	**5107**
1996–1998 average							
Kold	6RF	5183	4664	5520	4648	5326	5068
Scio	6RF	5193	5032	5260	4751	4744	4996
Steptoe	6RF	3936	4335	3889	3946	3548	3931
Strider	6RF/M	5165	5022	5882	4692	5278	5208
Average yield (lb/acre)		**4998**	**4440**	**4970**	**4418**	**4780**	**4721**
1996–1998 percent of trial average							
Kold	6RF	100	93	105	98	112	102
Scio	6RF	100	100	100	100	100	100
Steptoe	6RF	76	86	74	83	75	79
Strider	6RF/M	99	100	112	99	111	104

†Hermiston had hail damage in 1996.
‡LaGrande had frost damage in 1996.

Table 7. Oregon statewide variety testing program, spring wheat yields across four Columbia Basin locations, 1998.

Variety/line†	Market class	Hermiston	LaGrande	Moro	Pendelton	4-site average	Percent of trial average
Spring wheat		Yield (60 lb bu/acre; 10% moisture)					
Alpowa	SW	36	67	54	47	51	107
Alpowa w/o Gaucho	SW	36	60	51	39	47	97
IDO377S	HW	42	49	50	44	46	97
IDO505	SW	45	58	52	51	51	108
IDO506	SW	46	58	51	57	53	111
IDO523	HW	49	56	46	43	48	101
IDO533	HW	49	54	51	47	50	105
Jefferson (IDO462)	HR	41	58	57	60	54	113
OR3900362	HR	43	58	54	47	50	106
OR4870255	HW	38	58	44	40	45	94
OR4920307	HW	39	53	49	46	47	98
OR942845	SW	47	55	44	44	48	100
Penawawa	SW	46	54	53	43	49	103
Pomerelle	SW	46	44	46	44	45	94
Scarlet (WA7802)	HR	38	63	50	54	51	107
WA7850	SW	44	53	58	60	54	113
WPB 936	HR	24	55	45	54	44	93
WPB BZ 897-331	HR	23	47	45	44	40	83
WPB BZ 992-108	SW	44	50	56	43	48	101
Wawawai	SW	42	50	51	49	48	100
Whitebird	SW	41	48	43	41	43	91
Winsome (OR4870453)	HW	45	52	47	42	46	97
Yecora Rojo	HR	21	70	41	53	46	97
WPB 881	Durum	20	48	39	54	40	84
WPB YU 894-15	Durum	28	52	43	56	45	94
ML107-455	HW	38	—	—	—	—	—
ML042-115A	SW	42	—	—	—	—	—
ML057-32A	SW	51	—	—	—	—	—
Average		39	55	49	48	48	—
PLSD (5%)		10	11	9	9	—	—
PLSD (10%)		8	9	8	8	—	—
CV		16	12	12	12	—	—
P-value		0.00	0.00	0.00	0.00	—	—

†All seed was treated with fungicide and Gaucho insecticidal seed treatment unless otherwise noted.

Table 8. Oregon statewide variety testing program spring barley yields across four Columbia Basin locations, 1998.

Variety/line†	Market Class	Hermiston	LaGrande	Moro‡	Pendelton	3-site average	Percent of trial average
		Yield (lb/acre; 10% moisture)					
Bancroft (78AB10274)	2RM	3936	4086	—	3894	3972	104
BZ 594-19	2RF	3474	3981	—	4099	3851	101
Baronesse	2RF	4147	4070	—	3414	3877	101
Chinook	2RM	3873	3299	—	3773	3648	95
Gallatin	2RF	3866	3978	—	3511	3785	99
H3860224	2RF	4238	3704	—	3613	3852	101
MT920073	2RF	4243	4319	—	4228	4263	111
Orca	2RF/M	3071	3557	—	4320	3650	95
Steptoe	6RF	3349	3903	—	3946	3732	97
Tango	6RF	3212	3519	—	3572	3434	90
UC958	2RF	3118	3860	—	4072	3683	96
Idagold	2RF	3428	—	—	—	—	—
C32	2RM	3609	—	—	—	—	—
Galena	2RM	3536	—	—	—	—	—
BCD 12	2RF/M	3414	3996	—	4190	—	—
BCD 22	2RF/M	3448	4543	—	4587	—	—
BCD 47	2RF/M	3273	4180	—	4215	—	—
Average		3602	3928	—	3959	3830	—
PLSD (5%)		591	NS	—	541	—	—
PLSD (10%)		492	NS	—	449	—	—
CV		10	12	—	8	—	—
P-value		0.00	0.16	—	0.00	—	—

†All seed was treated with fungicide and Gaucho insecticidal seed treatment.

‡Moro spring barley trials had high variability, making variety comparisons meaningless.

Table 9. Oregon statewide spring grain yields across four Columbia Basin locations, 1996–1998.

Variety/line†	Market class	Hermiston	LaGrande	Moro	Pendleton	All sites average
1996		-------------------------Yield (60 lb bu/acre; 10% moisture)-------------------------				
Alpowa with Gaucho	SW	83	84	55	45	67
Alpowa w/o Gaucho	SW	68	84	54	39	61
IDO377S	HW	81	75	48	41	61
Jefferson (IDO462)	HR	83	65	—	—	—
Penawawa	SW	84	67	54	39	61
Pomerelle	SW	81	80	44	43	62
WPB 936	HR	72	60	49	43	56
Wawawai	SW	80	61	50	43	58
Whitebird	SW	76	79	52	39	62
Yecora Rojo	HR	73	24	50	38	46
1996 trial average yield (bu/acre)		**78**	**67**	**48**	**39**	**58**
1997						
Alpowa with Gaucho	SW	60	113	96	54	81
Alpowa w/o Gaucho	SW	55	102	87	47	73
IDO377S	HW	50	106	86	62	76
Jefferson (IDO462)	HR	55	86	77	48	67
Penawawa	SW	49	86	79	63	69
Pomerelle	SW	54	102	80	58	74
WPB 936	HR	45	98	88	45	69
Wawawai	SW	47	94	72	49	65
Whitebird	SW	37	82	80	45	61
Yecora Rojo	HR	42	86	54	31	53
1997 trial average yield (bu/acre)		**47**	**95**	**75**	**49**	**67**
1998						
Alpowa with Gaucho	SW	36	67	54	47	51
Alpowa w/o Gaucho	SW	36	60	51	39	47
IDO377S	HW	42	49	50	44	46
Jefferson (IDO462)	HR	41	58	57	60	54
Penawawa	SW	46	54	53	43	49
Pomerelle	SW	46	44	46	44	45
WPB 936	HR	24	55	45	54	44
Wawawai	SW	42	50	51	49	48
Whitebird	SW	41	48	43	41	43
Yecora Rojo	HR	21	70	41	53	46
1998 trial average yield (bu/acre)		**39**	**55**	**49**	**48**	**48**

Table 9 (continued). Oregon statewide spring grain yields across four Columbia Basin locations, 1996–1998.

Variety/line†	Market class	Hermiston	LaGrande	Moro	Pendleton	All sites average
		Yield (60 lb bu/acre; 10% moisture)				
1996–1998 average						
Alpowa with Gaucho	SW	60	88	69	49	66
Alpowa w/o Gaucho	SW	53	82	64	42	60
IDO377S	HW	58	77	61	49	61
Jefferson (IDO462)	HR	60	70	67	54	63
Penawawa	SW	60	69	62	48	60
Pomerelle	SW	60	75	57	48	60
WPB 936	HR	47	71	60	47	56
Wawawai	SW	56	68	57	47	57
Whitebird	SW	51	70	58	42	55
Yecora Rojo	HR	45	60	48	40	48
Average yield 1996–1998 (bu/acre)		**55**	**72**	**57**	**45**	**57**
1996–1998 percent of trial average						
Alpowa with Gaucho	SW	109	122	120	108	115
Alpowa w/o Gaucho	SW	96	113	112	92	104
IDO377S	HW	105	106	107	108	107
Jefferson (IDO462)	HR	109	96	117	119	110
Penawawa	SW	109	96	108	107	105
Pomerelle	SW	110	104	99	107	105
WPB 936	HR	86	98	106	104	98
Wawawai	SW	103	94	100	103	100
Whitebird	SW	93	96	102	92	96
Yecora Rojo	HR	83	83	84	89	85

†All seed was treated with fungicide and Gaucho insecticidal seed treatment unless otherwise noted.

Table 10. Oregon statewide spring barley yields across four Columbia Basin locations, 1996–1998.†

Variety/line	Market class	Hermiston	LaGrande	Moro	Pendleton	All sites average
		Yield (lb/acre; 10% moisture)				
1996						
Baronesse	2RF	5443	4028	3700	3523	4174
Steptoe	6RF	4526	2774	3777	3287	3591
1996 trial average yield (lb/acre)		**4251**	**4234**	**3512**	**2839**	**3709**
1997						
Baronesse	2RF	2985	5801	6496	4177	4865
Steptoe	6RF	2042	6574	6044	4157	4704
1997 trial average yield (lb/acre)		**2505**	**6349**	**4943**	**3700**	**4374**
1998						
Baronesse	2RF	4147	4070	—	3414	3877
Steptoe	6RF	3349	3903	—	3946	3732
1998 trial average yield (lb/acre)		**3602**	**3928**	**—**	**3959**	**3830**
1996–1998 average						
Baronesse	2RF	4191	4633	5098	3705	4407
Steptoe	6RF	3306	4417	4911	3796	4108
Average yield 1996–1998 (bu/acre)		**3453**	**4837**	**4228**	**3499**	**4004**
1996–1998 percent of trial average						
Baronesse	2RF	121	96	121	106	111
Steptoe	6RF	96	91	116	108	103

†The small number of varieties that have been grown in the spring barley trials for at least three years reflects a change in direction of spring-barley breeding programs. Barley stripe rust (BSR) resistance has become a primary focus of breeding programs in the Pacific Northwest. Many BSR-resistant lines have been developed and have been in the statewide trials for two years (1997 and 1998). These lines will appear in the three-year summaries next year, after data for the 1999 trials has been collected.

TILLAGE AND RAINFALL EFFECTS UPON PRODUCTIVITY OF A WINTER WHEAT-DRY PEA ROTATION

W.A. Payne, P.E. Rasmussen, C. Chen, and R. Goller

Introduction

Fresh peas *(Pisum sativum* L.) are grown under dryland conditions near the Blue Mountains of northeastern Oregon and southeastern Washington. During recent decades, fresh- pea acreage has declined due to reduced local market demand and increased international competition. From 1978 to 1987, total fresh-pea acreage in the inland Pacific Northwest decreased from 58,000 acres to 37,500 acres (Kraft et al., 1991). During the past fifty years, fresh-pea yields have increased little and remain highly variable. This is due to abiotic stresses, including unfavorable rainfall and high temperature (Pumphrey et al., 1979), and to biotic stresses, including diseases caused by *Fusarium solani, Pythium* spp., and *Aphanomyces* (Allmaras et al., 1987).

As mean annual precipitation in this region decreases to less than approximately 18 in., winter wheat *(Triticum aestivum* L)/fresh-pea rotations under dryland conditions are gradually replaced by winter wheat/summer fallow rotations. The deleterious effects of summer fallowing on the physical and chemical properties of soil and, in some cases, upon nitrate leaching, were documented long ago (Stephens, 1939; Smith et al., 1946), and have been repeatedly confirmed (e.g., Duff et al., 1995).

Where rainfall amount is marginal for fresh-pea production, dry field peas offer a potential alternative to summer fallowing. Although dry peas are grown in the Palouse region of Washington and Idaho, they are currently seldom grown in this portion of the inland Pacific Northwest. The potential benefits of growing dry peas instead of summer fallowing include the addition of increased organic residue, the biological fixation of N, and erosion protection (Beck et al., 1991). Substituting legumes for fallow would also reduce the downward movement of water in the soil, and thereby counteract nutrient leaching. Additionally, similar to fresh peas, dry peas would aid in the control of weeds and disease associated with wheat monocultures. Even in the wetter zones, dry peas may provide an alternative to fresh peas if market opportunities (e.g., availability of contracts from packing companies) are poor because they have broader market opportunities related to both domestic and foreign demand (Muehlbauer et al., 1983).

The potential for soil-water erosion is great in many parts of the inland Pacific Northwest because of steep slopes and predominantly winter rainfall falling on frozen soils (Pikul et al., 1993). Despite this fact, many farmers continue to use conventional clean-tillage to reduce heavy crop residues and to help control insects, pathogens, and weeds. A common tillage sequence for dry pea production in the Palouse area includes plowing, harrowing, cultivating with a harrow, two more harrowings, planting, and packing the soil with a roller and attached harrow (Hoag et al., 1984). There exists, therefore, a need to reduce rates of soil degradation without adversely affecting the production levels of winter wheat/pea cropping systems. Tillage systems that maintain residue cover, especially during the winter months, are recognized as important methods of reducing soil degradation and erosion. Young et al. (1994b) cite estimates that conservation tillage could reduce soil erosion by 35 percent in much of the inland

Pacific Northwest. This would enable many farmers to meet conservation compliance of the US Food Security Act of 1985 and subsequent legislation. According to Young et al. (1994a), the success of conservation tillage systems in the inland Pacific Northwest has been limited largely by lack of weed control.

The purpose of this study was to evaluate the agronomic performance of a winter wheat/dry pea rotation under four different tillage systems in a rainfall zone considered marginal for fresh pea production.

Materials and Methods

Data were gathered from one of several long-term studies located at the Columbia Basin Agricultural Research Center, near Pendleton, OR, where mean annual rainfall was 16 inches. From 1967 to 1991, fresh peas were grown in rotation with wheat. Beginning in 1992, dry peas were used instead of fresh peas.

The experimental design was a split plot with four replications. Each replicate contained eight plots (two crops × four tillage treatments). The location of peas and wheat within a replicate alternated from year to year. Individual plot size was 24 × 120 ft.

Semi-dwarf soft white winter wheat (cv. Stephens) was seeded as soon after October 10 as soil moisture was sufficient for germination and early crop growth. Dry peas (cv. Columbia) were seeded in late March or early April and harvested in July.

Wheat received 80 lb. N/acre as ammonium nitrate (34-0-0) broadcast before seeding. Peas traditionally received 20 lb. N/acre broadcast every second pea crop as ammonium phosphate-sulfate (16-20-0-14S).

The primary tillage treatments for wheat and pea residue are summarized in Table 1.

Table 1. Primary tillage treatments for wheat and pea residue at Columbia Basin Agricultural Research Center, 1990–1997.

Tillage treatment	Wheat stubble	Pea vines
1. Max till	Fall disk	Fall disk/hisel
2. Fall till	Fall plow	Fall plow
3. Spring till	Spring plow	Fall plow
4. Min till	Fall skewtread	Summer sweep

Additional details on secondary tillages are given below.

Treatment 1, "Max Till"

Wheat stubble was disked twice at a depth of 4 in. in the fall. In the spring, plots were sprayed, then swept once with a noble sweep at a depth of 1 in., and then rod-weeded with a Calkins rod. Pea vines were chisel-plowed with a JD chisel twice to a depth of 12–15 in. in the fall. Plots were sprayed if necessary and then rod-weeded twice to a depth of 1 in. before seeding.

Treatment 2, "Fall Till"

Wheat stubble was moldboard-plowed in the fall to a depth of 8–10 in. In the spring, plots were sprayed, spring-toothed twice to a depth of 2–3 in., and roller-harrowed if necessary. Pea vines were moldboard-plowed in the summer to a depth of 8–10 in., sprayed if necessary, tilled twice with a light disc harrow 2–4 in. deep, and roller-harrowed to reduce clods.

Treatment 3, "Spring Till"

Wheat stubble was sprayed before being spring plowed. Secondary tillage was the same as treatment 2. Pea vines were also managed as in treatment 2.

Treatment 4, "Min Till"

Wheat stubble was skew-treaded once or twice to a depth of 1 in. in the fall, swept with a Noble Sweep once to a depth of 1 in., and rod-weeded once with a Calkins to a depth of 1 in. Stubble was busted once with a rotary mower after harvest and before skew-treading until 1996, when this operation was discontinued. Pea vines were skew-treaded 2–3 times in the summer to a depth of 1 in.. In the spring, plots were sprayed if necessary, and rod-weeded twice to a depth of 1 in. Pea vines were sprayed in the spring before secondary tillage.

Analysis of variance was made once using year and tillage as factors. Total winter (October through March) and growing season (April through July) rainfalls were used as covariates in a second analysis of variance. This was because of the heavy dependence of pea- and wheat-yield upon rainfall amount and distribution, and because odd years during the study tended coincidentally to be much wetter than even years. For the years 1990 through 1997, winter rainfall was negatively correlated with growing season rainfall (Fig. 1) and, inconsistent with larger trends of the past thirty years (Rasmussen et al., 1998), gradually increased during the span of this study.

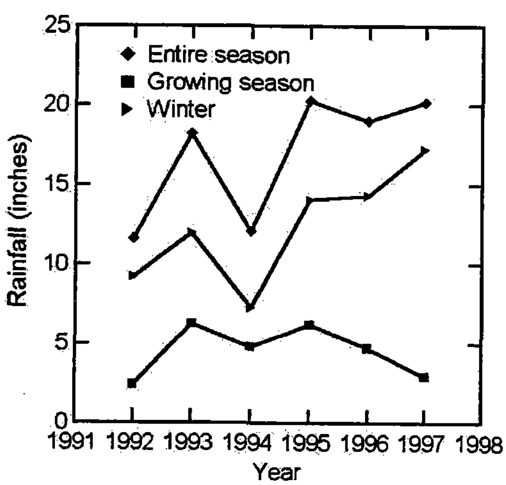

Figure 1. Winter (October–March), growing season (April–July) and entire season (Winter+growing serason) rainfall amounts at Pendleton Experiment Station, 1990–1997.

Grain protein content of wheat was calculated from percent nitrogen and standard regression equations.

Results

Wheat and pea yields varied widely from year-to year, reflecting such environmental variables as heat and rainfall amount and distribution (Pumphrey et al., 1979). Pea yields were very low in 1992 (Fig. 2), when growing season rainfall was low (Fig. 1).

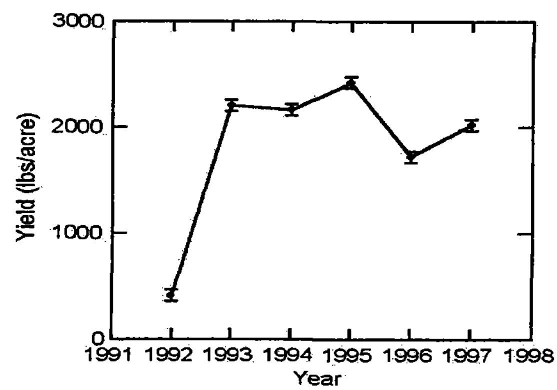

Figure 2. Dry pea yields from a winter wheat/dry pea rotation at the Pendleton Experiment Station

Pea yield was less affected by low growing season rainfall in 1997, presumably because of high winter rainfall. For wheat, 1992 and 1994, which were dry in terms of total and winter rainfall, were associated with low yields (Fig. 3).

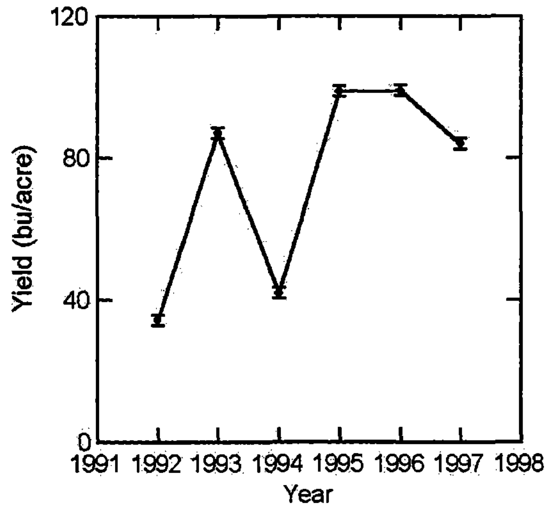

Figure 3. Winter wheat yield from a winter wheat/dry pea rotation at the Pendleton Experiment Station.

Analyses of variance models using year and tillage as factors revealed no significant effect of tillage upon pea yields, and a significant tillage × year interaction, indicating that the ranking among tillage treatments changed from year-to-year. For wheat, there was also a tillage × year interaction, as well as a significant effect of tillage. Analysis of variance using winter and growing season rainfalls as covariates revealed that by far the most important yield-determining factor was rainfall amount and distribution. Sums of squares of these data suggest that, while both crops were highly influenced by growing season and winter rainfall, wheat yield was more sensitive to winter rainfall, whereas pea yield was more sensitive to growing season rainfall.

Peas yield was highly variable despite correcting for rainfall, and there was no significant effect of tillage upon yield (Fig. 4).

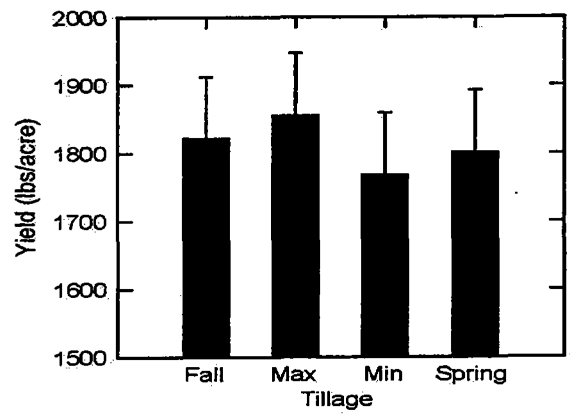

Figure 4. Dry pea yields as affected by four tillage systems at the Pendleton Experiment Station, 1992-1997. Winter and growing season rainfalls have been used as covariates. Bars represent one standard error of the mean.

Wheat yield was clearly least in the min-till treatment (Fig. 5), which had the least amount of soil disturbance and the greatest amount of residue left on the surface. There could be a number of explanations for this smaller yield, including a visually perceived higher incidence of downy brome (*Bromus tectorum* L.). Young et al. (1994a, b) report that yield response to tillage was dependant upon level of weed control. Smaller wheat yields of the min till

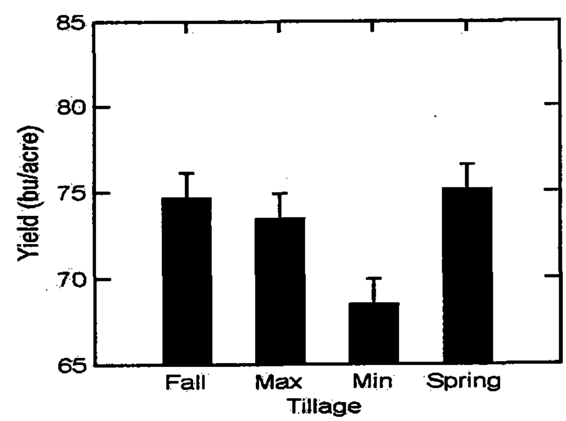

Figure 5. Winter wheat yields as affected by four tillage treatments at the Pendleton Experiment Station from 1992 to 1997. Winter and growing season rainfalls have been used as covariates. Bars represent one standard error of the mean.

treatment were associated with generally smaller protein percentages (Fig. 6), suggesting that perhaps wheat yield was also

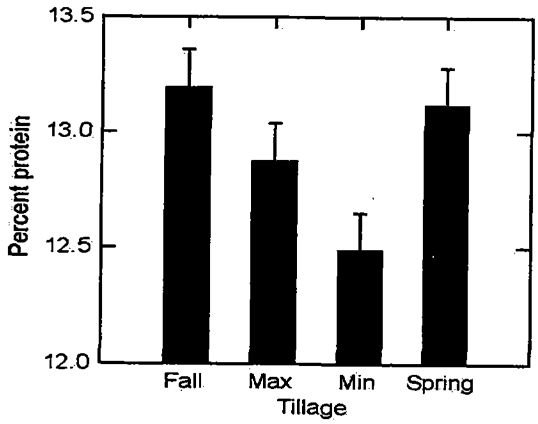

Figure 6. Wheat protein content as affected by four tillage treatments in a winter wheat/ dry pea rotation from 1992 to 1997 at the Pendleton Expeiment Station.

limited by N supply. It is also possible that greater residue reduced N availability through , for example, greater immobilization of nitrogen by microbial populations.

All in all, our results for dry peas are consistent with those of Pikul et al. (1989), who found no consistent differences in fresh pea production levels despite measurable changes in soil properties due to tillage treatment.

The fact that minimum tillage maintained comparable pea yields suggest wheat yield was also limited by N supply. It is also possible that greater residue reduced N availability through, for example, greater immobilization of nitrogen by microbial populations. All-in-all, our results for dry peas are consistent with those of Pikul et al. (1989), who reported no consistent differences in fresh-pea production levels despite measurable changes in soil properties from tillage treatment. The fact that minimum tillage maintained comparable pea yields suggests that minimum tillage may be an economically viable management option for peas. While Pikul et al. (1989) detected no differences in winter wheat yield from tillage, and Young et al. (1994b) reported increased wheat yields after conservation tillage, our results suggest that conservation tillage resulted in an average yield decrease of six to eight bu/acre. The results underscore the need for effective weed management in conservation tillage systems (Young et al., 1994a), and possibly for increased or differentially applied N.

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PREDICTING CARBON SEQUESTRATION IN AGRICULTURAL CROPLAND AND GRASSLAND SOILS

Ron W. Rickman, Clyde L. Douglas, Jr., Stephan L. Albrecht and Jeri L. Berc

Introduction

Atmospheric carbon dioxide (CO_2) concentration has been increasing at an accelerating rate for the past several decades (Keeling and Worf, 1994). Average global air temperature has also risen during the same period (Jones and Briffa, 1992). Certain physical laws indicate that atmospheric CO_2 and global air temperature may be correlated (Doos, 1975). Carbon dioxide is one of the gases known as a greenhouse gas. It permits the transmission of short wavelength radiation (visible and ultraviolet light received from the sun) and inhibits the transmission of long wavelength radiation (infrared or heat radiation that is emitted by the earth) in the same manner that glass does. The end result of this wavelength-dependent transmission of energy is a net storage of heat in the earth's atmosphere, just as heat is stored in a glass-roofed greenhouse on a bright sunny day.

Scientists predict that several processes occurring on the earth may be accelerated or aggravated by increasing the heat load on our atmosphere (Doos, 1975). In addition to increasing air temperature, problems could occur from melting ice fields and rising sea levels, from shifting weather patterns that contribute to flooding and drought, and increasing numbers and intensities of extreme weather events (Strain and Cure, 1985, Meier 1985). Human activity is one of the main causes of increased CO_2 and other greenhouse gases. It should, therefore, be possible to reduce the human contribution to CO_2 buildup and the greenhouse effect associated with atmospheric warming.

The increase in atmospheric CO_2 can be slowed by retaining the C that is captured by plant photosynthesis. Organic matter in soil is a natural reservoir for organic C. Unfortunately, some agricultural practices do not preserve soil organic matter. Conservation tillage practices that keep residues on the soil surface and utilization of cover crops, crop rotations, and organic amendments, usually maintain or increase the soil organic matter reservoir (Rasmussen and Parton, 1994).

If we as a nation are to contribute to a global effort to slow the increase of atmospheric CO_2, it will be necessary to determine the amount of C that can be sequestered by any method. Production agriculture, by adopting appropriate management systems, can contribute to C sequestration. There is an immediate need for a tool that will estimate how selected management systems will effect organic C storage in soils. These estimates could be provided by a field-level, C-sequestration model that is sensitive to local soils, climate, crop and tillage management systems, crop rotations, fertilization, cover crops, and organic amendments (Berc, 1999). It is highly desirable that this model operate in the field utilizing readily accessible data sets. This model can be applied to assist farm-planning efforts to enhance C sequestration. It can also be added to national, resource-inventory protocols to track regional and national scale soil-C stocks. Such a tool can help policy and program development for C sequestration just as soil-loss equations have been used to develop and evaluate erosion-control policies.

Objective

Staff of the Agricultural Research Service (ARS) at the Pendleton Research Center have been developing a C sequestration model named "CQESTR" that will compute the decomposition rate and residence time-in-the-soil of C from antecedent organic matter, crop residues, crop roots, and organic C-containing amendments such as compost, manure, sewage sludge, or other biosolids.

Methods

The core of the model was the residue decomposition model "D3R" (Douglas and Rickman, 1992). The D3R model used air temperature and residue N content as the primary controller of decomposition rate. Residue location above or below the soil surface, as determined by tillage practices, provided an index for the effect of water on rate of decomposition. Decomposition computations by D3R have been compared and found to accurately predict the decomposition of residues from data sets for a variety of crops from Alaska; Washington; Oregon; Idaho; Missouri; Indiana; North Carolina; Georgia; Texas; Colorado, Saskatchewan, Canada; and Uppsula, Sweden (laboratory study) (Curtin et al., 1998; Douglas and Rickman, 1992; Moulin and Beckie, 1993, 1994).

Microbes convert the majority of residue and organic C added to a soil to CO_2. A small fraction of residues is consumed by worms, insects, and small mammals. This nonmicrobial consumption will depend strongly on climate, the kind and mass of surface residue present, the length of time residue has been on the soil surface, and the local population of soil fauna. Predicting this consumption would be an independent modeling project that was not attempted in CQESTR. If this fraction was known to be locally significant, relative to microbial oxidation, it should be subtracted from the residue mass input to CQESTR. Physical removal of organic matter and residue from a field by wind or water erosion was not computed by CQESTR. Grazing or mechanical removal of a fraction of harvested residue was also assumed to be accounted for in the values of residue mass provided as input to CQESTR.

Much of the information required by CQESTR can be obtained nationally from existing data files that have been created for the use in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE). The N content of residues may be obtained from local information, values published in the literature, or existing compilations of plant nutrient content, such as the database "CPIDS" developed for the Water Erosion Prediction Project (WEPP) or the FAO Tropical Feeds database. The FAO database is available on the internet at www.fao.org/WAICENT/FAOINFO/AGRICULT/AGA/AGAP/FRG/TFEED8/index.htm
It lists crude, protein content of hundreds of plant species produced under a wide variety of growing conditions. Nitrogen content for crop residues can be calculated using the N content for protein of 16 percent. Soil organic matter content by layer, and layer depths, can be obtained from the national soil surveys (available from the MUIR database) and local Natural Resources Conservation Service (NRCS) offices. Root distributions may be determined from an exponential decay-with-depth relationship that will depend upon crop type and local climate (Belford et al., 1987; Gerwitz and Page, 1974).

One requirement for validation of CQESTR has been to compare the predicted decomposition rate for antecedent soil organic matter to observed values. Another requirement was to verify the conversion rate of the very slowly decomposing fraction of added residues into soil organic matter.

Observations for these two factors will be obtained from long-term soil organic matter data, for management treatments with differing amounts and types of residue added. These data were available from the long-term management plots on the Pendleton Research Center and from other U.S. and international, long-term management experiments. Many of these data sets are available from the Soil Organic Matter Network (SOMNET) of the Global Change and Terrestrial Ecosystems (GCTE) project of the International Geosphere-Biosphere Programme. Scientists at the Pendleton location are fully contributing members of SOMNET.

Results

CQESTR will compute C sequestration in the soil of a field as affected by climate, soil, crop production, and management practices used in that field. The amount of C stored and the time to equilibrium of C content will be provided using a "windows" format computer program that allowed point-and-click selection of most input data. It will also allow construction of batch files for runs of multiple sites and management scenarios. The program's output will include, for all rotations and management options requested, both short- and long-term trends of surface and buried residues, and changes in the soil organic matter content.

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AGRONOMIC RATES OF BIOSOLIDS FOR SOFT WHITE WINTER WHEAT PRODUCTION

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Introduction

Biosolids are stabilized solids derived from municipal wastewater treatment that meet Federal criteria for land application. They are an inexpensive source of nutrients and organic matter (Sullivan, 1998). Successful land application of biosolids has occurred in Oregon for the past 20 years and, with current economics, long distance transport to central Oregon is a viable option for large, western Oregon, wastewater treatment facilities. Biosolids application rates are based on supplying adequate N for the crop, without excessive nitrate losses via leaching. The rate of biosolids application that substitutes for normal N fertilization practices is known as the "agronomic rate".

Field trials with anaerobically-digested, dewatered biosolids in central Washington, showed that 26 to 31 percent of the applied biosolids N was recovered as available N (ammonium + nitrate-N) 9 to 12 months after application (Cogger et al., 1998). The lowest biosolids application rate in the study (approximately 300 lb N/acre) produced equivalent grain yields with higher grain protein than anhydrous ammonia (50 lb N/acre).

Previous biosolids research in Sherman County (Sullivan et al., 1998) showed that an application of about 230 lb biosolids N/acre (2.4 dry ton/acre) produced grain yield and plant N concentrations equivalent to those produced with application of 50 lb N/acre as anhydrous ammonia.

The present research continues our evaluation of agronomic rates of biosolids for soft-white wheat production in the 10–14 in. precipitation zone of eastern Oregon. To determine the agronomic rate, we compared plant-available soil N, grain yield, and N uptake for biosolids vs. anhydrous ammonia fertilization. We also collected soil and plant tissue samples to assess the effect of biosolids application on the supply of other plant-essential nutrients.

Materials and Methods

Site

Data was collected from one on-farm test site, located in the SW ¼, SW ¼ Section 16, T1N, R17E, 2 mi south of Wasco on Hwy 97 in Sherman County, Oregon. The soil has been mapped as a Walla Walla silt loam (> 60 in.). The cooperating grower (L.P. McClennan) performed routine tillage and crop management practices associated with a typical wheat-fallow rotation. The site had a winter wheat crop in 1996 (before our study) and in 1998 (completion of our study). Common soft-white wheat *Triticum aestivium* (Stephens/Madsen mix) was seeded in late September 1997.

Experimental Treatments and Design

Biosolids (anaerobically-digested and dewatered, 17 percent dry matter, 83 percent water) were supplied by the Unified Sewerage Agency (USA) of Washington County, Oregon. Biosolids trace-element concentrations met Federal requirements for land application.

Three biosolids rates (low, medium, and high) were applied using a rear-delivery manure spreader equipped with a hydraulic ram (Table 1). Biosolids treatments were applied in the fall after crop harvest (16 Oct. 1996) and in the spring before the first fallow tillage (25 Apr. 1997). The interval between biosolids application and the first fallow tillage was about six months for the fall application and about one month for the spring application. These application dates represent the most workable application times for biosolids in a wheat-fallow cropping system.

Table 1. Fertilizer application rates and timing. McClennan Farm, Sherman County, 1996-97.

Fertilizer applied †	Application date	Biosolids rate	Total nutrients applied ‡		
			N	P	S
		dry ton/acre	lb/acre		
None	-	-	-	-	-
Anhydrous ammonia	9 June 97	-	60	-	-
BS low	16 Oct. 96	1.7	140	120	40
BS medium		3.4	290	230	70
BS high		5.1	430	350	100
BS low	25 Apr. 97	1.7	170	90	40
BS medium		3.4	340	180	70
BS high		5.1	510	270	100

†BS = Biosolids applied to standing stubble the fall after crop harvest (16 Oct. 1996), or in the spring prior to first fallow tillage (25 Apr. 1997).

‡Based on biosolids application rate and biosolids total N, P, and S analyses performed by AgriCheck Inc., Umatilla, OR.

The composition of the biosolids varied somewhat from fall to spring (Table 1), because the wastewater treatment process changed seasonally. Biosolids produced in the fall are a combination of solids from primary, secondary, and tertiary wastewater treatment. Tertiary wastewater treatment, using alum (aluminum sulfate), removes additional P from the wastewater. The high-P residuals from tertiary treatment become part of the fall biosolids. In the spring, the biosolids contain only solids from primary and secondary wastewater treatment.

The biosolids applications were compared to an anhydrous ammonia control (60 lb N/acre, applied 6 June 1997) and an unfertilized control. Biosolids and unfertilized plots measured 40 × 350 ft, and the anhydrous ammonia plots measured 60 × 350 ft (to accommodate the anhydrous ammonia applicator).

Soil Sampling

Soil samples were collected in 12 in. increments in the fall of the fallow year (3 Sept. 1997; 0–24 in depth), before rapid growth in the spring of the crop year (20 Mar. 1998, 0–60 in depth), and after grain harvest (30 July 1998, 0–60 in depth). The samples at the end of the fallow year (3 Sept. 1997; 0–24 in depth) were collected manually with a 0.75 in i.d. push tube (Arts

Manufacturing, American Falls, ID). The deep-soil samples (0–60 in) were collected with a hydraulic auger probe (Kauffman Mfg., Albany, OR) mounted on a small tractor. Soil samples were dried at 80 °F, ground, and sieved to pass through a 0.08 in sieve. We also collected surface-soil samples (0–6 in) on 20 Mar. 1998 for analysis of additional nutrients.

Plant Sampling

We collected 30 flag leaves from each plot for determination of leaf-nutrient concentrations at early flowering (23 May 1998, Feekes 10.5). Biomass (grain + straw) samples were hand-harvested from five, 1-m sections of row from each plot on 15 July 1998. We used the biomass samples to determine grain harvest index and to obtain straw samples for N analysis. Sample bundles were threshed to remove the grain with a small plot thresher. The straw exiting the thresher included the grain chaff.

At harvest, we measured grain yield from a 27-ft swath from the center of each plot. We collected a 2-lb sub-sample from each plot for determination of grain test weight and protein.

Results and Discussion

Biosolids application rate had a major impact on grain yield, crop nutrient concentrations, and soil nutrient concentrations. Biosolids application date (fall vs. spring) had only a small impact on these variables.

Available soil N

The slope of the regression line for each sampling date was used to estimate the increase in available soil N caused by biosolids application (Fig. 1). Biosolids application increased available soil N (ammonium-N + nitrate-N) for the fall fallow sampling and the spring sampling. Postharvest soil samples showed that there was no significant increase in residual soil N from biosolids application.

For the fallow sampling, the slope of the regression line indicated that approximately 22 percent of the applied biosolids N was recovered in plant-available forms 4 to 10 months after application (Fig. 1a). Over 60 percent of this available soil N was recovered from the 0–12 in. depth.

For the spring sampling, approximately 30 percent of the biosolids N applied was in plant-available forms (Fig. 1b). Nearly all of the available N was in the nitrate form and was concentrated at the 12–24 in. depth (Fig. 2). The accumulation of nitrate at this depth suggested that little of the available N was lost from the root zone over the winter.

For postharvest sampling, the slope of the regression line indicated that biosolids application did not increase available soil N (Fig. 1c). The decline in soil N concentration between the spring of the crop year (Fig. 1b) and crop harvest largely reflects crop N uptake (Fig. 3d). Crop N uptake ranged from 43 to 66 percent of the available N present in the soil profile in early spring (Fig. 1b). This is a similar N uptake efficiency to that (45 to 70 percent) reported by others for soft white winter wheat (Fiez et al., 1995; Kjelgren, 1984). Additional soil N was also taken up by a heavy infestation of cheatgrass (*Bromus tectorum*). Cheatgrass biomass increased with biosolids application rate.

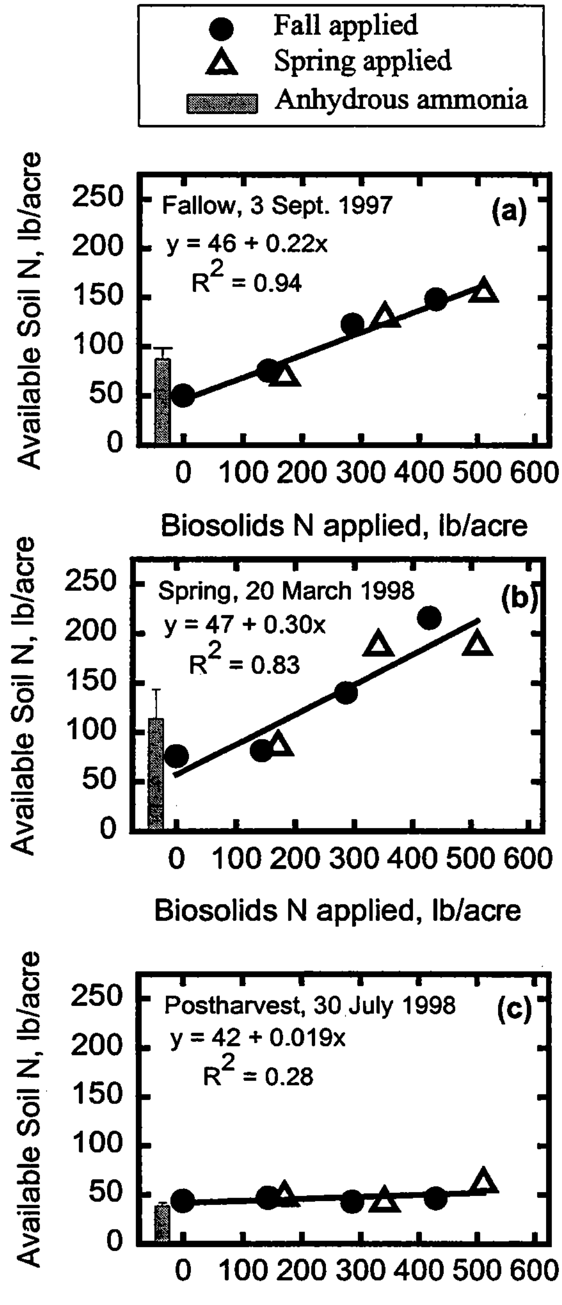

Figure 1. Anhydrous ammonia (AA; 60 lb N/acre) and biosolids effects on available soil N (ammonium-N + nitrate-N) in fallow (a); spring of the crop year (b); and postharvest (c). McClennan Farm, Sherman County, 1997–1998.

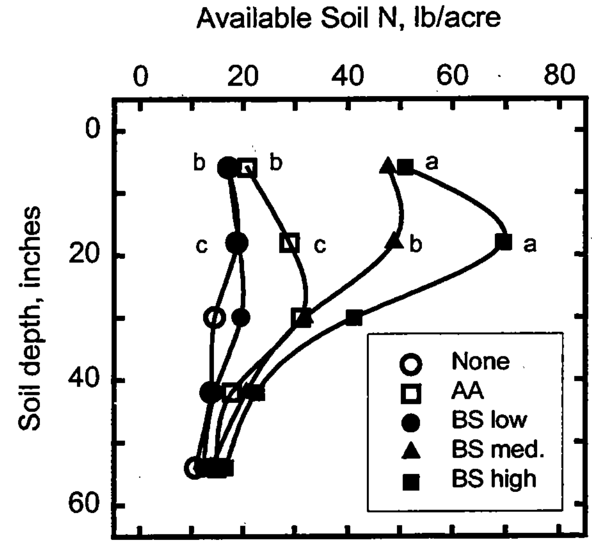

Figure 2. Anhydrous ammonia (AA; 60 lb N/acre) and biosolids effects on soil-profile distribution of available soil N (ammonium-N + nitrate-N), sampled in the spring of the crop year (20 Mar. 1998). For the 0–12 in. and 12–24 in. depths, symbols followed by a different letter were significantly different at P = 0.05. Values shown were the average for the fall and spring biosolids applications. McClennan Farm, Sherman County, 1998.

For this site, postharvest soil-N results were in general agreement with previous research in the 10 to 14 in. precipitation zone of eastern Oregon and Washington. Previous research in Sherman County showed that a biosolids application rate of 230 lb biosolids N/acre did not increase postharvest available soil N (Sullivan et al., 1998). Cogger et al. (1998) reported slightly higher postharvest nitrate levels with application of 300 lb biosolids N/acre than with 50 lb N/acre as anhydrous ammonia.

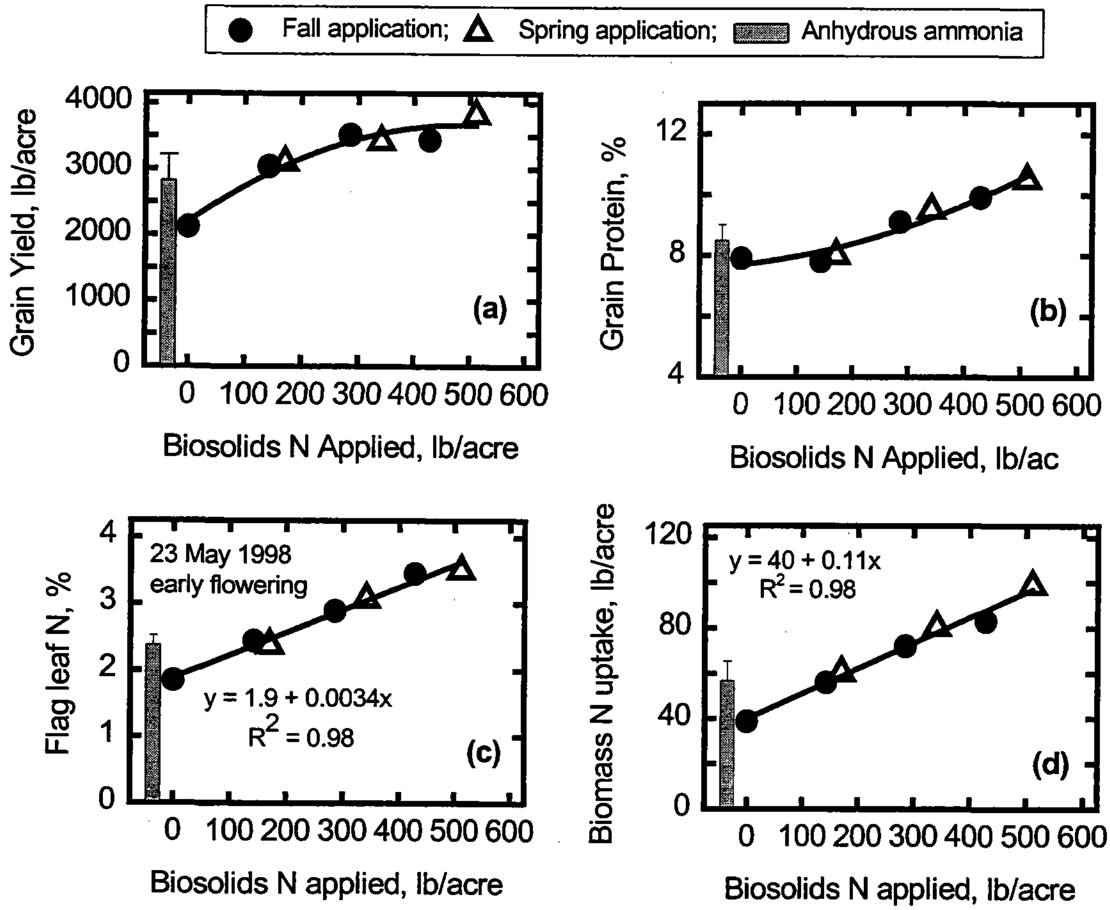

Figure 3. Anhydrous ammonia (AA; 60 lb N/acre) and biosolids effects on grain yield (a); grain protein (b); flag leaf N (c); and biomass (grain + straw) N uptake (d); of soft white winter wheat (Stephens/Madsen mix). McClennan Farm, Sherman County, 1998.

Grain yield and uptake of N

A number of agronomic measures were used to assess the effects of biosolids application rate on N availability, including grain yield, grain protein, flag-leaf N concentration, and biomass N uptake.

The low biosolids rate produced grain yield equivalent to that produced with the anhydrous ammonia. Yield-response to increasing biosolids rate was described by a quadratic regression model (Fig. 3a). The medium and high rates of biosolids produced significantly higher grain yields compared to anhydrous ammonia. High quality grain was produced with all rates of biosolids. Grain test-weight was greater than 60.7 lb/bu for all biosolids application rates vs. 61.2 lb/bu for anhydrous ammonia.

Grain protein (Fig. 3b) was equivalent for the anhydrous ammonia (8.5 percent) and biosolids at the low rate (7.9 percent). Biosolids applied at the medium and high rates increased grain protein to 9.3 and 10.2 percent, respectively.

Flag-leaf N concentrations, another indicator of plant N status, were also similar for anhydrous ammonia and the low biosolids rate. Flag-leaf N concentrations increased linearly with increasing biosolids rate (Fig. 3c).

Biomass N uptake (grain + straw) also increased linearly with biosolids rate. The low biosolids rate had equivalent N uptake to that produced with anhydrous ammonia (Fig. 3d). Increased grain protein (Fig. 3b) was responsible for most of the increase in biomass N uptake observed at higher biosolids rates. Straw N concentrations increased from 0.2 percent for anhydrous ammonia and the low biosolids rate to 0.3 percent for medium and high biosolids rates.

Based on crop response data for grain yield, grain protein, flag-leaf N concentration, and biomass N uptake, we concluded that the low rate of biosolids (140 to 170 lb biosolids N) supplied as much available N as 60 lb N/acre as anhydrous ammonia. Because of the timely and abundant rainfall during this cropping cycle, yield response to biosolids continued beyond the low biosolids rate (Fig. 3a). Maximum yield was produced with about 300 lb biosolids N applied, similar to results in previous studies (Sullivan et al., 1998; Cogger et al., 1998).

The detrimental effects of excess N at the high biosolids application rate, such as lodging, grain shrivel, very high grain protein (> 12 percent) and high residual nitrate-N were not apparent in the present study. Several factors were at work. First, the wheat varieties grown at this location, Stephens/Madsen, are moderately resistant to lodging, in contrast to the lodging-susceptible Eltan variety grown in previous studies (Cogger et al., 1998). Second, precipitation was above-average, with timely rainfall near the end of May. The abundant soil moisture reduced the risk of grain shrivel and high protein associated with luxuriant vegetative growth. Third, the cheatgrass proliferation at our site consumed all excess nitrate-N, whereas other sites had few weeds.

Availability of other nutrients

Biosolids application increased soil-test P, Cu, and Zn values (Table 2). It's unlikely that the grain-yield response observed at this location was related to any other nutrient besides N because micronutrient levels were above levels reported for deficiencies (Lindsay and Norvell, 1978; Marx et al. 1996). These nutrients could provide a benefit at locations with higher-yield potential or for crops with higher-nutrient demand.

Table 2. Effect of biosolids and anhydrous ammonia application on soil test values †
Spring crop year sampling, 20 Mar.1998. McClennan Farm, Sherman County, 1998.

Fertilizer applied ‡	Application date	Soil test value (0–6 in. depth)				
		pH	Soluble salt conductivity	P	Zn	Cu
			mmhos/cm	ppm		
None	-	5.9	0.18	49	0.9	2.1
Anhydrous ammonia	9 June 1997	5.9	0.17	52	0.9	2.0
BS low	16 Oct. 1996	5.8	0.19	61	1.2	2.4
BS medium		5.7	0.26	81	1.7	2.7
BS high		5.7	0.30	95	1.8	3.4
BS low	25 Apr. 1997	5.8	0.21	54	1.1	2.3
BS medium		5.6	0.31	59	1.4	2.4
BS high		5.4	0.49	69	1.7	2.6
PLSD (0.05)		0.13	0.14	8	0.3	0.4
CV (%)		2	33	8	14	12

†Soil testing performed by OSU Central Analytical Laboratory (Horneck, 1989). Phosphorus via Bray-1 extraction, zinc, and copper via DTPA extraction.

‡ BS = Biosolids applied to standing stubble the fall after crop harvest (16 Oct. 1996), or in the spring prior to first fallow tillage (25 April 1997).

Phosphorus. Biosolids application increased the availability of soil-test P for the medium and high application rates (Table 2). The fall biosolids application increased available soil-test P more than the spring application. The greater P availability demonstrated with fall application was probably related to seasonal changes in biosolids production practices. The fall biosolids contained added P-rich residues from tertiary wastewater treatment, resulting in higher P application rates (Table 1). Also, the tertiary wastewater treatment residues present in the fall biosolids may contain P forms with higher availability. Soil-test P levels for all treatments were far above the level corresponding to P deficiency (20 ppm, Marx et al., 1996). The increased soil test P levels may provide a long-term benefit to crop production, but they can also lead to greater risk of off-site pollution of surface water. Biosolids application had limited effects on crop-P uptake as indicated by flag-leaf and grain P concentrations (Table 3).

Flag-leaf S concentrations were higher with the fall-applied biosolids indicating a greater

Table 3. Effect of biosolids and anhydrous ammonia application on flag-leaf and grain nutrient concentrations. McClennan Farm, Sherman County, 1998.

Fertilizer applied †	Application date	Flag-leaf‡			Grain§		
		P	S	Zn	P	S	Zn
		---- % ----		ppm	---- % ----		ppm
None	-	0.23	0.15	10	0.33	0.10	18
Anhydrous ammonia	9 June 1997	0.24	0.18	11	0.32	0.09	15
BS low	16 Oct. 1996	0.26	0.24	13	0.32	0.10	17
BS medium		0.26	0.34	14	0.33	0.12	20
BS high		0.27	0.45	16	0.32	0.12	18
BS low	25 Apr. 1997	0.27	0.19	12	0.31	0.10	17
BS medium		0.27	0.26	15	0.31	0.11	17
BS low		0.26	0.30	17	0.31	0.13	18
PLSD (0.05)		NS	0.04	2	NS	0.01	NS
CV (%)		7	11	10	6	7	12

† BS = Biosolids applied to standing stubble the fall after crop harvest (16 Oct 1996) or the spring before first fallow tillage (25 Apr. 1997).

‡ Flag-leaf sampled 23 May 1998, early flowering (Feekes 10.5).

§ Sampled 24 July 1998, final harvest.

Sulfur. Biosolids increased extractable soil sulfate-S in samples taken in the fall of the fallow year. The increase in S availability averaged 15 percent of the biosolids S applied. Flag-leaf N:S ratios, an indicator of S deficiency, varied from 9:1 to 11:1, indicating that S was sufficient for all treatments (calculated from data in Table 3 and Fig. 3c). N:S ratios greater than 17:1 are associated with S deficiency (Rasmussen, 1996). Therefore, we conclude that S supply did not limit yield.

supply of available S (Table 3). The fall-applied biosolids contained alum (aluminum sulfate) residues from tertiary wastewater treatment, while the spring-applied biosolids did not.

Zinc. Biosolids application increased DTPA-extractable soil Zn (Table 2). Soil-test Zn values without biosolids were near reported deficiency levels (Marx et al., 1996; Lindsay and Norvell, 1978). Biosolids application increased flag-leaf Zn but did not increase grain Zn concentrations (Table 3).

Other nutrients. Biosolids application did not change extractable soil Ca, Mg, K, Na, B, or Fe. Small increases in DTPA-extractable soil Cu (+ 0.6 ppm) and soil Mn (+ 1.0 ppm) were measured for the high biosolids rate.

Soil pH and soluble salts. Overall, biosolids had little impact on soil pH andsoluble salts (Table 2). There was no change in soil pH or soluble salt conductivity with the low rate of biosolids application. The medium and high rates of biosolids decreased soil pH and increased soluble salt conductivity. This reduction in soil pH, associated with soluble salts, was likely temporary. Soluble salts, such as the ammonium and nitrate present in the spring soil sample, reduced the measured soil pH. Available N was depleted by the end of the growing season (Fig. 1c). Other indicators of soil acidity, extractable soil Ca, and lime requirement (SMP buffer pH) remained the same for all treatments.

Soil testing results from this site confirmed earlier observations. Previous research in Sherman County demonstrated that biosolids provided plant-available P, S, and Zn with no change in soluble salts or soil pH (Sullivan et al., 1998).

Summary and Conclusions

Plant-available N supplied by biosolids was equal to 22 percent of the total N applied at seeding (4 to 10 months after application); it was 30 percent in the spring of the crop year. At harvest, no residual available N was measured with biosolids rates up to 510 lb total N/acre.

Biosolids applied at 140 to 170 lb biosolids N/acre produced grain yield and plant N concentrations equivalent to those produced with anhydrous ammonia at 60 lb N/acre. Maximum grain yield was produced with about 300 lb biosolids N applied, similar to reported biosolids N rates for maximum yield in previous studies (Sullivan et al., 1998; Cogger et al., 1998). For grain production, fall- and spring-applied biosolids performed similarly. Increased biosolids application rates resulted in higher grain protein and flag-leaf N concentrations.

Biosolids application increased P, S, Cu, Mn, and Zn soil-test values. The grain-yield response to biosolids application was probably related only to the N supply. Biosolids applied at the low rate had no effect on soil pH or on soluble salt conductivity. Biosolids applied at the medium and high rates decreased the pH 0.2 to 0.5 units. This reduction in soil pH is probably temporary.

For the two sites where on-farm research has been conducted in Sherman County, the agronomic rate for soft-white wheat production is approximately 200 to 300 lb biosolids N/acre (2 to 3 dry ton/acre). This provides about 60 to 90 lb available N per acre for the first crop after application. The lower rate is recommended for high-tech manure spreaders that can accurately deliver 2 dry ton/acre (about 12 ton "as-is" biosolids/acre) and the higher rate for low-tech spreaders. Application rates above 300 lb biosolids N/acre (3 dry tons/acre) did not provide any agronomic benefits and may increase production risks. Greater risks of lodging, grain shrivel, cheatgrass proliferation, and high grain protein are associated with excessive application rates of biosolids.

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DISEASE MANAGEMENT FOR ANNUAL CROPS IN LOW-RAINFALL REGIONS

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Introduction

Most nonirrigated wheat in low-rainfall regions of the Pacific Northwest (PNW) is produced in a winter wheat-summer fallow rotation. The two-year fallow rotation reduces soil quality, increases soil erosion, and is plagued with annual weeds, surface crusting, and diseases of early planted wheat. Several of these conditions could be resolved if spring crops could be included in the rotation and annual cropping was profitable. A large Federal investment in research and extension to address these needs in the PNW has been made through a special appropriation named "Solutions to Environmental and Economic Problems" (STEEP) (Michalson et al., 1999). Research teams funded by STEEP are examining annual cropping systems that reduce the amount of land fallowed between winter wheat crops. The prevalence and importance of diseases is anticipated to change as crop management systems are modified. Diseases must be monitored and predicted as new management practices are developed.

Key disease constraints for producing cereals annually include Cephalosporium stripe, Fusarium foot rot, take-all, Rhizoctonia root rot, Pythium root rot, Fusarium foot rot, and nematodes (Cook and Veseth, 1991; Ogg et al., 1999; Smiley 1996; Smiley and Wilkins, 1993; Smiley et al., 1992). Cephalosporium stripe can be eliminated, and Fusarium foot rot can be diminished when winter cereals are minimized in the rotation sequence. Severe economic losses from strawbreaker foot rot experienced with winter wheat-summer fallow rotations are greatly diminished or eliminated under direct-drill (no-till) systems.

Practices that reduce damage from take-all include avoiding short rotations or growing continuous cereals, controlling grassy weeds, planting winter cereals early or spring cereals late, applying starter fertilizer below the seed, forcing the plant to feed preferentially on the ammonium form of nitrogen, using a seed treatment, and reducing the amount of surface residue in the seed row. Rhizoctonia root rot damage is reduced by rotating cereal crops in cycles of two or more years, planting winter cereals early or spring cereals late, avoiding the "Green Bridge", placing starter fertilizer below the seed, reducing the amount of surface residue in the seed row, tilling immediately before planting, and using a seed treatment. Pythium root rot is reduced by planting winter cereals early or spring cereals late, planting high-quality seed, avoiding the "Green Bridge", placing starter fertilizer below the seed, and using a seed treatment. Combining three or more of these plant-health promoting practices will minimize the impact of diseases known to occur in conservation cropping systems.

Objectives of this project were to quantify the impact of diseases in the STEEP team projects near Pilot Rock, OR, and Ralston, WA, and to complement those studies by examining resource-conserving, annual, cereal systems in low-rainfall regions near Echo and Moro, OR. Progress toward those goals is reported here.

Methods

Experimental procedures differed at each location and are described individually.

Pilot Rock, OR

Replicated on-farm research was conducted on two, shallow, soil sites in a 12-in. rainfall zone near Pilot Rock. Scientists, extension agents, and growers met in 1993 to establish experimental parameters. Dr. Dan Ball was the coordinator for this team research. Rotations were established with farm-size equipment on two farms (Gilliland and Shaw farms) during the spring of 1993. Each site contained four replicates of seven cropping systems in randomized complete blocks. Best management practices were used for tillage, residue management, fertilizers, varieties, pesticides, and planting dates. Seven systems were compared: continuous no-till hard red spring wheat, spring barley-summer fallow-winter wheat with conventional chisel plow and either postharvest light disking or a chemfallow treatment applied during early fall, fallow-canola-winter wheat with conventional chisel plow and rodweeding, and winter wheat-fallow with fallow prepared with 1) moldboard plow followed by cultivation and rodweeding, 2) light disking after harvest and then chisel plow and rodweeding, or 3) an early fall chemfallow treatment followed by chisel plow and rodweeding. The goal of the study was to examine difficulties encountered when conventional plow-based wheat-fallow systems are converted to a higher residue and/or a more intensive cropping system. Evaluations included pest and agronomic considerations, profit and economic risk, and compliance with conservation regulations.

Winter and spring wheat plants were collected twice each year and evaluated in our laboratory at Pendleton to identify and quantify diseases on roots, crowns, and foliage. Data were submitted to the project director (Dan Ball) for incorporation into the master database. Dr. Ball plans to summarize grain yields, weed data, and overall results after the project is concluded during August 1999.

Ralston, WA

Replicated on-farm research was also conducted on a 20-acre site in an 11-in. rainfall zone near Ralston WA. Dr. Frank Young was the coordinator for this team. Scientists, extension agents, and growers met to establish experimental parameters. Rotations were established with farm-size equipment during August 1995. Plots (30 × 500 ft) were in randomized complete blocks with four replicates. The experiment was duplicated on two fields so that each crop in each rotation was grown every year. Best management practices were used for tillage, residue management, fertilizers, varieties, pesticides, and planting dates. Five systems were compared: continuous spring wheat, spring wheat-spring barley, spring wheat-fallow, winter wheat-fallow, and a grower-directed flexible cropping system (growers determine tillage, crops, and timing). The primary focus of this study was to convert the winter wheat-fallow rotation to annual cropping over five years (1995–2000). The goal was to transition into annual cereals first then to incorporate rotation crops to break disease cycles and increase the efficiency of the system. Evaluations included all pest and agronomic considerations, profitability and economic risk, and compliance with conservation regulations. The OSU pathology group at Pendleton collected winter and spring wheat and barley plants once or twice each year. Plants were evaluated to identify and quantify diseases on roots, crowns, and foliage. Data were submitted to the project director, at Pullman, for incorporation into the master database. Progress reports for the overall project were prepared annually in special publications prepared by Dr. Frank Young.

Echo and Moro, OR

Experiments were established in northeast Oregon to complement the work at Ralston. This work was coordinated by the pathology team at Pendleton, led by Richard Smiley. Experiments were performed near Echo on the 66 Ranch operated by the Mader and Rust families, and near Moro on the OSU Sherman Experiment Station. Precipitation at the Oregon and Washington sites is comparable in amount (about 11 in.) and distribution.

A commercial planting of annual no-till hard red spring wheat at the Echo site was heavily damaged by a complex of Fusarium foot rot, Rhizoctonia root rot and take-all during the fourth consecutive year (1995) of that cropping system. Experiments began in 1996 to determine if root damage could be minimized without altering the overall philosophy of a system designed to reduce soil erosion. The 1996 experiment at Moro followed summer fallow and the 1997 and 1998 plantings were placed over the same site to simulate second- and third-year recropping.

The only tillage on these plots was a postharvest sweep to control Russian thistle. Light cultivation was performed one year to align straw so that it would not plug the single-rank drill used in these experiments. During 1998, a second experiment at Moro was planted directly into standing winter wheat stubble without any sweep or cultivation treatment. Except as noted for specific experiments, fertilizer was applied during February either as a surface broadcast of ammonium nitrate, urea, or ammonium sulfate, or as urea ammonium nitrate solution injected with a spoke-wheel applicator. Rates of fertilizer application varied annually according to interpretations of soil tests taken to 4-ft depth. Weeds were killed by applying Roundup about one month before planting. This practice increases seedling vigor and yield by breaking the "green bridge" (Smiley et al., 1992). Seed was planted during March into 5 × 30 ft plots with a plot drill equipped with four John Deere HZ openers with modified points (to allow banding fertilizer below the seed) and split-packer wheels spaced at 14-in. intervals. Seed was placed 1-in. deep into moist, cool soil. Unless stated otherwise, seed was treated with Dividend + Apron + Gaucho (1.0 + 0.045 + 2.0 fl oz/cwt), and was planted into five replicated plots at the rate of 20 seeds/ft^2. Where indicated, a starter fertilizer was banded directly under the seed at the time of planting. The starter fertilizer was a dry mixture of 16-20-0-24 (11 lb N/acre) plus 0-0-60 (8 lb K_2O/acre). Harmony Extra either with or without Bronate was applied to control weeds. Diseases on roots, subcrown internodes, crowns, basal stem and foliage were assessed on seedlings, and white heads were counted as plants neared maturity. Grain yields, test weights, and protein contents were determined. Dr. Penny Diebel, OSU-La Grande, is performing an economic analysis of these experiments.

Twenty spring wheat varieties were evaluated at both locations during 1996 and 1997. In 1998, the variety nursery was repeated at Moro but not at Echo.

During 1996 and 1997, individual experiments were established to determine if yields could be improved by planting a specific variety, treating seed with a broad-spectrum seed treatment, or banding fertilizer below the seed at the time of planting. The best of these practices were examined as an integrated management system during 1998.

Management experiments in 1998 were in a factorial design with three varieties, four seed treatments, and with or without fertilizer below the seed. Varieties included WB 936 (a hard red spring wheat, included to allow data to be compared with results from earlier years) and representatives of the highest yielding soft white and hard white spring wheats (Vanna and ID 377S, respectively) at these sites during 1996 and 1997. Seed treatments included Raxil Thiram + Gaucho, Dividend + Apron, Dividend + Apron + Gaucho, and Dividend + Apron + Gaucho + Bacillus L324. Starter fertilizer was either applied or not, using the blend and rates described earlier. The experiment at Echo during 1998 followed six spring wheat crops planted annually with no tillage except a post-harvest sweep. Soil tests indicated sufficient residual N to produce the crop with no additional N; none was applied except to examine the starter fertilizer variable. The experiment at Moro was placed into standing winter wheat stubble as a second-year direct seeding.

Results and Discussion

Results are described separately by location.

Pilot Rock, OR

Observations of plant health in the rotations at the Gilliland and Shaw farms sometimes failed to show clear differences among treatments when viewed in isolation for a single site during a single year. It was only after the experiment was nearly complete that important trends became evident. Stress from diseases was amplified by shorter rotations and by higher amounts of surface residue. This observation was exemplified by the three 3-yr rotations: winter wheat produced in a winter wheat-spring barley-summer fallow rotation (chisel plow fallow with either a light disking or chemfallow), and in a winter canola-winter wheat-summer fallow rotation. Rhizoctonia root rot and take-all were less damaging (almost nonexistant) where canola was included as the second crop, rather than spring barley.

We also had an opportunity to compare winter wheat diseases in three 2-yr rotations: winter wheat-summer fallow with 1) moldboard plow inversion tillage plus rodweeding, 2) light disking after harvest and then chisel plowed and rodweeded, and 3) an early fall chemfallow treatment followed by chisel plow and rodweeding. Rhizoctonia root rot and take-all were more damaging in the conservation tillage systems than in the moldboard plow system. Strawbreaker foot rot was more prevalent in the 2-yr chem-fallow rotation treatments and least prevalent in the 3-yr rotation that included canola.

Annual no-till hard red spring wheat was heavily damaged by Rhizoctonia root rot and damaged to a lesser extent, albeit still significantly, by take-all and root lesion nematode.

Ralston, WA

Damage from Rhizoctonia root rot was moderate to severe in the winter wheat-summer fallow rotation. In 1998, Rhizoctonia root rot appeared as patches of stunted plants (the "bare patch" phase of this disease) during the spring. Subcrown internode lesions caused by Fusarium foot rot were also significantly damaging. Strawbreaker foot rot and take-all occurred on low percentages of plants and were considered minor and unlikely to affect yield.

Rhizoctonia root rot and take-all were the most important diseases of spring wheat. It also became clear over time that irregularities were occurring in disease severity for specific treatments during the first three years of this experiment. Reversals of disease importance were occurring within comparable treatments during alternate years, depending on which of the two fields (east vs. west side of road) was planted that year. For instance, in 1997 root damage was least where spring barley followed spring wheat, and the opposite occurred during 1998. During the search to explain these irregularities it was discovered that incomplete information was obtained when the experiment was being designed. The two fields did not have comparable management histories, as had been understood initially. The plot area on the east side of the road, which had a high level of damage from root diseases, had four cereal crops during the five years preceding this experiment; winter wheat in 1990–1991, spring barley in 1992 and 1993, summer fallow in 1993–1994, and winter wheat in 1994–1995. Diseases in the experiment were minor on the west side of the road, where it is now recognized that only one cereal crop was grown during the previous five years; summer fallow (1990–1991), winter canola, summer fallow, winter wheat, and summer fallow (1994–1995). The explanation of these puzzling results during research on root diseases clearly emphasized the importance of rotations as a defense against root diseases.

Echo and Moro, OR

Seedling emergence was excellent in all treatments for this high-residue, minimum-tillage, annual, spring wheat system. Primary constraints to yield included Rhizoctonia root rot, take-all, Fusarium foot rot, barley yellow dwarf, Hessian fly, root lesion nematode, and low plant density (e.g., the 14-in. row spacing). Yield in 1997 was affected by a mid-spring drought; no rain occurred for six weeks during April and May. Yield in 1998 was influenced by drought through the winter and early spring, plentiful rain during May, and onset of hot, dry conditions during late June and July. Field mice caused considerable damage at Moro during 1998; an adjacent 10-yr-old CRP grassland was plowed at a time when our plot was the only nearby "green island".

Grain yields (Table 1) at Echo during 1996 and 1997 indicated that varieties with the highest two-year average (>28 bu/acre) included the soft white varieties Centennial, Dirkwin, Penawawa, Pomerelle, Treasure, Vanna, and Whitebird. Only one variety (a durum, WPB 881) yielded less than 25 bu/acre. Test weights were 54–59 lb/bu in 1996 and 57–61 bu/acre in 1997. All hard spring wheat varieties contained protein in excess of 14 percent (range of 14.3 to 16.8 percent) during 1997, and all soft wheat cultivars had protein contents less than 14 percent (range of 12.0 to 13.6 percent).

The three highest yielding soft white cultivars (Dirkwin, Treasure, and Vanna) out-yielded the best hard red (Spillman) and hard white (ID 377S) cultivars by three to five bushels per acre. There are known examples of fields where N has accumulated below the root zone, in low rainfall areas where hard spring wheat is produced continuously. This accumulation reflects the higher amounts of N applied to produce hard wheat for the high-protein market, compared to lower N rates for soft white wheat, destined for low-protein markets. Evaluations contrasting the ecological and economic risks and benefits of hard vs. soft spring wheat production are being conducted. Hard red and hard white spring wheat have higher ecological risk from residual N in the soil profile, higher fertilizer application costs, and premium prices paid for high-protein compared to soft white wheat, which requires less fertilizer and is higher yielding but attracts lower prices.

Starter fertilizer at Echo during 1997 led to dramatically earlier and more vigorous growth. Plants were taller and had more tillers where starter fertilizer had been applied. None of the diseases were influenced by fungicide or starter fertilizer treatments. Percentages of prematurely maturing wheat heads (e.g., whiteheads) did not differ among fungicide treatments but were considerably higher in plots with starter fertilizer than without starter fertilizer. Grain yield was increased by applying starter fertilizer below the seed (29 vs. 22 bu/acre; LSD = 2) but was not affected by fungicide treatments. Test weights (60 lb/bu) did not differ among fertilizer or fungicide treatments.

Grain yield at Moro in 1997 varied from 23 to 45 bu/acre (LSD = 4). Varieties with highest yield (>40 bu/acre) were Dirkwin, ID 377S, Pomerelle, Treasure, and Vanna. Varieties with lowest yield (<30 bu/acre) in 1997 were Klasic, WPB 881, and Yecora Rojo. Spring wheat varieties with highest 2-yr average yields (above 44 bu/acre) were Alpowa, Dirkwin, Treasure, and Vanna. Varieties with the lowest two-year average yields (less than 38 bu/acre) were Klasic, Spillman, WPB 881, and Yecora Rojo. Test weights during 1997 varied from 60 to 64 lb/bu. Protein contents for the 20 varieties ranged from 10 to 14 percent, with two hard types being below 12 percent (ID 377S and Spillman).

Yields at Moro during 1998 (Table 1) varied from 34 to 48 bu/acre and test weights from 59 to 63 lb/bu. Varieties with highest yield (>45 bu/acre) included two that are resistant to Hessian fly: Wawawai, and WB 926. This insect appeared to reduce yields of the susceptible varieties (Alpowa, Treasure, and Vanna) that had highest yields in previous years at Moro. Varieties with lowest yields continued to include Klasic, WPB 881, and Yecora Rojo.

There were no differences in severity of disease among fungicide-seed treatments at either location during 1998. Starter fertilizer led to an increase in incidence of take-all, Rhizoctonia root rot, and pupae of Hessian fly as well as an increase in tillering and plant height. Yield at Moro was improved 3 bu/acre (from 34 to 37 bu/acre; LSD = 2) when Gaucho insecticide was added to the Dividend + Apron treatment. Yields did not vary for the fungicide-seed treatments. Vanna and ID 377S yielded higher than WB 936 (Table 1). Starter fertilizer boosted yield by 7 bu/acre at Moro (from 31 to 38 bu/acre; LSD = 2) and 3 bu/acre at Echo (from 21 to 24 bu/acre; LSD = 2). Test weights varied among varieties (Vanna was 1 to 2 lb/bu less than the others). Test weights were not affected by seed treatment but were increased by starter fertilizer, 0.4 lb/bu at Moro and 1.3 lb/bu at Echo. Protein differed among varieties: at Moro, ID 377S yielded 12 percent; WB 936, 12 percent; and Vanna, 10 percent while at Echo, ID 377S yielded 15 percent; WB 936, 16 percent; and Vanna, 14 percent. Starter fertilizer did not affect protein content.

Summary

The spectrum and intensity of diseases often shifts in concert with changes in cropping systems. The objective of this root disease research was to monitor diseases in each treatment and season them to develop modifications to minimize damage and economic loss from diseases. Special emphasis was given to the root diseases Rhizoctonia root rot, take-all, and Fusarium foot rot. These diseases damaged wheat and barley in experiments near Ralston, Pilot Rock, Echo and Moro. Benefits of a crop rotation were shown at Ralston and Pilot Rock. Yield benefits were shown at Echo and Moro for the selection of a spring wheat variety, application of a seed treatment insecticide, and placement of starter fertilizer directly below the seed at the time of planting. This research had three specific findings:

1. The three, highest-yielding, soft-white, spring wheat varieties (Treasure, Vanna, and Dirkwin) yielded 3 to 5

bu/acre higher than best hard red (Spillman) or hard white (ID 377S). This finding had one exception: when Hessian fly was active, the highest yields were with the fly-resistant varieties Wawawai and WPB 926R.
2. All modern, fungicide-seed treatments led to yields slightly higher than from untreated seed, but there were no differences among fungicides. This finding also had one exception: Gaucho insecticide increased yield up to 3 bu/acre when barley yellow dwarf and Hessian fly were active.
3. Starter fertilizer placed directly below the seed led to more vigorous spring wheat seedling growth and grain yields up to 7 bu/acre higher than where no starter fertilizer was applied.

Experiments are being continued and refined to capture further low-cost benefits from minor changes in production practices. This research and extension activity will help determine whether annual cropping systems can improve farm profitability while reducing soil erosion and improving soil quality. Input and output data from each location are currently being evaluated in an economic analysis. Yield data from research at Echo and Moro were posted on Dr. Russ Karow's OSU Cereals Extension WebPage at http://www.css.orst.edu/cereals/.

Acknowledgements

Pilot Rock, OR

Principal Investigators. Dan Ball (OSU, weeds), Penny Diebel (OSU, economics and risk), Don Wysocki (OSU, fertility and crop residue), Bill Payne (OSU, agronomy).

Cooperators. Bob Adelman (NRCS, conservation compliance), Tom Golke (NRCS, technology transfer), Mike Stoltz (OSU, aphids and tours), Dale Wilkins (ARS, weeds), Ted Gilliland and Jeff Shaw (land and resources).

Grower Advisory Committee. 6 growers

Funding. STEEP, OSU, USDA-ARS, Oregon Wheat Commission, and agribusiness.

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Grower Advisory Committee. 12 members including representatives of the Washington Wheat Commission and Washington Association of Wheat Growers.

Funding. STEEP; USDA-ARS; WSU; OSU; Washington Department of Energy (PM-10); Washington Wheat Commission; Oregon Wheat Commission; agribusiness; and Adams, Lincoln, and Whitman counties.

Echo and Moro, OR

Cooperators. Russ Karow (OSU, varieties), Kim Kidwell (WSU, varieties), Penny Diebel (OSU, economics), Mike Stoltz and Katherine Kettel (OSU, tours), Frank and

Yvonne Mader and Tim and Shannon Rust (land and crop donation), and Pro-Mar Seeds and Western Plant Breeders (seed).

Funding. Oregon Wheat Commission, STEEP, OSU, and agribusiness.

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Table 1. Spring wheat yields (bu/acre) at low-rainfall sites near Echo and Moro during 1996, 1997 & 1998.

Variety and Class		Echo (Buttercreek Area)			2-yr mean†		Moro (Experiment Station)				3-yr mean†	
		1996	1997	1998‡	rank	yield	1996	1997	1998	1998‡	rank	yield
Alpowa	SW	23.5	27.9		12	25.7	50.7	37.6	41.4		6	43.2
Calorwa	Club	25.7	29.0		7	27.4	48.7	31.9	36.3		14	39.0
Centennial	SW	24.5	31.6		6	28.1	45.5	39.0	39.3		11	41.3
Dirkwin	SW	28.3	33.1		3	30.7	45.7	42.8	46.9		1	45.1
ID 377S	HW	25.7	28.9	24.4	8	26.3	43.3	40.7	42.6	35.7	8	42.2
Klasic	HW	24.5	26.9		12	25.7	38.7	26.1	35.5		20	33.4
Nomad	HR	24.9	26.7		11	25.8	47.1	30.6	42.1		12	39.9
Penawawa	SW	30.8	28.9		4	29.9	46.5	35.4	37.0		13	39.6
Pomerelle	SW	27.2	30.2		5	28.7	41.4	45.1	44.2		4	43.6
Spillman	HR	27.7	26.8		8	27.3	44.4	30.5	40.3		15	38.4
Sprite	SW	28.6	25.8		9	27.2	45.5	32.9	35.0		16	37.8
Treasure	SW	31.4	32.2		1	31.8	47.1	41.6	44.3		2	44.3
Vanna	SW	30.5	31.2	25.6	2	29.1	51.0	40.5	39.9	36.8	3	43.8
Wawawai	SW	24.9	29.6		8	27.3	44.8	37.4	47.6		5	43.3
Westbred 906	HR	24.9	26.1		13	25.5	48.6	30.9	44.6		10	41.4
Westbred 926	HR	26.4	25.2		11	25.8	48.9	31.8	48.0		7	42.9
Westbred 936	HR	23.9	26.1	16.9	14	22.3	48.0	32.1	44.5	32.0	9	41.5
Whitebird	SW	25.7	30.5		6	28.1	43.3	33.9	35.1		17	37.4
WPB 881	Durum	21.3	19.9		15	20.6	44.6	26.7	33.8		19	35.0
Yecora Rojo	HR	23.7	29.3		10	26.5	48.5	23.3	35.4		18	35.7
mean		26.2	28.3	22.3		27.0	46.1	34.5	40.7	34.8		40.4
P > F		0.15	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01		<0.01
LSD (P < 0.05)		ns	5.4	1.8		2.6	4.6	4.3	5.7	1.8		3.5

†Rankings include duplicate entries (more than one #8, etc.) for entries with equal yield. Management trials (‡) in 1998 had 3 varieties and were not included in means averaged for each location.

‡Management trials. Seed treatments did not boost yields. Starter fertilizer below seed boosted yields at Echo and Moro 3.2 and 6.8 bu/acre, respectively.

Echo: Minimum-till annual spring wheat; the 5th, 6th and 7th years were harvested in 1996, 1997 and 1998. The plot area was tilled once with a shallow (3-in. deep) sweep following each harvest, and was otherwise handled as "no-till". For comparison, winter wheat varieties in an adjacent WW/fallow rotation yielded 40–77 bu/acre in 1998; Stephens yielded 69 bu/acre and was boosted to 77 bu/acre when treated with Gaucho.

Moro: Spring wheat in 1996 followed winter wheat harvested in 1994 and fallow in 1995. The variety trial area was cropped annually thereafter, and was tilled shallow between crops. Winter wheat yields were 50–86 bu/acre in nearby experiments during 1998; Stephens was 86 bu/acre. The management trial during 1998 was direct drilled into standing winter wheat stubble.

DIRECT SEEDING WINTER CANOLA INTO WHEAT STUBBLE

Dale Wilkins and Don Wysocki

Introduction

Traditional Pacific Northwest (PNW) dryland farming systems continue to degrade soil through erosion and loss of soil organic carbon (SOC). Long-term field experiments with various crop rotations and tillage practices at the Research Center near Pendleton, Oregon, show that SOC has continually declined in traditional winter wheat-fallow production systems (Rasmussen and Parton, 1994). Intensive tillage coupled with fallow promotes rapid oxidation of SOC and leaves the land vulnerable to soil erosion. Reduced tillage and elimination of fallow offer possible solutions to degradation of PNW soil. An option for maintaining SOC and reducing soil erosion is to rotate broadleaf crops with wheat in an annual cropping system.

Canola (*Brassica napus*) is a broadleaf plant that has potential as an alternate crop with cereals in the Columbia Plateau. Fall-seeded canola is preferred because the yield is typically twice the yield of spring canola in eastern Oregon (Wysocki et al., 1992). Stand establishment of fall seeded canola after wheat in annual cropping systems is a major challenge. Shallow seed placement (1/2–1 in. deep) with adequate soil moisture (1 bar) is desirable for optimum seedling emergence (Wysocki et al., 1992; Brotemarkle, 1989). Good seed germination and emergence is especially difficult to obtain because seedbed soil water is typically marginal and direct seeding into wheat residue is difficult. Wheat depletes the soil profile of available water. Water content of the seedbed is likely to be marginal for early fall seeding because the 68-yr average September precipitation at the Pendleton Research Center is less than 0.75 in. Seed placement with good seed-to-soil contact is difficult when directly seeding into cereal stubble. Drills with disc openers tuck wheat residue into the seed furrow, and hoe-type openers tend to plug with crop residue.

The objective of this research was to evaluate adjustments of direct-seeding equipment and to evaluate options for residue management to improve stand establishment of fall-seeded canola.

Methods

A replicated factorial field experiment with two levels of four factors was conducted using a Conserva Pak model CP1212A[1] no-till drill to evaluate wheat residue management and seed placement on stand establishment of canola. Factors included flailing and not flailing wheat stubble before seeding, seeding depth of 0.75 and 1.5 in., with and without coulters in front of the seed openers, and 2 and 4 in. depth of soil disturbance in front of the seed opener. The coulters were smooth, 18.5 in. diameter, and mounted on a single gang at the front of the drill. This drill had fertilizer shanks that normally were set to place fertilizer to the side and below the seed. For these studies, the fertilizer shanks were used to loosen the soil ahead of the seed openers and to move residue away from the seed furrow. These shanks were adjusted to

[1] Reference to a company name or trade name is for specific information only and does not imply approval or recommendation of a product by the USDA to the exclusion of others that may be suitable.

disturb soil 2 or 4 in. deep, and no fertilizer was applied at seeding time.

The experiment was conducted at the Pendleton Research Center in fall, 1998. Soil was a well-drained Walla Walla silt loam. Spring wheat was grown in the experimental area in 1998. About 4,300 lb/acre of crop residue in the form of standing stubble (8 to 10 in.), chaff, and raw straw were on the soil surface. Erica canola was seeded at the rate of 10 lb/acre on September 11, 1998. Three-foot-long emergence observation sites were established for individual rows in three locations for each plot. The number of emerged seedlings per foot of row was evaluated on September 24 , 28, and October 16. Gravimetric soil-water content measurements were taken with an incremental sampler (Pikul et al., 1979) on September 30 in the seed zone in 0.8-in. increments from the surface to 3 inches in two treatments. These two treatments were: 1) no coulter, 0.75-in. seeding depth, 2-in. soil disturbance in the seed furrow and stubble not flailed and 2) coulter, 1.5-in. seeding depth, 4-in. soil disturbance in the seed furrow and stubble flailed. These two treatments represented the extremes of soil disturbance in the seed furrow. Seed depth was measured by carefully excavating soil until seeds were exposed and then measuring from the soil surface to the seeds.

Results and Discussion

It was hot and dry following seeding on September 11 (Fig. 1). The average maximum air temperature was 90 °F for the first 7 d following seeding, and there was only a trace of precipitation. The pan evaporation averaged 0.3 in. per day. A light rain 3 d before seeding produced 0.4 in. precipitation, but total precipitation (including the 0.4 in.) was less than 0.5 in. from wheat harvested in July until canola was seeded. The amount of soil water was marginal for stand establishment. Precipitation totaled 0.82 in. during the remainder of September, when the seed was germinating and seedlings were emerging.

The mean soil-water contents on September 30 are shown in Table 1.

Table 1. Soil-water content in canola seed zone, Pendleton Research Center, September 30, 1998.

Depth	Soil water content
---in.---	% dry basis
0.0 - 0.8	8.2 A†
0.8 - 1.6	12.1 B
1.6 - 2.4	11.3 B
2.4 - 3.2	9.5 A

† Numbers within a column followed by the same letter are not significantly different as determined by the LSD test (*P* α 0.05).

There was not a significant difference (F test with *P* α 0.05) in soil-water content between the two treatments, but soil-water content varied with depth (Table 1). Soil water content was significantly lower in the surface increment (0 to 0.8 in.) and from 2.4 to 3.2 in. as compared to the middle increments. The highest soil-water content was 12 percent, well below the optimum soil water content of 15 percent (1 bar) for germination and emergence of canola. The hot, dry conditions following seeding created a very stressful condition for developing canola seedlings.

In spite of the harsh seedbed conditions, some treatments produced good stands (Figs. 2–5). Coulters, flailing residue, soil disturbance in the seed furrow, and seeding depth all influenced seedling emergence. Emergence was first observed on September 24. Coulters (Fig. 2), flailed stubble (Fig. 3), low soil disturbance in the seed furrow (Fig. 4), and shallow seeding (Fig. 5) produced significantly higher (F test with P α 0.05) stands for the observations taken on September 24 and 28 as compared to no coulters, not flailing, high soil disturbance in the seed furrow, and deep seeding. The final stand observations, taken on October 16, showed that only soil disturbance in the seed furrow and seeding depth had significantly (F test with P α 0.05) influenced final stand establishment.

Because canola stand establishment is sensitive to seed depth, measurements were taken to determine if coulters, flailed residue and soil disturbance in the seed furrow impacted seed- placement depth. Seed depth was highly influenced by seed-furrow soil disturbance and seeding depth (Table 2). Using coulters or flailing stubble did not affect the depth of seed placement. Figure 6 shows the relationship between seed depth and plant stand established on September 28. Seeds that were placed less than one inch deep emerged rapidly, seeding 1 to 2 in. deep suppressed emergence, and seeds deeper than 2 inches failed to emerge. The seeder tended to place seeds deeper with increased soil disturbance in the seed furrow. This effect could be compensated for by manually adjusting the seeding depth. For these tests, the same drill seeding depth settings were used for all treatments.

Conclusions

Adequate stands of canola were established with a hoe-type drill seeding into a nontilled dry wheat stubble field, with marginal soil water for germination and emergence. Coulters in front of seed openers and flailing the stubble did not improve the final stand established. Seeding less than an inch deep was necessary for maximum stand establishment. Factors that influenced seed depth were important to stand establishment. Drill-seed depth setting and soil disturbance in the seed furrow were critical drill adjustments that influenced seed depth.

Acknowledgements

We thank Robert Correa for techincal assistance with field operations, including setting and operating the drill, and Tami Johlke and Amy Baker for their assistance in collecting plant and soil data.

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Table 2. Influence of coulters, stubble management, seeding depth, and soil disturbance in seed furrow on depth of seed placement and stand establishment of Erica canola, Pendleton Research Center, September 1998.

Treatment					
Coulter	Stubble flailed	Seeding depth	Soil disturbance	Seed depth†	Stand‡
		--------------------	in.	--------------------	Plants/ft^2
Yes	Yes	0.75	2	0.75	17.0
No	No	0.75	2	0.75	11.0
Yes	No	1.5	2	1.2	9.4
No	Yes	1.5	2	1.3	7.0
Yes	No	0.75	4	1.2	0.7
No	No	1.5	4	2.3	0.1
Yes	Yes	1.5	4	2.4	0.0

† Seed depth measurements taken in block 2 on Sept. 29, 1998.

‡ Mean stand observations taken on Sept. 28, 1998.

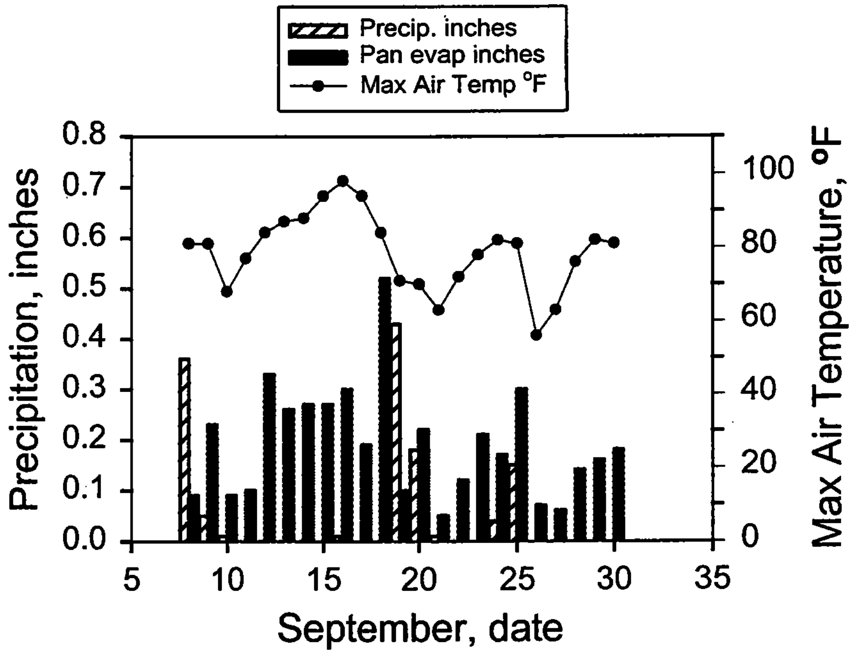

Figure 1. Precipitation, pan evaporation, and maximum air temperature, Pendleton Research Center, September 1998.

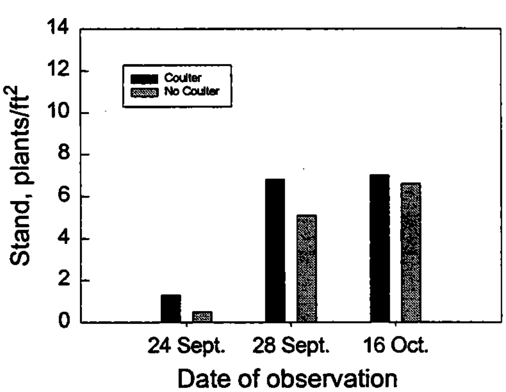

Figure 2. Effect of coulters in front of furrow openers on canola stand establishment, Pendleton Research Center, fall 1998.

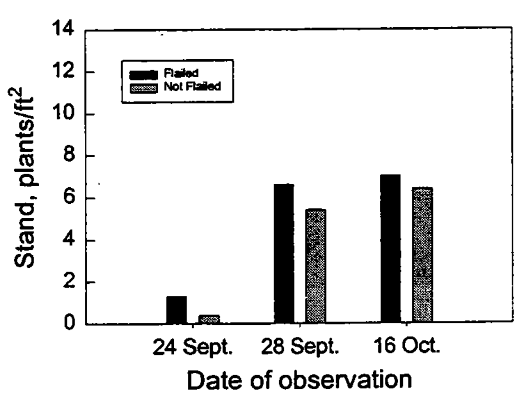

Figure 3. Effect of flailing wheat residue before seeding on canola stand establishment, Pendleton Research Center, fall 1998.

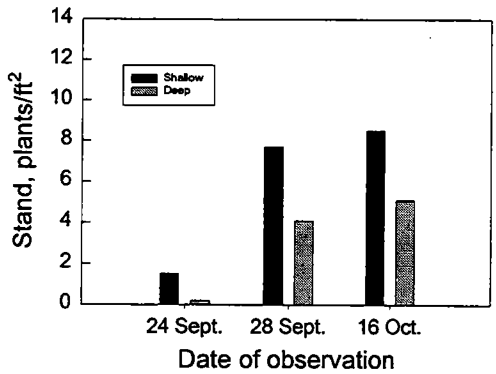

Figure 4. Effect of depth of soil disturbance in the seed furrow on canola stand establishment, Pendleton Research Center, fall 1998

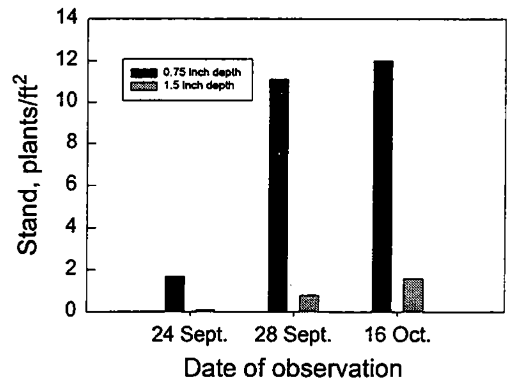

Figure 5. Effect of seeding depth (0.75 and 1.5 in. for shallow and deep seeding, respectively) on canola stand establishment, Pendleton Research Center, fall of 1998.

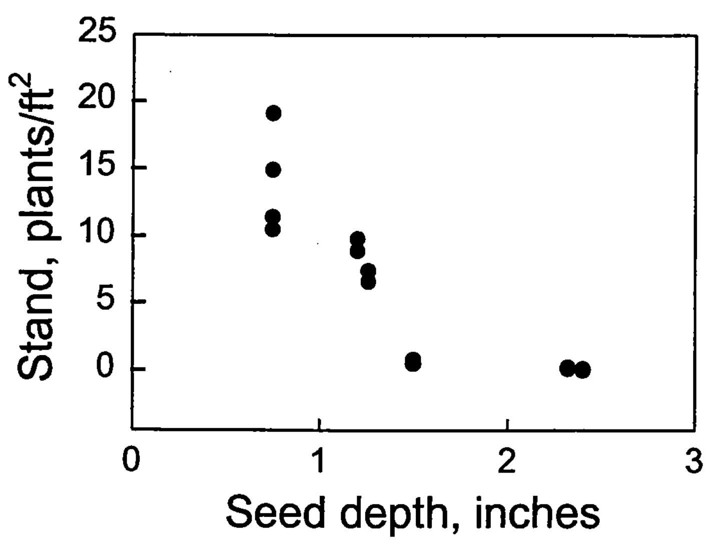

Figure 6. Effect of seed depth on canola emergence, Pendleton Research Center, September 1998.

INSTRUMENTATION OF THE LONG–TERM CROP RESIDUE PLOTS FOR HYDROLOGIC AND SOIL EROSION EVALUATION

John D. Williams, Chengci Chen, Clyde L. Douglas, Jr.,
Ron W. Rickman, and William (Bill) A. Payne

Introduction

Scientists with the U.S. Department of Agriculture (USDA)-Agricultural Research Service (ARS), Columbia Plateau Conservation Research Center (CPCRC), and Oregon State University (OSU), Columbia Basin Agricultural Research Center (CBARC), are expanding the scope of research conducted within a long-term crop residue study begun in 1931 (Rasmussen and Smiley, 1994). In this study, attention focused on the relative merits of various crop residue and fertilizer management strategies in the production of winter wheat (Rasmussen and Parton, 1994). Some of the most important research findings in intermountain, western U.S., cropland production result from crop yield and soil attribute collected in this study (Rasmussen et al., 1998). Most recently, a team of ARS and OSU scientists led by John Williams (ARS) and Bill Payne (OSU) began the process of demonstrating how these long-term treatments effect soil hydrology, water quality, and crop water-use efficiency in a number of the treatments (Table 1). This paper describes the instrumentation and techniques used to collect data on weather, runoff, infiltration, soil temperature, and soil erosion.

Materials and Methods

We collected a wide range of weather related data. Two recording raingages, a weighing and a tipping-bucket, electronically recorded 15-min rainfall intensity. The weighing raingage also recorded rainfall data on a strip chart. A standard raingage served as a backup to the recording raingages. Rainfall depths must be measured and recorded by a person at the site. We checked this raingage on a frequent basis during runoff events for quality assurance/quality control (QA/QC) of rainfall records. In 1997–1998, we found that all but the largest storms lasted less than one hour and that runoff from many of the treatments occurred for 20 min or less within the rainfall period. By measuring rainfall intensity in 15-min intervals, we hoped to more accurately describe the weather conditions that create runoff. Wind speed, air temperature, solar radiation, and relative humidity were also recorded 1.5-m above the soil surface automatically every 15 min using a Davis Instrument Crop.-GroWeather System*. These measurements provided information about the effects of crop residue management strategies on crop water-use efficiency (Fig. 1).

We collected extensive moisture and temperature data at 15-min intervals at several depths through the soil profile in the 6 percent slope, spring-burn, 0 kg/ha fertilizer treatment (Fig 2.). These data, in combination with the rainfall and runoff data, will help us develop our understanding of crop residue management strategies on crop-water relations and soil physical properties (heat exchange and water or solute balances). Time domain reflectometry (TDR) probes (Dalton and Van Genuchten, 1986) measured volumetric moisture at soil depths of 20, 40, 80, 160, 320 mm. Neutron attenuation measurements determined soil moisture at deeper depths after runoff events (Gardner, 1965) at 300 mm intervals to a depth of 1.8 m. Core samples are

* Mention of manufacturer or brand names does not constitute endorsement by USDA or its employees.

periodically collected to measure solute distribution in the soil profile. Thermisters recorded soil temperatures at 10, 20, 40 80, 160, 320 mm depths (Taylor and Jackson, 1965). We also installed two frost-tubes in all of the treatments to measure the depth of frozen soil before and after runoff events and to provide a rapid assessment of the soil frost conditions (Fig. 3). These tubes must be manually read and the information recorded (Ricard et al., 1976).

We installed a system to measure the runoff water resulting from rainfall, snowmelt—or a combination thereof—and soil erosion. Lister furrows routed runoff from within each treatment to drop–box weirs (Bonta, 1998) that controlled runoff to provide a depth measurement (stage depth) (Fig. 4). Stage depth was converted to a volume per unit time value. The drop-box weir was designed to accurately measure low volume runoff that is heavily laden with eroded material. We measured stage depth using two electronic methods, Global Water* weir sticks (Fig. 5) and Lindhal* sonic range finder. To check the accuracy of the electronic measurements, we collected timed samples (grab samples). The electronic samplers record depth values every 2 min. From this data we will determine the total volume of runoff, the amount of rainfall required to initiate runoff, and the length of time after rainfall begins to the start of runoff. We also measured the amount of runoff generated within the lister furrow separately from the cultivated treatment area (Fig 6).

We installed Sigma* Sediment samplers to collect samples of material washed from the treatments plots (Fig. 2). A tube installed immediately below the weir mouth collected a sample of mixed bedload and suspended material. The sediment samplers were triggered by a liquid-level switch to start collecting samples when runoff begins (Fig. 7). Samples (50 ml) were collected from a catch basin below the weirs (Fig. 8), beginning with the onset of runoff and once every 20 min thereafter until flow ended. We chose the sampling interval based on observations in 1997–1998 of runoff duration and the number of samples that we could reasonably process, store, and analyze given our resources. The samples were analyzed for total eroded material that includes mineral soil (silt, sand, clay), suspended solids (total N, total C, and total P), and dissolved solids and nutrients (PO_4, NO_3, NH_4) (Brakensiek et al., 1979; Stevenson, 1982; Keeney and Nelson, 1982; Nelson and Sommers, 1982; Olsen and Sommers, 1982). To insure QA/QC of the automatically collected, eroded material, we analyzed the grab samples used for runoff QA/QC for the same eroded material components.

Our goal was to establish an automated data-collection system to meet our QA/QC standards but requiring minimal maintenance. The plots were visited daily to insure that weeds did not block the weirs and that water ran from the lister furrows into the weirs and not into rodent holes. During runoff events lasting for more than one hour, we collected at least one timed sample from each plot generating runoff. We also monitored the ditches carrying water away from the weirs to insure they remained open. Data from electronic recording devices were downloaded and checked for anomalies after every storm resulting in runoff from two or more treatments.

Conclusion

The automated system now in place insures that we will not miss collecting data resulting from unexpected rainstorms, day or night. This system reduces the amount of work hours required to monitor weather patterns and forecasts as well as time spent awaiting storms that might create measurable runoff from two or more treatments.

Acknowledgments

Installing and maintaining the equipment for this effort required a team effort. In addition to the authors, the following individuals have contributed considerable time and energy. Steve Albrecht, Bob Correa, Roger Goller, Daryl Haasch, and Joy Matthews participated in the weir installation. Daryl Haasch, Joy Matthews and Stephen Osborn were responsible for day-to-day plot maintenance and data downloading. Bob Correa developed the liquid level switch for the Sigma Samplers, a task for which he received special recognition in the form of a USDA-ARS Spot Award. In the laboratory, Tami Johlke and Amy Baker processed runoff samples to determine erosion and water quality.

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Table 1. Long–term crop residue treatments instrumented for evaluation of runoff and erosion, Agricultural Research Center, Pendleton, OR, 1998–1999 erosion season.

Slope (%)	Crop status	Burn treatment	Fertilizer
6	In crop	No burn	Manure
6	In crop	Spring burn	0 kg/ha
6	In crop	Fall burn	0 kg/ha
6	In crop	No burn	90 kg/ha
6	Standing stubble	No burn	Manure
6	Standing stubble	No burn	90 kg/ha
2	In crop	No burn	Manure
2	In crop	Spring burn	0 kg/ha
2	In crop	Fall burn	0 kg/ha
2	In crop	No burn	90 kg/ha
2	Standing stubble	No burn	Manure
2	Standing stubble	No burn	90 kg/ha

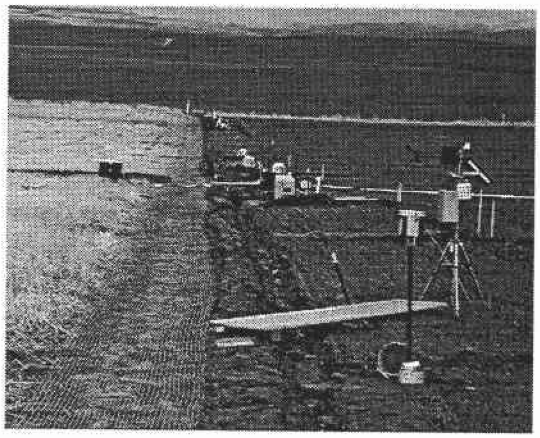

Figure 1. Crop residue study site. Plots at left of photograph are in standing crop residue, plots on the right are current year winter wheat crop. Instrumentation in the foreground is on a 6 percent slope, and the cluster of instruments at the far end of the red walkway are on a 2 percent slope. The box in stubble holds data-loggers for thermister and TDR probes. GroWeather* weather station and a standard raingage are in the foreground. Agricultural Research Center, Pendleton, OR, January 1999.

Figure 2. Walkway leads to TDR and thermister probes in the plot. Sediment sampler and weir are in the foreground. Agricultural Research Center, Pendleton, OR, January, 1999.

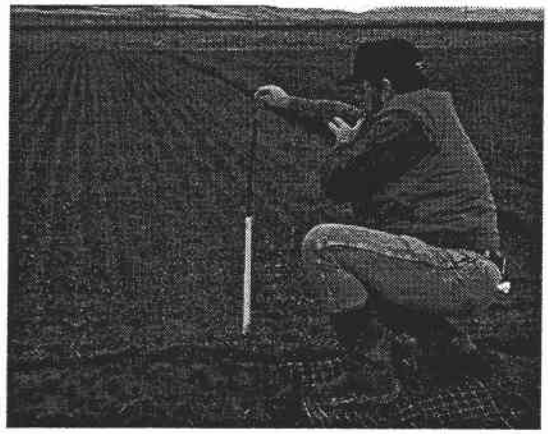

Figure 3. Two frost–tubes are in-place in the northwest corner of each plot. Frost depth is indicated by a change in color of the material in the tube. Agricultural Research Center, Pendleton, OR, January 1999.

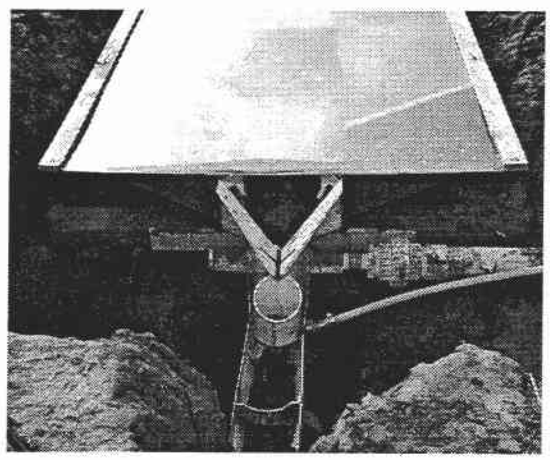

Figure 4. Water flows into the collection trough from lister furrows and is directed into the drop-box weir in the center of the photograph. A plexiglass cover protects the flow in the weir from strong winds and prevents clogging by wind-blown weeds. The 2.5-in. pvc pipe leads to stilling wells for the depth sensors and liquid-level switch. Agricultural Research Center, Pendleton, OR, January 1999.

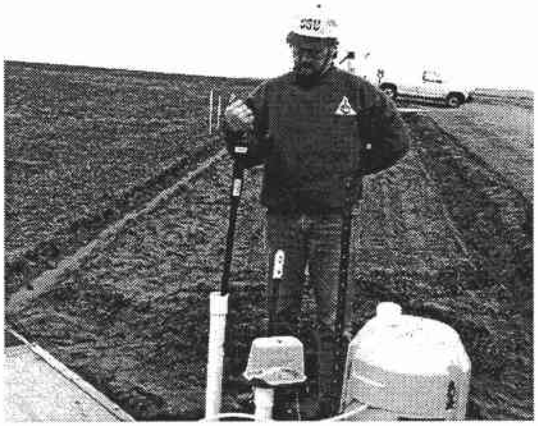

Figure 5. Global Water weir stick measured and recorded stage depth in the weir. Sufficient memory existed to make measurements every 2 min for 8 d. Agricultural Research Center, Pendleton, OR, January 1999.

Figure 6. Grab samples were collected from the lister furrows that direct water and eroded material from the treatment area (to the right of the furrow). The purpose of these samples was to separate treatment effects from furrow effects. Agricultural Research Center, Pendleton, OR, January 1999.

Figure 7. Liquid-level switch on the stilling well used to sense flow and start the sediment sampler. Agricultural Research Center, Pendleton, OR, January 1999.

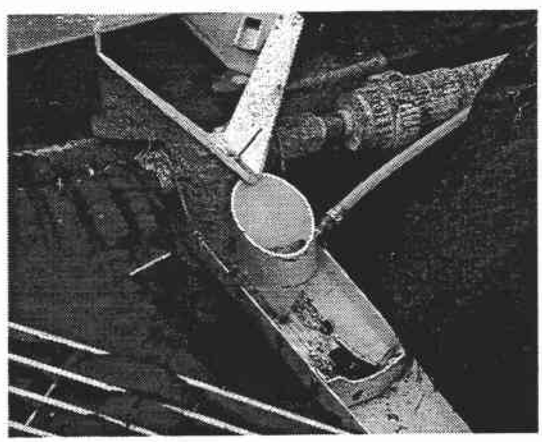

Figure 8. Catch basin used to capture sufficient runoff for collection of 50 ml sample by sediment sampler. The position and size of the basin were designed to provide a thoroughly mixed runoff sample. Agricultural Research Center, Pendleton, OR, January 1999.

CROP RESIDUE AND PLANT HEALTH: RESEARCH OVERVIEW AND IMPLICATIONS FOR NO-TILL

Stewart Wuest and Katherine Skirvin

Introduction

Over the past four decades, researchers have examined the effects of crop residue on the growth of plants. Results have been mixed and sometimes controversial. This article summarizes those findings and draws conclusions for our local cropping systems.

Residues have been shown to damage wheat and other crops in both laboratory and greenhouse studies (Elliot et al., 1978; Patrick and Toussoun, 1965). Toxic effects can be simulated by simple water extractions and also by more elaborate incubations and extractions of residue (Cochran et al.,1977; Kimber 1973; Lodhi et al., 1987; Martin et al., 1990; Mason-Sedun et al., 1986). Toxic substances, from simple acetic acid (vinegar) to hormones, sometimes originate with microbial activity but can also be present under sterile conditions (Kimber, 1967; Purvis, 1990). This discussion will not distinguish between chemical toxic effects of residue and those of pathogens stimulated by the presence of residue.

Only recent, unweathered residues produce a toxic effect. Researchers have found that when kept dry, residue loses its phytotoxic potential in a year or less (Kimber 1967; Mason-Sedun et al., 1986; Purvis and Jones, 1990). When fresh residues become moist and start to decay, the length of time residue has negative effects on plant growth ranges from a few weeks to several months. After this initial period of negative impact, some residues have shown a yield-enhancing effect. If a layer of soil separates residue from plants, the toxic effects are usually diminished or eliminated altogether. The amount of sand, clay, and organic matter in a soil can influence the toxicity of residues (Patrick and Toussoun, 1965; Purvis and Jones, 1990).

Growth impairments relate to germination, emergence, growth rates, or tillering. Often the responses are very specific, for example, no effect on germination but a definite effect on shoot growth (Mason-Sedun, 1986). A recently completed greenhouse study reported that wheat seedling height was reduced by 20 percent 20 d after planting when 3-mo-old wheat residues were placed about an inch below the seed (Stewart Wuest, unpublished data, 1998) (Fig. 1). There was also a delay in the developmental rate of the seedlings whose roots grew into fresh wheat residue.

The effects of residue on plant health are very complex. Dozens of substances have been extracted from fresh residues and shown to inhibit growth of plants in the laboratory. These substances can either stimulate or inhibit microbial growth in the soil, including microbes that are wheat pathogens. In the laboratory, residues have also been shown to make roots vulnerable to root infection and affect pathogen activity (Patrick and Toussoun, 1965).

In field studies it becomes more difficult to demonstrate that buried residues reduce crop vigor or crop yield, but this is not surprising given the complex nature of the interactions among residues, soil, microbes, and plants. Residue from different cultivars of wheat as well as differences in the age of the residue, the moisture conditions while it aged, and soil type produce varying amounts of toxicity.

There are other crop-health problems that may be caused by the presence of residue in the seed bed: disease, light interference, difficulty in seed placement, and immobilization of nutrients (Elliott et al., 1981; Wilkins et al., 1988). Understanding why certain plants in a crop stand are less vigorous or more prone to diseases becomes very challenging.

Given the number of questions about the role of residue in plant health, it might seem difficult to learn how to manage residues in a way that both protects soil productivity and maximizes crop production. There are, however, some useful conclusions we can draw from what we know about the potential toxicity of residues.

Conclusions

Residue toxicity is only likely to cause problems in fall-seeded crops because this is when we have large quantities of unweathered residues. In the Columbia Basin there is little moisture to start decomposition of residues between summer harvest and fall planting. Annual spring cropping systems should not encounter much, if any, phytotoxicity of residue because the residue has been well leached and partially decomposed. Disease problems found in annual winter wheat cropping systems may be due to toxins, as well as pathogens found in unweathered residues. These residues are often plowed under the surface where they are intercepted by the roots.

There are both advantages and disadvantages to fall no-till systems regarding the potential phytotoxic properties of fresh residues. No-till presents the opportunity to plant into ground with no buried residue. As long as seeding equipment does not bury residue and keeps it from contacting the seed, it should be possible to avoid problems with germination and prevent growing roots from encountering toxins.

Fresh residues left on the surface of the soil remain a concern. Should these be pushed away from the seed row, or is an inch or so of soil above the seed enough to absorb and detoxify any leachates from the wet residues above the seed? There may be other reasons to clear residue from the seed row when planting fall wheat. Research at Pendleton has demonstrated that standing stubble can reduce light penetration into the seed row enough to reduce seedling vigor and tillering of winter wheat (Wilkins et al., 1988). Whether this results in a reduction in yield will depend on circumstances later in the growing season.

The risks and benefits of not disturbing standing stubble and residue on the soil surface need to be weighed. In many areas of the United States, standing stubble catches blowing snow and makes an important contribution to soil water. This may not be an important factor in much of the Pacific Northwest. On the other hand, ultra-low disturbance seeding systems have been credited with a reduction in weed populations. If low disturbance systems that help control weed populations can be developed for the Pacific Northwest, the weed control benefits might outweigh the shading or phytotoxic effects of surface residue over the seed row. Standing stubble may also be part of a profitable solution in areas where blowing soil degrades soil productivity and damages seedling wheat.

Loss of soil moisture by evaporation is another factor whose importance will vary in different areas. In the no-till spring cropping systems in Alberta, Canada, heavy, wet, cold soils are a major problem. In contrast, here in the Pacific Northwest, leaving residue near the seed row to reduce evaporation is an advantage when we plant fall crops into our light, dry soils.

For a cropping system as a whole, crop residue benefits soil productivity and erosion control; we would be shortsighted to view it only as a liability. Our knowledge of the potential toxic effects of residue should allow us to maximize the benefits of surface residue cover produced in no-till and avoid the hazards to plant health in fall-seeded systems.

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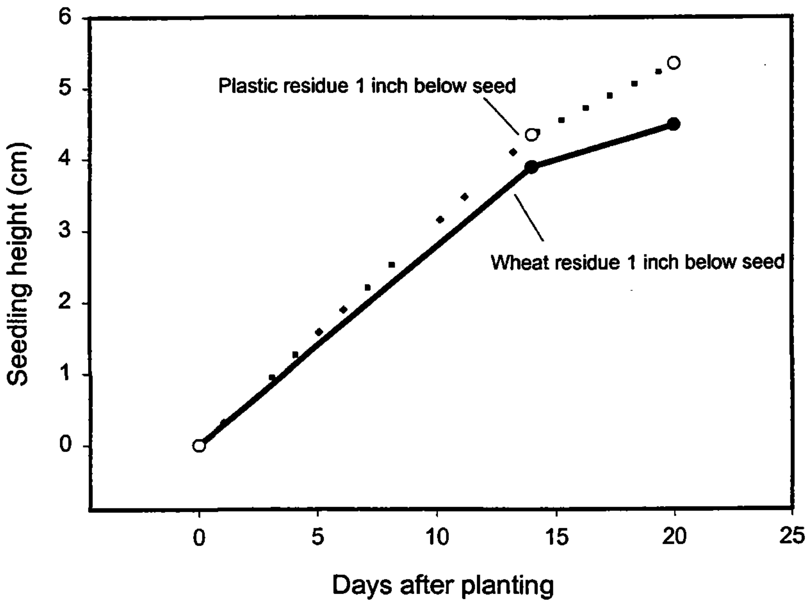


Figure 1. Height of winter wheat (Madsen) seedlings with roots growing through fresh wheat or plastic residues placed 1 in. below the seed. Pendleton, OR 1998.

PRECIPITATION SUMMARY - PENDLETON

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

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
69 Year Average	**.73**	**1.36**	**2.06**	**2.05**	**1.96**	**1.50**	**1.72**	**1.54**	**1.48**	**1.23**	**.35**	**.48**	**16.47**
1978-79	1.61	0	1.68	2.28	1.31	1.54	1.74	1.82	1.15	.18	.12	2.08	15.51
1979-80	.17	2.56	2.31	1.05	2.85	1.55	2.12	1.20	2.45	1.42	.23	.18	18.09
1980-81	1.24	2.96	1.81	1.99	1.26	2.31	2.30	1.29	2.30	2.12	.40	.02	20.00
1981-82	1.51	1.62	2.41	3.27	2.61	1.86	1.99	1.54	.48	1.12	1.02	.50	19.93
1982-83	1.68	2.68	1.46	2.69	1.63	2.97	3.90	1.23	2.08	1.92	1.00	.68	23.92
1983-84	.82	.91	2.79	3.44	.99	2.56	3.23	2.37	2.11	2.05	.05	1.25	22.57
1984-85	.98	1.18	3.43	1.96	.69	1.49	1.33	.65	.89	1.42	.05	.98	15.05
1985-86	1.54	1.34	2.66	1.27	2.38	3.04	1.94	.83	1.79	.09	.61	.19	17.68
1986-87	1.87	.91	3.41	.95	2.08	1.31	1.85	.83	1.63	.62	.47	.06	15.99
1987-88	.04	0	1.44	1.61	2.60	.32	1.65	2.59	1.79	.94	0	0	12.98
1988-89	.40	.08	3.65	1.10	2.86	1.55	2.95	1.94	2.19	.33	.15	1.19	18.39
1989-90	.24	1.00	1.65	.49	1.43	.63	1.89	1.77	2.14	.70	.37	.76	13.07
1990-91	0	1.37	1.73	1.18	1.15	.86	1.71	1.01	4.73	2.22	.15	.24	16.35
1991-92	.03	.89	4.18	.97	.96	1.34	.85	1.29	.20	.90	1.74	.78	14.13
1992-93	.58	1.70	2.61	1.30	2.43	1.04	2.32	2.67	1.58	2.01	.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	0.39	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	0.40	4.71	2.96	1.18	2.16	1.23						
20 Year Average	**.80**	**1.28**	**2.45**	**1.87**	**2.04**	**1.61**	**2.03**	**1.66**	**1.88**	**1.13**	**.40**	**.61**	**17.73**

PRECIPITATION SUMMARY - MORO

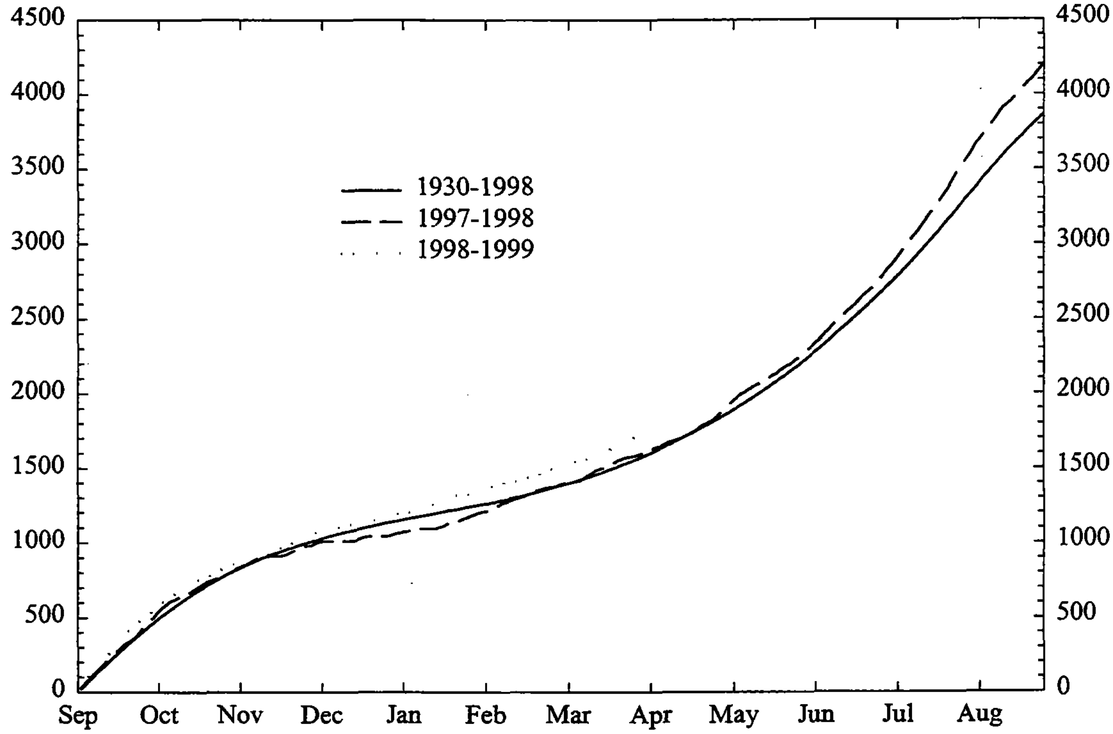
CBARC - Sherman Station - Moro, Oregon
(Crop year basis, ie; September 1 through August 31 of following year)

Crop Yr.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
89 Year Average	**.59**	**.93**	**1.70**	**1.65**	**1.64**	**1.17**	**.99**	**.80**	**.84**	**.69**	**.23**	**.28**	**11.52**
1978-79	.33	.01	.79	.69	1.59	1.54	.99	1.06	.28	.10	.07	1.05	8.50
1979-80	.53	2.59	2.23	.65	3.41	1.83	.94	.89	1.27	1.37	.16	.11	15.98
1980-81	.42	.79	1.73	2.95	1.52	1.22	.65	.41	1.06	1.15	.20	0	12.10
1981-82	.92	.82	1.99	4.73	1.10	.72	.55	1.45	.37	1.15	.21	.40	14.41
1982-83	1.42	1.96	1.08	1.89	1.40	2.43	2.74	.61	1.96	.39	.80	.60	17.28
1983-84	.52	.62	2.45	2.31	.17	1.07	2.34	1.32	.97	1.09	.17	0	13.03
1984-85	.53	.86	3.18	.41	.27	.97	.44	.14	.63	.92	.05	.14	8.54
1985-86	1.11	1.09	1.19	1.12	1.84	2.39	.98	.34	.35	.06	.54	.07	11.08
1986-87	1.52	.45	1.53	.78	1.68	1.10	1.54	.28	.99	.29	.78	.11	11.05
1987-88	.07	.01	.66	3.23	1.60	.21	1.25	2.21	.55	1.02	.04	0	10.85
1988-89	.56	.02	2.51	.22	1.33	.77	1.91	.84	.91	.08	.11	.50	9.76
1989-90	.07	.59	.96	.48	1.91	.17	.76	.79	1.36	.39	.15	1.43	9.06
1990-91	.29	1.27	.61	.74	.87	.60	1.43	.40	.77	1.27	.33	.16	8.74
1991-92	0	1.40	2.57	1.02	.47	1.64	.64	2.38	.04	.28	.81	.02	11.27
1992-93	.68	.85	1.50	1.68	1.42	1.47	1.68	1.22	1.42	.87	.39	.30	13.48
1993-94	.02	.09	.41	.68	1.40	.90	.55	.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								
20 Year Average	**.56**	**.97**	**1.68**	**1.56**	**1.58**	**1.24**	**1.17**	**1.01**	**.98**	**.68**	**.33**	**.29**	12.06

CUMULATIVE GROWING DEGREE DAYS

(BASE = $0^{\circ}C$)

PENDLETON



MORO