1997 COLUMBIA BASIN AGRICULTURAL RESEARCH ANNUAL REPORT

Special Report 977
Agricultural Experiment Station • Oregon State University
in cooperation with Agricultural Research Service • USDA

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COLUMBIA BASIN AGRICULTURAL RESEARCH ANNUAL REPORT, 1997

Columbia Basin Agricultural Research Center
Oregon State University

in cooperation with

Columbia Plateau Conservation Research Center
USDA-Agricultural Research Service

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Ron Rickman

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INTRODUCTION

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

PROMOTIONS AND AWARDS

Daniel Ball was promoted from the rank of Assistant to Associate Professor in the Department of Crop and Soil Science, and was granted tenure at Oregon State University. Dr. Ball is the weed scientist at the Columbia Basin Agricultural Research Center, and is a past president of the Oregon Society of Weed Science. He was elected chair of the Western Regional Research Coordinating Committee, and chair of the Western Society of Weed Science Education and Regulatory Committee. Erling Jacobsen and Sandra Ott received Certificates of Recognition for ten years of service to Oregon State University.

Within the USDA staff, Dale Wilkins, was promoted to Research Leader and Location Coordinator; Craig Cameron was promoted from Physical Science Technician to Engineering Technician; Steve Albrecht was promoted to GS-14 and Tami Johlke received a Quality Step Increase promotion. Phil Dailey received a Certificate of Merit with a cash award.

STAFF CHANGES

Dr. Bill Payne became the cropping systems agronomist at the Columbia Basin Agricultural Research Center. He is a native of Indiana, received the Ph.D. degree in soil physics at Texas A&M University, and has extensive agricultural experience in semi-arid countries of west Africa. Dr. Payne moved from Niamey, Niger, where he was a plant physiologist at the Sahelian Center administered by the International Center for Research in the Semi-Arid Tropics (ICRISAT). He also coordinated ICRISAT cropping systems research programs for the African continent.

The OSU club wheat breeding program was combined with the USDA-ARS wheat breeding and genetics program located at Pullman, WA. Leadership of the Oregon club wheat program shifted from Dr. Warren Kronstad, OSU-Corvallis, to Dr. Jim Anderson, ARS-Pullman. Budget reductions in the program led to resignations of Mike Moore and Vicky Correa. Mr. Moore became program director for the Wyoming Crop Improvement Association and Ms. Correa took a position in the insurance industry. Karen Morrow, with eight years of experience in the Oregon club wheat research program, assumed responsibility for implementing components of the new club wheat program as they relate to tests at Pendleton and Moro.

Devesh Singh, from Lake Alfred, FL, was hired as a faculty research assistant in the weed science program led by Dr. Dan Ball. Sandra Ott resigned from the soil science program led by Dr. Don Wysocki. Ms. Ott became the native plant production manager for the Confederated Tribes of the Umatilla Indian Reservation. Sandra Alderman was employed through the year as a temporary employee in the plant pathology and weed science programs. Other temporary employees in OSU programs included Brian Arvidson, Julie Bain, Amy Baker, Christy Brown, Katie Cooley, Mark Despain, Mark Easley, Renee Foden, Jodi Justus, Kristen Kyles, Matthew Millar, Chris Petersen, Julie Rickman, Annie Sheard, and Robin Straughan.

In September of 1996, Betty Klepper, Research Leader, retired after 20 years of government service and was replaced by Dale Wilkins. Sharron Wart, Office Automation Assistant, resigned in February of 1996 and was replaced by Pat Frank. Jacque Grandbois, Office Automation Assistant, resigned in April of 1996, and the position was replaced with a Research Leader Secretary position. Jane Dailey was selected to fill this new secretarial position. Holli Krumbein was selected for the 1996 College Summer Intern position under Dale Wilkins and Mary Van't Hul was selected for the 1996 High School Research Apprentice position under Steve Albrecht. Rebecca Holowecky, Biological Science Technician, resigned in August of 1996 and was replaced in November by Amy Baker. Also in November of 1996, Ed Farren was selected to fill a 180 day Hydrologic Technician position to assist with the Rainfall Simulation Study and Claude Sterling was selected for a 1-year Biological Science Technician appointment. In January of 1997, K.C. Cross was selected for a 1-year part-time Cooperative Student position. Other temporary employees that worked during summer and school vacations in 1996 included Aaron Arvidson, Erin Bailey, Amy Baker, Heather Baune, Colette Coiner, Kristen Elliott, Melissa Hedman, Jennifer Kirby, Kimberly Miller, Andy Weidert, Jackie Whitesell and Jill Verkist.

NEW PROJECTS

Several new OSU projects were established to compliment on-going research funded by the Oregon Wheat Commission, USDA-STEEP III Research Program, agribusiness, and other funding agencies. Dan Ball initiated a project for integrated management of jointed goatgrass in Pacific Northwest dryland cropping systems. This is part of a five-year tri-state project to assess the usefulness of specific farming practices for the management of jointed goatgrass.

Richard Smiley joined an 11-scientist team from Pullman, WA (Washington State University and USDA-ARS), whose objective is to develop economical cropping systems less detrimental to soil and air quality in low rainfall regions. Principal research sites for the low-rainfall cropping systems project are near Ralston, WA and Echo, OR.

Don Wysocki and Dan Ball participated in annual crops demonstration projects led by Mike Stoltz, Umatilla County Extension Agent and OSU Professor of Crop and Soil Science. Demonstrations were performed throughout northeast and northcentral Oregon. Don Wysocki also coordinated a side-by-side field demonstration of five no-till drills on a local farm, and entered into a cooperative project to evaluate the use of municipal biosolids spread on range land. The biosolids project is led by Dr. Dan Sullivan, OSU-Corvallis, and involves plots on the Sherman Experiment Station and nearby private property.

Bill Payne initiated the new agronomy program by familiarizing himself with agricultural systems and research priorities for the region. Dr. Payne entered into a cooperative program with Dr. Bob Ramig (USDA-ARS; retired) and other ARS scientists to collate and publish soil water-use-efficiency data collected from several cropping systems experiments during the past decade. Dr. Payne also became coordinator of a multi-institutional project with the objective of developing a watershed level research and education center funded by the federal "Fund for Rural America".

Clyde Douglas and John Williams started a new project to evaluate the effects of tillage and residue management systems on soil and nutrient loss associated with frozen soil runoff events. They are using a rainfall simulator designed by Dr. Williams to test four different tillage systems. Dale Wilkins, Dan Ball and Richard Smiley, in cooperation with Tom Darnell, Umatilla County Extension Agent and John Kraft, ARS Plant Pathologist at Prosser, WA, started a new project for common root rot control in peas. This research is being funded in part by the Western Regional IPM Special Grants Program. Cover crops, seed treatment and plant resistance will be evaluated.

FACILITIES

Many improvements were made to OSU facilities and equipment and vehicle inventories. Trees (177) damaged and killed by Armillaria root rot, mountain pine beetle, locust borer, and blue mold were removed from the Sherman Station. An irrigated tree garden, funded by the Sherman Station Endowment Fund, was established to provide a living memorial for citizens who have positively influenced the Station and other agricultural programs in the northcentral counties. The Endowment Fund also installed a prominently displayed sign to acknowledge donors to the Fund, and purchased a flail mower and an air-flow fertilizer spreader for use at the Station. Renovation of the OSU office building continued at the Pendleton Station. Air conditioning, central heating, and electronic communication systems were installed and the electrical system was upgraded. Cabinets, counters, desks, and computers were renovated and/or replaced for the weed science, wheat breeding, agronomy, and soils programs. Nearly two decades of inefficient occupancy were concluded when technical staff were moved into offices in the newly renovated building.

The USDA-ARS local area computer network and the OSU system-wide electronic information and communications networks were expanded to include all the OSU buildings: wheat breeding lab, greenhouse, field office, and shop. All OSU staff at the Pendleton and Sherman Stations now have full access to modern communications systems. Four OSU vehicles were replaced: a sedan and pickups for the soil science, weed science, and crop science programs. Major repairs were made on several units of equipment and vehicles, including the John Deere MC tractor and 1-ton truck. The Oregon Wheat Commission (OWC) and Oregon Wheat Foundation (OWF) donated new equipment worth about $300,000 to improve research efficiency and expand research capabilities. Donations from the OWC included a plot combine, wheel tractor, air-flow fertilizer applicator, laboratory autoclave, analytical balance, and sample handling and processing equipment. Donations from the OWF included a seed drill and a cultipacker. Two John Deere 95H combines, donated by Lloyd and Joan

Rhinhart, and Amanda Weinke Dumond, enabled the Pendleton Station to replace two older combines.

The USDA facility upgrades for FY '96 included a completely new roof over the office and laboratory building, total remodel (which included new cabinets, flooring, ceiling and painting) of an underutilized room in the office/lab annex, and new cabinets in the microbiology lab. Accomplished or planned improvements and upgrades for this year include: painting the exterior of the office and lab building, replacing the roof over the annex and mechanical room, retrofitting the rest room in the annex to meet with ADA standards, replacement of the hot water heater, and insulating the metal shop bay.

TRAINING

OSU staff continued to maintain training requirements for pesticide application licenses, first aid, and cardio-pulmonary resuscitation. Gloria Eidam traveled to Corvallis for training with the OSU financial information system. Richard Smiley traveled to St. Louis, MO to participate in the Professional Society Leader's Training Program sponsored by the Council for Agricultural Science and Technology, The Farm Foundation, and The W.K. Kellogg Foundation.

On the USDA staff, all pesticide applicators completed training to maintain licensing. All staff received updates on CPR and first aid where needed. Dale Wilkins attended courses on Geographic Information Systems and Introduction to Multibody Modeling. John Williams attended a Supervisory seminar and GIS Applications in Hydrology and Water Resource Management. Phil Dailey attended Acquisition training in St. Louis, MO. Steve Albrecht, Jane Dailey, Clyde Douglas, Pat Frank, and Ron Rickman took a one day course on "Getting It All Done." Steve Albrecht and Clyde Douglas participated in a one day session on "How To Be A Better Technical Writer" and Pat Frank attended a session on "The Exceptional Assistant."

VISITORS

Distinguished visitors hosted by the staff at the center included:

Phyllis Johnson, ARS, PWA, Albany, CA

Chet Reder, Area Administrative Officer, ARS, PWA, Albany, CA

Ralph Nave, Assistant Director, ARS, PWA, Albany, CA

Brad Baugh Environmental Protection Specialist, ARS, PWA, Albany, CA

Alvin Humphrey, Area Safety and Health Manager, ARS, PWA, Albany, CA

Lori Powell, Health Physicist, ARS Riverdale, MD

ARS Consolidated Assistance Review and Evaluation Team (CARE), Lana Podielsky, Sandy Brinson, Washington DC, Pam Scalco, Greenbelt, MD, Earl Griffin, Griffin, GA, Terry Krutz, Stoneville, MS, C. Wayne Moore, Orlando, FL

Gregg Riegel, Forest Ecologist, USDA-FS, Bend, OR

James Dobrowolski, Associate Professor, Utah State University

Miro Jiranek, Bill Rose, Turf Seed Inc., Ohio

Tim Murray, Professor of Plant Pathology, Washington State University, Pullman

Dwane Miller, Professor of Crop Science, Washington State University, Pullman

Bob Forster, Professor of Plant Pathology, University of Idaho, Twin Falls

Jack Reisselman, Professor of Plant Pathology, Montana State University, Bozeman
Dan Biggerstaff, Research Director, Western Plant Breeders, Bozeman, MT
Jim Cook, Research Leader, Root Disease and Biological Control Unit, USDA-ARS, Pullman
Kay Simmons, Research Leader, Wheat Genetics, Physiology, and Disease Unit, USDA-ARS, Pullman
Jim Anderson, Research Geneticist, USDA-ARS, Pullman
Bob Allan, Research Geneticist, USDA-ARS, Pullman
Dan Hilburn, Administrator, Plant Division, Oregon Department of Agriculture, Salem
Bruce Andrews, Director, Oregon Department of Agriculture, Salem
Gary Smith, Regional Director, USDA-Animal and Plant Health Quarantine Service, Portland
Paul Risser, President, OSU
Les Risser, OSU
Roy Arnold, Provost, OSU
Lee Schroeder, Chief Business Officer, OSU
Thayne Dutson, Dean of the College of Agricultural Sciences, OSU
Mike Burke, Associate Dean of the College of Agricultural Sciences, OSU
Kelvin Koong, Associate Dean of the College of Agricultural Sciences, OSU
Bob Witters, Program Coordinator, College of Agricultural Sciences, OSU
Bill Braunworth, Program Coordinator, College of Agricultural Sciences, OSU
Bruce Sorte, Business Officer, College of Agricultural Sciences, OSU
Jim Rutledge, Associate Dean, Extended Education, OSU
Gary Lee, Director, Idaho Agricultural Experiment Station, Moscow
Richard Heimsch, Associate Director, Idaho Agricultural Experiment Station, Moscow
Jim Carlson, Associate Dean, College of Agriculture and Home Economics, Washington State University, Pullman
Vicki McCracken, Associate Director, Washington Agricultural Research Center, Pullman
Forrest Rodgers, Development Office, OSU
Don Wirth, Director of OSU Alumni Relations
Sharon Magnuson, OSU Portland Development Office
Angelo Gomez, Affirmative Action Department, OSU
Charles Boyer, Head, Department of Horticulture, OSU
Jim Fitzgerald, Head, Department of Animal Science, OSU
Sheldon Ladd, Head, Department of Crop and Soil Science, OSU
Stella Coakley, Head, Department of Botany and Plant Pathology, OSU
Tom Lumpkin, Chairman, Department of Crop and Soil Sciences, Washington State University, Pullman
Larry O'Keefe, Head, Department of Plant, Soil, and Entomological Sciences, University of Idaho, Moscow
Bill Nickleberry, Oregon State Land Board
Tom Winn, Executive Director, Oregon Wheat Commission, Portland
Jonathan Schlueter, Executive Director, PNW Grain and Feed Association, Portland
Gene Milbrath, Plant Pathologist, Oregon Department of Agriculture, Salem
Lavern Weber, Director of the Hatfield Marine Science Center, Newport
Phil Koch, Ciba Crop Protection, Greensboro, NC
Larry Aamold, US Bancorp, The Dalles

Foreign visitors included:

Gyula Zalabai, Josef Pařízek, Slovakia; Tatjana Dishnica, Ilir Sallaku, Irfan Tarelli, Ministry of Agriculture and Food, Albania

Lucy Gilchrist, Reynaldo Villareal, Iván Ortiz Monasterio, Raj (Sanjaya Rajaram), CIMMYT, Lisboa, Mexico

Li Changjie, Zhao Jiakum, Hu Xixiam, Yang Baoquan, Gao Lluanwen, Engineers, Peoples Republic of China

Dr.'s Berno Faust and Goetz Richter, University of Braunschweig, Braunschweig, Germany and 16 students

Claudio Mario Mundstock, Brazil

Vladimir Antonovich, Chief of Tyumen Committee on Food Market Regulation, Tyumen, Russia

Vasilij Konstantinovich, Deputy Head on Agricultural Administration, Orenburg, Russia

Vitalij Vasiljevich, Chairman of TOO Co., Orenburg, Russia

Sergej Sergeevich, General Director of JSC Omskagrokhimija, Omsk, Russia

Viktor Pyushpeki, Ciba-Geigy Ltd., Moscow, Russia

SEMINARS

The seminar series at the Center was coordinated by Don Wysocki and John Williams. Seminars were presented on the third Tuesday of each month unless scheduling problems arose with other research center events. Seminars were presented by the following speakers: John Williams, Hydrologist, USDA-ARS, Pendleton OR, *"Microbiotic Crust Influence on Soil Hydrology and Erosion";* Dick Smiley, Superintendent, Oregon State University, Columbia Basin Agricultural Research Center (OSU-CBARC), Pendleton OR, *"Karnal Bunt - Where are We?";* Devesh Singh, Research Assistant, Faculty Research Assistant, OSU-CBARC, Pendleton OR, *"Effect of Adjuvants on Efficacy, Rainfastness and Absorption-Translocation of Glyphosate";* Steve Albrecht, Microbiologist, USDA-ARS, Pendleton OR, *"Nitrogen Fixation and Nitrogenase" and "Cyanobacteria as a Source of Nitrogen for Cereal Plants";* Dennis Roe, Tri-state Team Leader, USDA-NRCS, Colfax WA, *"The Effects of Conservation Tillage on Northwest Farms";* Chris Pannkuk, Research Associate, Agricultural Engineering Department, Washington State University, Pullman WA, *"Small Grain Canopy Cover Effects on Water Erosion";* Joanna Fraser, Agriculture and AgraFood Canada, Lethridge, Alberta, Canada *"Annual Forage Legumes for Sustainable Cropping Systems in Alberta";* Rich Engle, Montana State University, Bozeman MT, *"Is Physiologic Leaf Spot of Wheat an Indicator of Inadequate Chloride Nutrition?";* Bill Schillinger, Agronomist, Washington State University, Ritzville WA, *"Agronomy Research Challenges for Low-Rainfall Dryland Areas in the Pacific Northwest";* and Bill Payne, Agronomist, OSU-CBARC, Pendleton OR, *"Integrated Cropping Systems in Semi-Arid Climates".*

LIAISON COMMITTEES

The Pendleton and Sherman Station Liaison Committees have region-wide representation and provide guidance in decisions on staffing, programming, and facilities and equipment improvement at the Stations. Membership is by appointment by the Director of the Oregon Agricultural Experiment Station and also, at Pendleton, by the Director of the Pacific West Area, USDA-ARS. These committees provide a primary communication linkage among growers and industry and the 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 coordinated by Chairman Kay Simpson (Pendleton: 541-276-3507) held meetings on November 6 and March 4. Gary Burt completed a term as chairman in November, and is commended for his many years of service and leadership. The Sherman Station Liaison Committee is coordinated by Chairman Ernie Moore (Moro: 503-565-3202), and meetings are held on June 12 and December 5.

EXPRESSIONS OF APPRECIATION

The staff wishes to express their appreciation to individuals, associations, and corporations who have given special assistance for the operation of experimental plots on or associated with the Center during 1996-97. 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 (Lloyd and Joan Rhinhart, Amanda Weinke Dumont), funds, seed, and/or chemicals (American Cyanamid Co., BASF Corp., Bayer Corp., CIBA Crop Protection Co., E.I. duPont de Nemours, FMC Corp., Mid-Columbia Producers, Monsanto Corp., Oregon Grains Commission, PROGENE, Rhône-Poulenc Ag Co., Sandoz Agro) or loaned equipment or facilities (Lieuallen Ranches, 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., Cargill Inc. [InterMountain Canola], CIBA Crop Protection, E.I. du Pont de Nemours & Co., Farm Credit Services, Farm Equipment Headquarters, First Interstate Bank, FMC Corp., Gustafson Inc., Huntington-Price, Inland Chemical Service, Inland Empire Bank, Pendleton Main Street Cowboys, Monsanto Co., Pendleton Bus Co., Pendleton Flour Mills, Pendleton Grain Growers, Pioneer Implement Corp., Rhône-Poulenc Ag Co., Rohm and Haas Co., Sandoz Agro, Smith Frozen Foods, The McGregor Co., UAP Northwest, Umatilla County Wheat Growers League, Walla Walla Farmer's Coop., Western Farm Service, Western States Equipment Co., 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: Ag-West Supply, Cargill Inc., Cascade Ranchers, Columbia River Bank [The Dalles Branch], First Interstate Bank [Sherman County Branch], Fred Myers, Gustafson Inc., Klickitat Valley Grain Growers, Mid-Columbia Bus Co., Mid-Columbia Producers, Monsanto Co., Morrow County Grain Growers [Lexington and Wasco], Northwest Chemical Corp., Richelderfer Air Service, Sandoz Agro, Sherman Aviation, Sherman County High School, Sherman Farm Chemicals, The Halton Co., U.S. Bank [The Dalles Branch], Western Tillage Equipment Co., and Wilbur-Ellis Co.

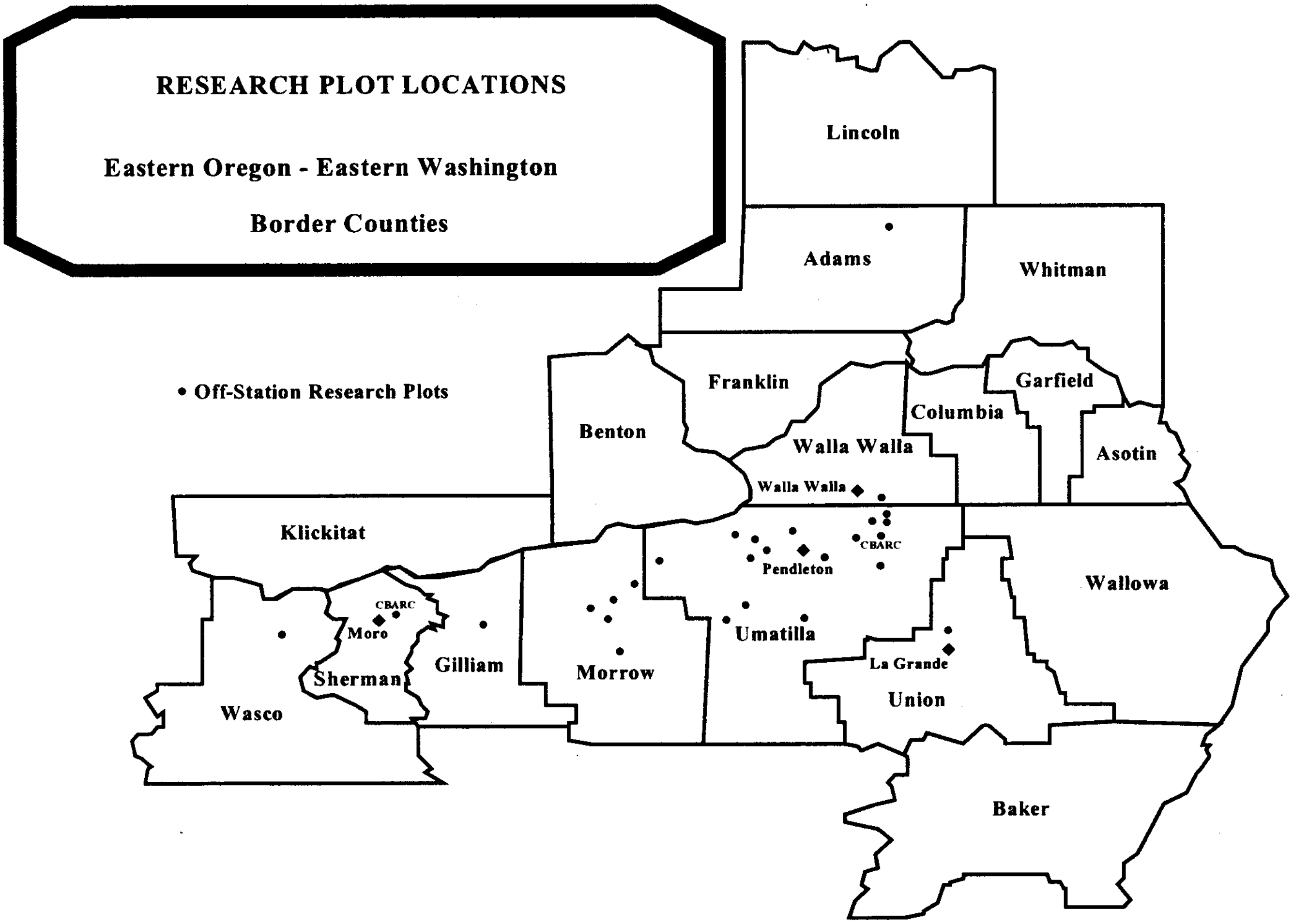
Cooperative research plots at the Center were operated by Warren Kronstad, Patrick Hayes, Chris Mundt, and Russ Karow. Additionally, we are very thankful for the ever-present assistance from the Extension Service personnel in all counties of the region, and especially from the following counties: Umatilla (*Mike Stoltz, Tom Darnell*), Union/Baker/Wallowa (*Gordon Cook*), Morrow (*Kathryn Kettel*), Sherman and Wasco (*Sandy Macnab*), and Gilliam (*Mike Spengler*) 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 property 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
Superintendent
OSU-CBARC

Dale Wilkins
Research Leader
USDA-ARS-CPCRC



ADAMS, WA
Curtis Hennings

GILLIAM, OR
Jim Rucker

MORROW, OR
Charlie Anderson
Bill Jepson
Frank Mader
Chuck Nelson
Tim Rust
Chris Raush

UMATILLA, OR
Dave Casper
Jim Duff
Ted Gilliland
Bob Hale
Maurice Johns
Robert Johns
Bryan Jones
Bob Newtson
Larry Newtson
Clint Reeder
Paul Reeder
Pendleton Exp. Station
Leon Reese
Jeff Shaw
Jerry Simpson
Mack Temple
Jim Whittaker

SHERMAN, OR
Sherman County Exp. Station

UNION, OR
John Cuthbert

WALLA WALLA, WA
Clint Reeder

WASCO, OR
Bob Brewer
David Brewer

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BIOSOLIDS IN COLUMBIA BASIN DRYLAND CROPPING SYSTEMS

Dan Sullivan, Sandy Macnab, Erling Jacobsen, Don Wysocki and Russ Karow

INTRODUCTION

This report introduces the rationale and some preliminary data from a new project with biosolids (digested sewage sludge) in Sherman County.

Biosolids are a byproduct of municipal wastewater treatment. Biosolids have been successfully land-applied for over 20 years in Oregon (Sullivan, 1996). Recent developments affecting biosolids utilization in Oregon include:

1. Current "heavy metal" concentrations in biosolids (cadmium, zinc, copper etc.) are much lower than 20 years ago, due to consistent enforcement of industrial wastewater quality standards. Current metal concentrations are far below those necessary for human and environmental safety (USEPA, 1993; National Academy of Sciences, 1996).

2. Improved biosolids processing technologies have increased solids content and product value (3 to 5 times higher nutrient value per unit weight).

3. Current economics make long-distance transport an economical alternative to winter storage for western Oregon wastewater treatment facilities.

4. Most western Oregon cities have experienced large increases in biosolids production, due to more sewer hook-ups and improved wastewater treatment processes. For many facilities, biosolids production has doubled over the last 10 to 15 years.

These developments have led to increased interest among central and eastern Oregon growers and western Oregon municipalities in working together to utilize biosolids. Biosolids are an inexpensive form of nitrogen (N), and growers perceive potential additional benefits from the organic matter in biosolids. From the environmental point of view, advantages to using biosolids in a wheat-fallow cropping system include:

1. There is little opportunity for biosolids runoff or public contact with biosolids after application.

2. Wheat and other cereals largely exclude metals like zinc and cadmium from the grain. There is little change in grain metal concentrations with agronomic biosolids application rates.

3. Wheat can capture nitrate to a depth of 4 to 6 feet, reducing nitrate movement to groundwater.

4. The increased crop residues accompanying biosolids application can reduce wind and water erosion.

Matching biosolids nitrogen to crop needs. Much of the total nitrogen provided by biosolids is not available to plants. The portion present in the ammonium form can be volatilized at application. The organic N in biosolids must be mineralized to plant-available forms (ammonium and nitrate) before plants can utilize it.

Matching the amount and timing of plant-available N released from biosolids is important from a crop production point of view. Recent research in the 10-14 inch annual precipitation zone in central Washington State (locations near Waterville and Ritzville) showed that rates of approx. 300 lb total N/acre as biosolids provided more than enough plant-available N for maximum grain yields (Sullivan et al., 1995). Higher biosolids application rates (> 300 lb total N/acre) reduced grain yield and quality via lodging, grain shrivel, and increased grain protein.

Availability of biosolids N is also important from an environmental point of view, because excess N that leaches below the root zone is a wasted resource, and may become a groundwater contaminant. Biosolids producers (wastewater treatment plants), farmers, and regulators all need good estimates of biosolids N availability to develop sustainable biosolids management programs.

OBJECTIVES

The long-range objectives of our study with biosolids are to:

1. Measure the availability of biosolids N (plant-available N/dry ton)
2. Determine the residual soil fertility effects of a one-time biosolids application
3. Determine the value of biosolids for dryland soft-white winter wheat production

This preliminary report addresses nitrogen availability only.

MATERIALS AND METHODS

This report includes only the fallow year data from one field location (Pinkerton Farm) in Sherman County. We plan to collect data at two sites from biosolids application to harvest. The Pinkerton site is situated on a Walla Walla silt loam soil, about 3 miles north of Moro (just west of Oregon State Hwy. 97). Soil depth varies from 3 to 6 + feet. Individual plot size is 40 x 300 ft. to accommodate biosolids application equipment and combine harvest.

Treatments at each experimental site include a 3 x 2 biosolids rate x application date factorial, an anhydrous ammonia control (grower rate of about 50 lb N/acre), and an unfertilized control with three replications. The biosolids rates are designed to supply a range of plant-available N rates. The biosolids application dates in our study (6 Nov. 1995 and 22 Apr. 1996) represent the most feasible application times for biosolids in a wheat-fallow cropping system (fall after crop harvest and spring of summer fallow year).

Unified Sewerage Agency (USA) of Washington County, Oregon supplied the biosolids used in our study. Biosolids from primary and secondary wastewater treatment were anaerobically-digested and dewatered at the Rock Creek plant in Hillsboro. The USA treatment process uses alum [$Al_2(SO_4)_3$] to precipitate additional phosphorus from the wastewater during the summer months. This alum was a component of the biosolids we applied in November, but was not present in the biosolids we applied in April. Characteristics of USA biosolids are shown in Table 1. The biosolids contained about 17 percent dry matter and 83 percent water as spread. Biosolids pH was 8.0, favoring rapid ammonia loss after application. Biosolids were applied via a rear-delivery manure spreader equipped with a hydraulic ram. The biosolids in each spreader load were weighed using portable weigh pads. Biosolids were not incorporated into the plow layer immediately after application. The interval between application and tillage was about six months for the fall application and about a month for the spring application.

We collected composite soil samples to a depth of 36 inches on 25 June 96. The sampling took place about a month after the initial fallow tillage. Each composite sample consisted of 20 cores from the surface 12 in., and 5 cores from the 12-24 and 24-36 in. depths. We measured inorganic N (NH_4-N + NO_3-N) at all depths.

RESULTS AND DISCUSSION

Most of the ammonium-N present in the biosolids at application (Table 1) was probably volatilized (lost as ammonia gas) before the first tillage.

Table 1. Average biosolids analysis for 1995-96 at Unified Sewerage Agency's Rock Creek wastewater treatment facility (Hillsboro, OR).

Element	lb/dry ton
Total nitrogen (N)	103
Ammonium-N (NH_4-N)	14
Nitrate-N (NO_3-N)	0
Phosphorus (P)	54
Potassium (K)	4
Sodium (Na)	1

volatilization is very rapid from dewatered biosolids because their pH is near 8. Volatilization of 50 to 80 percent of the biosolids ammonium-N is expected during the first week after application.

Biosolids application increased soil profile inorganic N (Table 2). The amount of soil inorganic N recovered increased with the amount of biosolids applied. A dry ton of biosolids supplied an average of 17 pounds of inorganic N. For biosolids applied in the fall, most of the N recovered was in the nitrate form. For spring-applied biosolids, most of the inorganic N was in the ammonium form. Both nitrogen forms have the same value for plant uptake. Ammonium-N will be converted to nitrate by soil micro-organisms.

Recent research in the 10-14 inch annual precipitation zone in central Washington showed that soil inorganic N recovered shortly after biosolids application was about 50 percent of that recovered during the two-year wheat-fallow cropping cycle (Cogger et al., 1997). Therefore, we expect additional

Table 2. Plant-available nitrogen (0 -36 in. depth) recovered during summer fallow. Pinkerton Farm, Sherman County

Nitrogen Source	Biosolids Rate	Application Date	Soil sampled 25 June 96 (in fallow)			
			NO_3-N	NH_4-N	NO_3-N + NH_4-N	
	dry ton/acre		lb/acre	lb/acre	lb/acre	lb/dry ton
None	0		19 d[1]	26 d	45 c	
None	0		18 d	28 cd	47 c	
Biosolids	1.4	06-Nov-95	36 bc	31 bcd	67 b	16
Biosolids	2.3	06-Nov-95	45 b	33 bcd	78 b	14
Biosolids	4.4	06-Nov-95	83 a	46 b	129 a	19
Biosolids	1.6	22-Apr-96	34 c	46 b	80 b	23
Biosolids	2.4	22-Apr-96	32 c	45 bc	77 b	13
Biosolids	4.5	22-Apr-96	37 bc	81 a	118 a	16
Biosolids average						17

[1]Numbers within a column are significantly different at $P < 0.05$ via protected LSD. Soil testing performed by standard methods at OSU Central Analytical Laboratory.

inorganic N to be mineralized from the biosolids as our study continues.

Future. This is the first year of our biosolids study. Nitrogen recovered during the summer fallow after biosolids application was similar to that observed at dryland locations in Washington. Grain yield results and additional soil data will soon be available from the Pinkerton site. We applied the same treatments to a second site in Sherman County in fall 1996/spring 1997. When our study is completed, it will assist biosolids producers (wastewater treatment plants), farmers, and regulators in making the best use of biosolids in dryland agriculture.

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CONTRIBUTIONS TO THE ESTABLISHMENT OF TMDL VALUES FOR THE UMATILLA RIVER WATERSHED

R.W. Rickman, J.D. Williams, C.F. Clifton, and M. Purser.

INTRODUCTION

The water quality of many streams in Oregon do not meet current Oregon state standards. The Umatilla River is among those water quality impaired streams. To address this problem the Oregon Department of Environmental Quality is working with the Umatilla Basin Watershed Council and the Confederated Tribes of the Umatilla Indian Reservation to establish values for the Total Maximum Daily Load (TMDL) of pollutants that can enter the river, yet allow the water quality to meet existing standards. Pollutants include nutrients such as fertilizer nitrogen and phosphorus, coliform bacteria, heat, soluble organic materials, and suspended solids. Biological growth of algae, bacteria, various aquatic insects, aquatic animals, and fish depend on water temperature for the balance of oxygen and nutrients to sustain their life cycles. To understand the growth and interactions of the various organisms living in the river, one must first understand the temperature fluctuations and cycles of the river. Water temperature in the river is dependent upon a very complex combination of water volume, stream channel characteristics, riparian vegetation, and weather.

To help describe and understand complex systems, models are often used. The water quality model named QUAL2E is available from the Environmental Protection Agency and has been used for assessing stream water quality problems at several locations throughout the United States. QUAL2E was created during the 70s and 80s in the southwestern United States. One of the objectives of this report is to examine the sensitivity of temperature predictions by QUAL2E to input weather and other model parameters. Another is to report on the collection of weather and water temperature data in the Umatilla Basin for the purpose of local calibration of the model. Objectives are not to match Umatilla River temperature patterns at this time, but to obtain sufficient experience and data to calibrate QUAL2E so that its computed responses are suitable for application to the Umatilla River.

Each time that QUAL2E is run it computes a steady state picture of temperature in a river system. This means that for each tributary and point source that supply water to the river, a constant flow rate and water temperature must be provided as input for the model. Output from the model is a pattern of temperature with distance along the length of the river. If a projection of river temperature is wanted for different flow volumes or inflow temperature conditions, a separate run of QUAL2E must be made using the specific flow volume and temperature conditions of interest.

For internal computations QUAL2E represents the river as a series of adjacent sections, called reaches. A reach may be as short as 1 mile or as long as several miles. Each reach represents a section of the river that has, at a scale of 1 mile increments, the same hydraulic or environmental characteristics such as river width, channel slope, channel roughness, or shading. Weather conditions such as air temperature, solar radiation, wind, and dew point temperature can be treated as identical for the full length of the river or they can be specified separately for each reach. River water temperature computations within QUAL2E are based on a conservation-of-energy budgeting procedure. Water temperature is modified by radiation energy from sunlight, heat conduction and radiation from air and the river bed, and evaporative cooling in addition to the mixing of waters of different temperature from tributaries or other sources.

PROCEDURE

The effects of changes in four environmental parameters (volume of water flow, solar radiation, air temperature, and wind speed) that are required inputs to QUAL2E were examined. Radiation, temperature and wind were treated as if they were constant for the full length of the river in order to examine the performance of QUAL2E in the simplest possible situation. The test values used for each parameter, listed in Table 1, provided sets of initial conditions for multiple runs of QUAL2E.

Table 1. Extreme values of environmental input variable used to examine calculations from QUAL2E. Values are representative of the Umatilla River between May and August.

Input Variable	High	Low	Units
Solar Radiation	786	395	Langleys/Day
Water Flow	700	100	cfs at Nolan
Air Temperature	90	70	F
Wind	10	0	mph

Several reaches were created to approximate the various hydraulic changes along the Umatilla River from the South Fork above Shimmiehorn Creek to Nolan below Pendleton (Figure 1 and Table 2). All water entering the river from head waters and tributaries was given a 50° F initial temperature so that only the test parameters, not input temperature, would modify the model outputs. The model outputs for water temperature of a river in one mile increments were compared for various combinations of the four test parameters.

Several recording thermometers were placed in selected locations in the Umatilla River and its tributaries in May of 1996 as part of the monitoring program of the TMDL committee of the Umatilla Basin Watershed Council. They were retrieved in September. Some of these temperature records will be used to calibrate QUAL2E.

Table 2. Reach segments, illustrated in Figure 1, for the Umatilla River from South Fork to Nolan.

Reach Name (Abbreviation)	Beginning River Mile	Beginning Elevation	Slope ft/ft	Manning's N
UMATILLA				
South Fork (SF)	97	2870	0.025	0.04
Corporation (CP)	91	2320	0.02	0.035
Reservation Tributaries (RT)	80	1750	0.005	0.025
Residential (RL)	61	1300	0.005	0.02
Canyons (CN)	50	950	0.003	0.02
TRIBUTARIES				
Meacham(MM)	19	2750	0.02	0.035
McKay (MK)	7	1350	0.01	0.02

RESULTS AND DISCUSSION

Figures 2 and 3 illustrate the water flow and in stream temperature patterns from QUAL2E for low and high flow of water in a river for unshaded - no wind, shaded - no wind, unshaded - 10 mph wind, and shaded - 10 mph wind input on a hot (90° F) August day. The projected temperatures in Figure 2 are, as should be expected

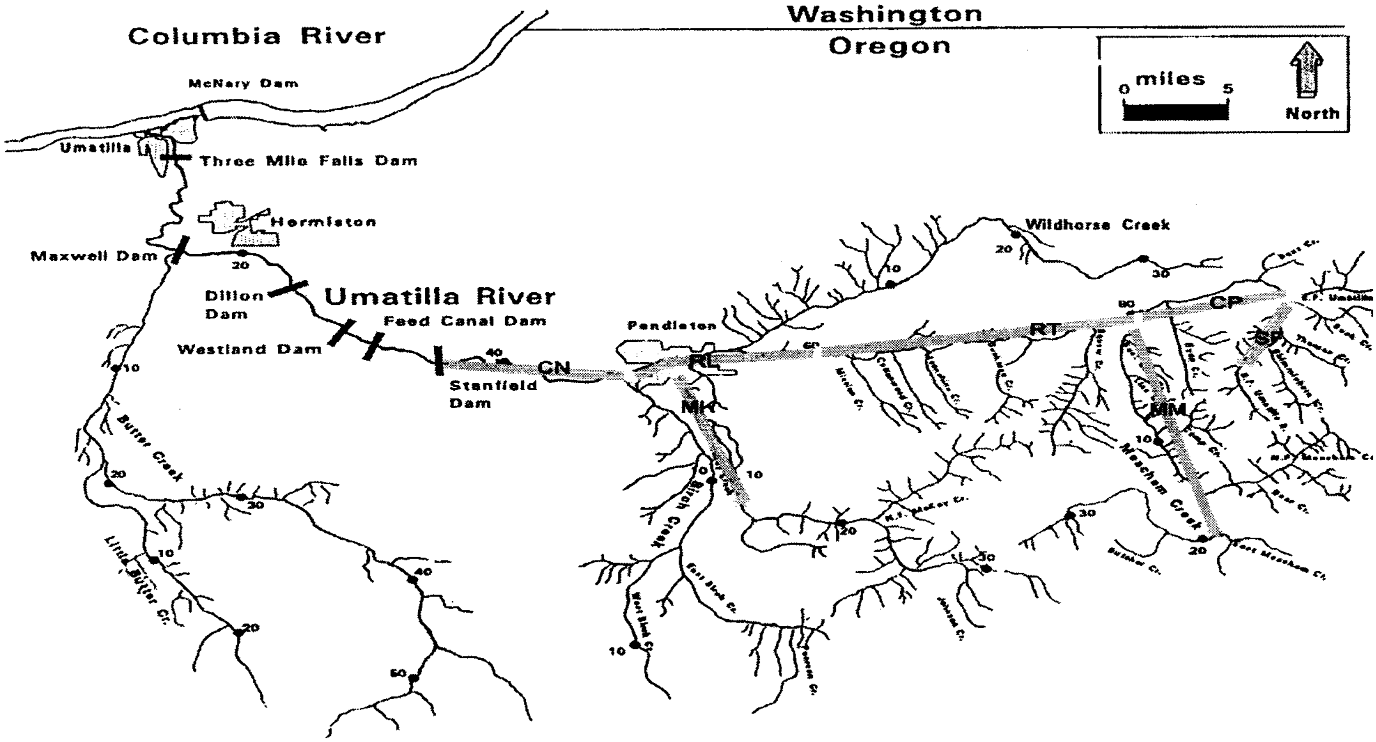

Figure 1. Location of reach segments, described in Table 1, representing water flow in the Umatilla River

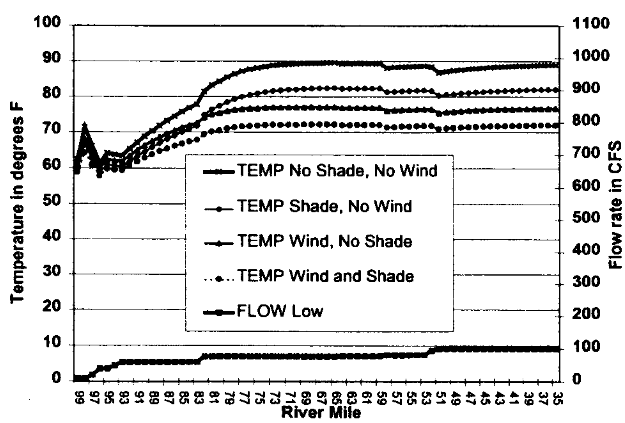

Figure 2. Temperature patterns predicted by QUAL2E in a river with low flow, high air temperature.

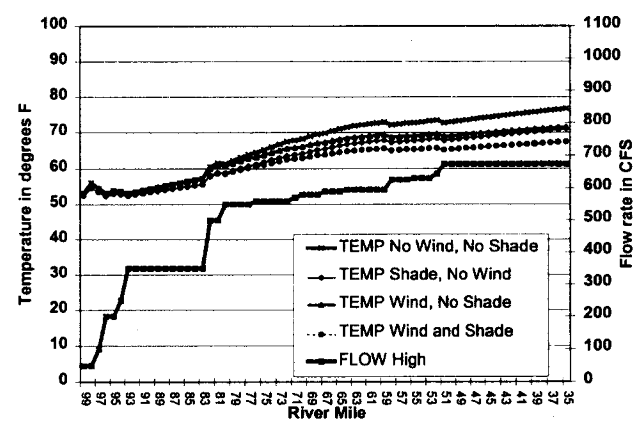

Figure 3. Temperature patterns predicted by QUAL2E in a river with high flow, high air temperature.

with the low water flow, warmer in all reaches than with the high water flow represented in Figure 3. The temperature patterns in Figure 2 indicate that for the low flow condition, water temperature had increased to near a maximum value by approximately river mile 75 for all 4 combinations of wind and shade input conditions. With the high flow of Figure 3, river temperature was projected to remain cooler and not reach a maximum temperature condition within the length of river that was analyzed.

In Figures 4 and 5 input air temperature of 70° F vs. 90° F provided patterns of river temperature comparable to those predicted for a shaded vs. unshaded river at 90° F air temperature in Figures 2 and 3. Wind of 10 mph in both cases was predicted to reduce river temperature by a surprisingly large amount. If the effect of wind is truly that large, it will be important to measure wind at several sites along the river to interpret observed water temperatures. If

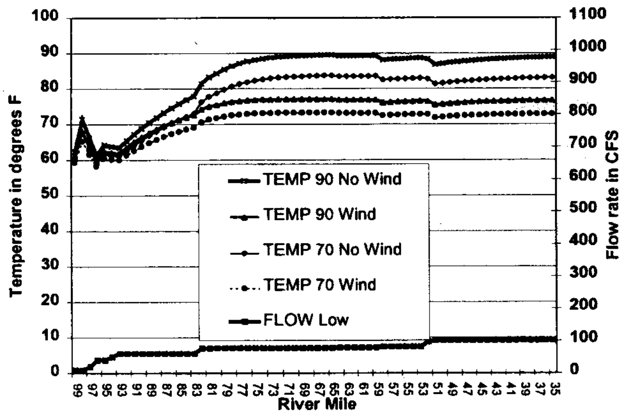

Figure 4. Temperature patterns predicted by QUAL2E in a river with low flow, high radiation, high and low air temperature.

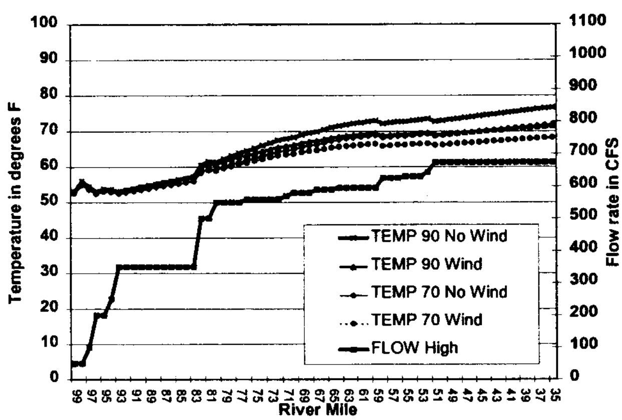

Figure 5. Temperature patterns predicted by QUAL2E in a river with high flow, high radiation, high and low air temperature.

the large effect of wind is not found in observed river temperature data, input wind values must be held constant when other parameters are investigated with QUAL2E.

Observed daily solar radiation, average air temperature, and total daily wind records for 1996 from the Columbia Plateau Conservation Research Center near Pendleton and IZR Consulting near Hermiston were compared to characterize the range of environmental conditions from the mouth to approximately river mile 65 in the Umatilla Basin. Figures 6,7, and 8 illustrate a consistent high correlation between locations for all three parameters. For the Umatilla Basin

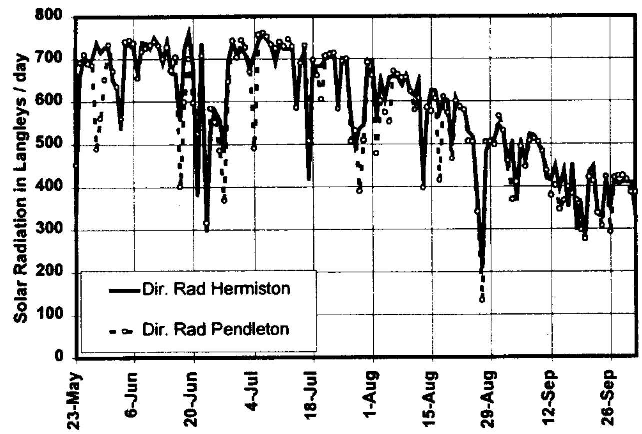

Figure 6. Solar radiation at Pendleton and Hermiston for 1996.

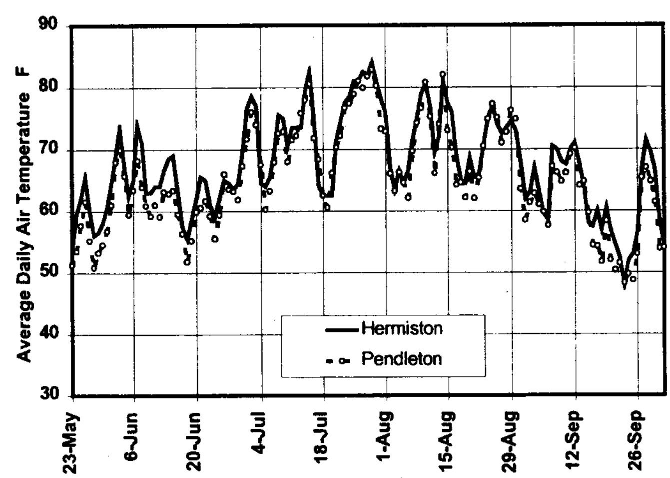

Figure 7. Average daily air temperature at Pendleton and Hermiston for 1996.

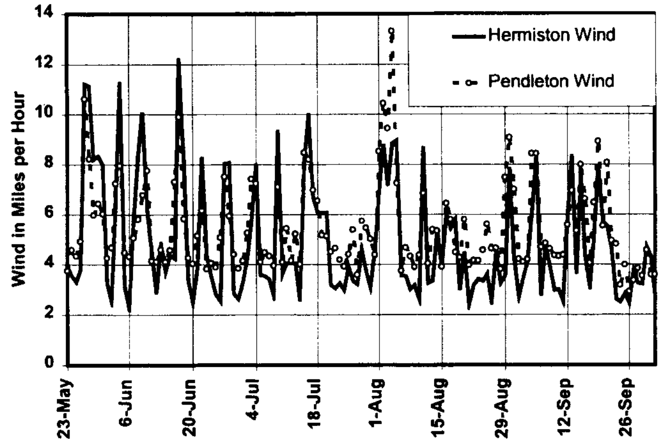

Figure 8. Daily wind at Pendleton and Hermiston for 1996.

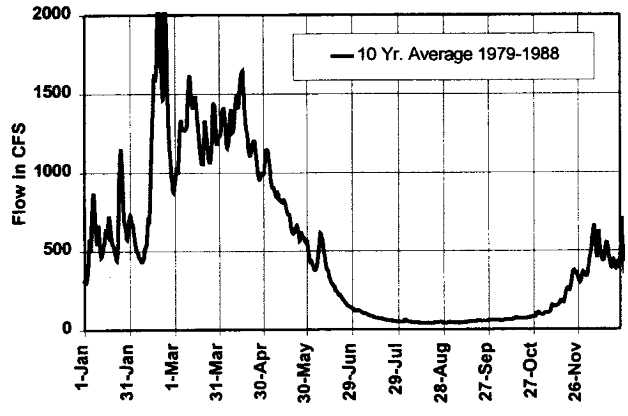

Figure 9. Ten year average of water flow in the Umatilla River at Pendleton Oregon.

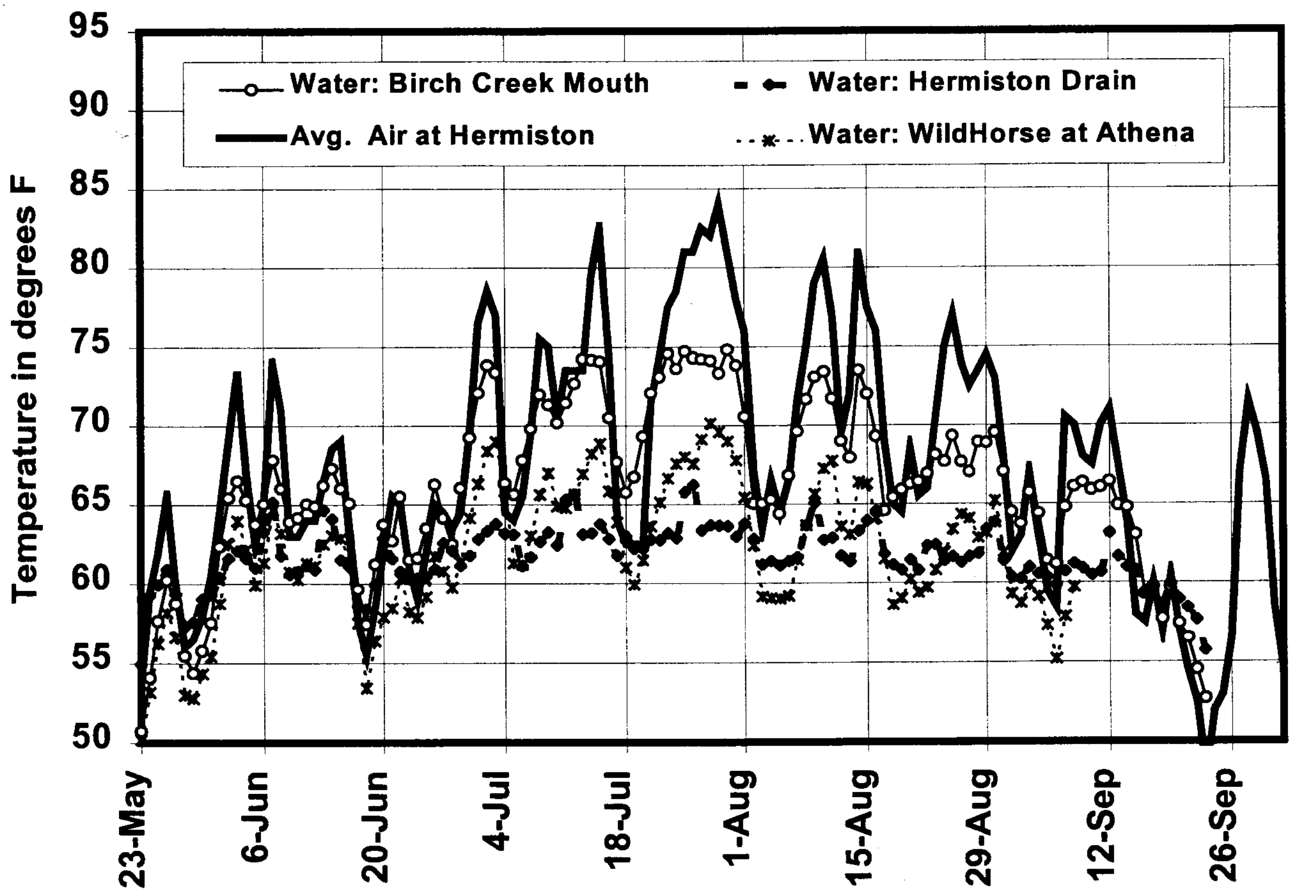

Figure 10. Water temperature at three locations in the Umatilla Basin in 1996.

from Pendleton to the mouth of the river at Umatilla OR., one set of environmental parameters (radiation, air temperature, and wind) could be used as a good first approximation of daily weather for all of the reaches.

Water flow and daily weather interact to control river temperature. Flow varies from year to year but does have a seasonal pattern. The 10-year average flow of the Umatilla River at the city of Pendleton is shown in figure 9. Water quality problems of the river are most evident during the low flow of the summer months.

Measured water temperature at three locations in the Umatilla Basin (Hermiston Drain, Birch Creek mouth, and Wildhorse Creek at Athena) are reported here for discussion and preliminary analysis. The water temperatures at all three locations are plotted with the Hermiston air temperature in Figure 10. The coefficient of correlation (r^2) for water temperature and air temperature at each location are 0.66, 0.84, and 0.83 respectively. An r^2 value of 1.0 indicates perfect correlation and 0.0 is no correlation. Two thirds of the variation in water temperature at the Hermiston drain is related to air temperature, while over 80% of the water temperature variation at Birch creek and Athena is related to air temperature. Even though water and air temperature are closely correlated, each location has a different relationship between air and water temperature. At Birch creek water temperature changed about 0.6 degrees for each 1 degree change in air temperature. In Athena the water temperature change was 0.5 degrees for each 1.0 of air temperature, while at the Hermiston drain water temperature changed only 0.2 degrees for each 1.0 degree of air temperature.

The uniform and relatively low temperatures at the Hermiston Drain were a bit surprising. The thermometer was actually in the South Drain, not in the river. One of the major differences between the Hermiston drain and Birch Creek, for example is shading. The Hermiston Drain measurement site was totally shaded by Russian Olive trees while there was no shade from any source at the mouth of Birch Creek. Extreme fluctuations in temperature that are present in the water at the mouth of Birch Creek are not present at the Hermiston Drain site. Shading at Athena is intermediate to the Birch Creek and Hermiston Drain sites. When water temperature at any of three sites is regressed with air temperature, from either Pendleton or Hermiston, the difference between observed water temperature and that computed from air temperature is not related to wind. This is a good example of why models must be calibrated to local conditions. The calculated difference between water temperature with and without wind blowing by the default parameters in QUAL2E seems to be much greater than would be expected from the water temperature, air temperature, and wind observations recorded during the summer of 1996.

The water flow data for 1996 from the various tributaries are not yet summarized. When those data are available they will be combined with the temperature data from the tributaries and other sites along the Umatilla river to calibrate QUAL2E to the Umatilla River. QUAL2E will then be used to examine the nutrient budgets of the river and help to display patterns of water quality along the length of the river. Once these computed patterns are suitably matched with water quality measurements taken from the river, QUAL2E will be used as one of several tools for guiding the selection of appropriate TMDL values to bring the water of the Umatilla River into compliance with Oregon State water quality standards.

EFFECT OF TILLAGE ON DOWNY BROME SEED DISTRIBUTION

Dale Wilkins and Brian Whitten

INTRODUCTION

Downy brome (*Bromus tectorum* L.) is a grass weed that is difficult to control in the inland Pacific Northwest dryland wheat farming region. Downy brome is often more difficult to control with conservation tillage systems that leave crop residue on and near the soil surface for erosion control than with inversion tillage (Veseth el al., 1994). This control problem in conservation tillage systems may be partially due to these systems leaving downy brome seeds in a favorable location for seedling emergence.

Downy brome seedlings usually emerge from the top inch of soil but may occasionally emerge from as deep as 4 inches (Wicks el al., 1971). Primary tillage provides a means of burying weed seeds deeper than 4 inches. In long-term tillage plots in Wisconsin, 60 percent of all weed seeds were found in the top 0.4 inches in plots that were not tilled as compared to 30 percent of the seeds in the top 0.4 inches in chisel plowed plots (Yenish et al., 1992). Moldboard plowing evenly distributed weed seeds in the top 7.5 inches. In other tests, 50 percent of foxtail millet (*Setaria italica* L. Beauv.) seeds applied before tillage were found within 1.6 inches of the surface following chisel plowing compared to 10 percent in the moldboard plowed plots (Staricka et al., 1990). Downy brome seeds are less dense and more elongated than the seeds used by Yenish et al.(1992) and Staricka et al. (1990). The lighter and more elongated downy brome seeds might tend to be more difficult to bury.

This research was conducted to determine downy brome seed distribution in no tillage, chisel plow and moldboard plow based tillage systems.

METHODS

A field experiment with four replications of primary tillage treatments that included chisel plowing 4 inches deep, moldboard plowing 7.5 to 8 inches deep and no tillage (no-till) was conducted on a Walla Walla silt loam at the Columbia Plateau Conservation Research Center, Pendleton, Oregon. The field had been in winter wheat the previous year and wheat stubble was standing when the tests were initiated.

Downy brome seeds were spread on the soil surface with a 40 inch wide Gandy drop spreader prior to tillage. Seeds were spread at of 180 seeds per square foot. Prior to spreading downy brome seeds, they were dyed red to facilitate identification of seeds in the recovery process.

The moldboard plow was a 5 bottom pull type with 16 inch wide bottoms. The chisel plow had 4 inch wide twisted shovels spaced 15 inches apart. Tillage speed was approximately 3 mph. After primary tillage, soil was firmed by skew treading twice with the gangs angled at 15 degrees. A Giddings hydraulic soil sampler was used to collect six, 2.5 inch diameter by 8 inch long vertical soil cores from each plot. The cores were incrementally sliced into 0.8 inch sections and corresponding increments from each plot were composited. Downy brome seeds were extracted from soil cores by a liquid density separation technique (Ball and Miller, 1989). A solution of magnesium sulfate, sodium hexametaphosphate, sodium bicarbonate, and water was used to separate seeds and plant material from soil. Seeds floated to the top with plant material and were decanted off and caught on filter paper. The dyed downy brome seeds were hand picked from the filter paper and counted.

RESULTS

As expected, most of the seeds were found in the top increment in the non-disturbed no-till plots (Figure 1). The highest concentrations of weed seeds were at 1 and 6-inch depths, respectively, for chisel plowing and moldboard plowing. Chisel plowing left significantly (0.05 probability level) more seeds in the 0 to 2.4 inch depth and significantly less in the 4.8 to 7.2 inch depth than moldboard plowing.

More than 90 percent of the downy brome seeds were found in the top 2 inches in chisel plowed plots and 80 percent of the seeds were buried below 4 inches in the moldboard plowed plots (Figure 2). These results are similar to those found by Straicka et al., (1990). They found 85 percent of millet seed and spherical tracers in the top 2 inches in plots that were chisel plowed and 75 percent of the millet seed and tracers below 4 inches in plots that were moldboard plowed. Chisel plowing depth was the same in their tests as ours but moldboard plowing depth was 2 inches deeper than ours. The decreased percentage of seeds below 4 inches in Straicka et al., (1990) tests may be due to tillage speed and moldboard shape that resulted in incomplete furrow inversion. Yenish et al., (1992) measured weed seed distribution in the soil profile after several years of tillage in long-term plots. They found 57 percent of the weed seeds in the top 2.4 inches in plots that were chisel plowed and 54 percent of the seeds below 3.5 inches in plots that were moldboard plowed. The apparently more uniform weed seed distribution in Yenish et

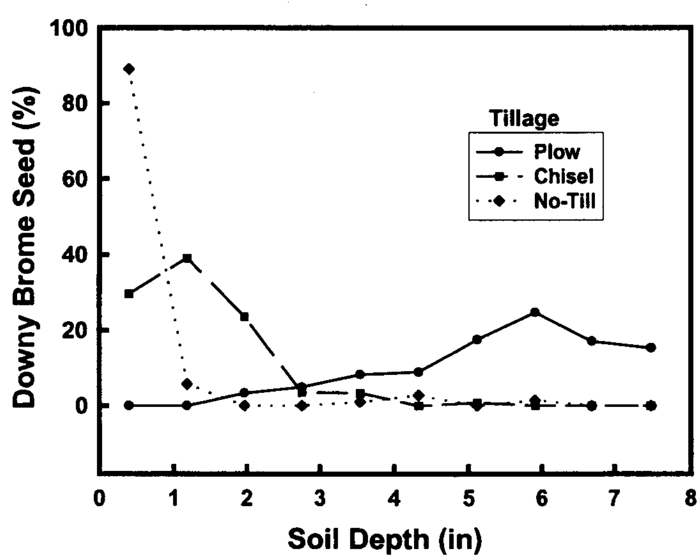

Figure 1. Percentage of downy brome seeds found in each depth increment for the three tillage systems near Pendleton, Oregon in 1994.

al., (1992) tests was probably due to the difference in test methods. In the tests conducted by Yenish et al., (1992), all weed seeds in the profile were counted but in the tests reported here only the dyed seeds that were spread on the surface with the drop seeder were counted. Yenish et al., (1992) included seeds that did not germinate or decay and remained in the profile and were subject to possible relocation with subsequent tillage.

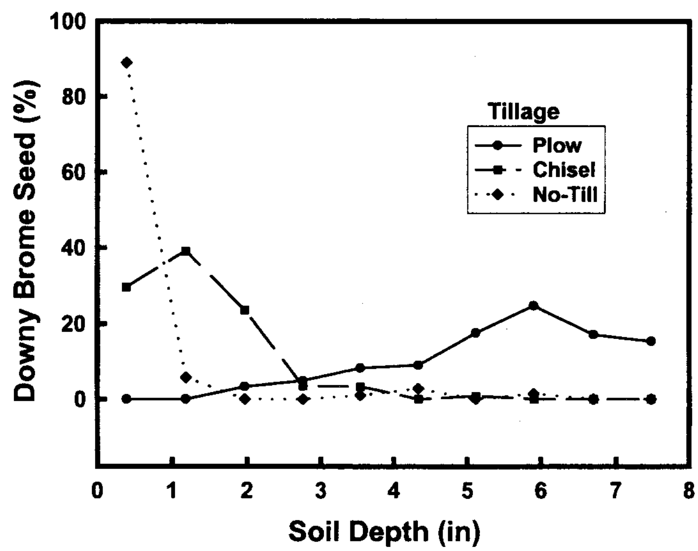

Figure 2. Accumulative distribution of downy brome seed near Pendleton, Oregon in 1994.

CONCLUSIONS

Downy brome plants establish from shallow placed seeds. Moldboard plowing placed 80 percent of the seeds below 4 inches where they likely will not produce emerged seedlings. Chisel plowing, a conservation tillage technique, left 90 percent of the seeds in the top 2 inches where they can germinate and develop into seedlings. If chisel plowing is used in fields where downy brome has been a problem, additional weed control measures such as selective herbicides and secondary tillage will be necessary to control downy brome.

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KARNAL BUNT AND ITS RISK TO THE PACIFIC NORTHWEST

R. W. Smiley

INTRODUCTION

Karnal bunt is a smut of wheat caused by the fungus *Tilletia indica*. The disease was first detected in the USA during March, 1996. This report provides a brief review of the disease (addendum) and its potential to become established in the Pacific Northwest.

The reported distribution of the Karnal bunt pathogen is limited to a few countries. Nearly all countries that import wheat use quarantines to delay the introduction of this pathogen. Most quarantines do not allow any spores (zero tolerance) of the Karnal bunt fungus. Consequences of contamination are severe for the Pacific Northwest, which exports 85% of its wheat to overseas customers. Major shifts in markets and prices are possible if this pathogen is introduced and becomes established in the Pacific Northwest.

The first report of Karnal bunt in the USA involved wheat produced in Arizona during 1995. The USDA-Animal and Plant Health Inspection Service (APHIS) implemented a program to eradicate the pathogen from areas known or thought to be infested, and to prevent further export of contaminated seed, products, equipment, and transport containers from areas where Karnal bunt occurred. The pathogen was then discovered in wheat produced in several southeast states (Alabama, Georgia, and Tennessee), and in grain produced as early as 1992 in Arizona and California. Seed from these states was distributed to farmers, millers, storage elevators, and wheat breeding and testing programs in other states and countries before *T. indica*-contaminated seed was discovered. The known distribution of this pathogen in the USA is increasing.

A smut fungus resembling the Karnal bunt pathogen has also been detected in seed of annual and perennial ryegrass and tall fescue produced in Oregon. The pathogen is present in 60 percent of the ryegrass seed lots and has been detected in seed packaged as early as 1989. It is also present in ryegrass seed imported into Oregon from at least seven other countries, including one seedlot dating back to 1967. It is still true, however, that the Karnal bunt fungus has not been detected in wheat produced anywhere in the Pacific Northwest, including wheat produced adjacent to ryegrass fields in Oregon. It remains unknown whether the fungi causing head smut of ryegrass and Karnal bunt of wheat are identical. Ryegrasses are susceptible to infection by *T. indica* (shown with artificial inoculations in the greenhouse, but never yet reported from field plantings) but it is not yet known whether the ryegrass pathogen can infect wheat. Nevertheless, current studies with the smut on ryegrasses in Oregon re-emphasize the need to evaluate the potential for the Karnal bunt fungus to become established on wheat. This information will become very important if soils in the region become contaminated with sufficiently high numbers of spores.

The potential for the Karnal bunt fungus to survive and infect wheat in the Pacific Northwest has not been reported. Data from other regions indicate that the potential geographic range for Karnal bunt is restricted less by physical requirements for survival of the pathogen than by synchronization of wheat heading with climatic conditions favorable for teliospore germination, secondary sporidial multiplication, and penetration, and infection.

Survival of spores through the winter seems likely in most wheat producing locations in the Pacific Northwest. Teliospores of *T. indica* are durable and persist in soil for up to four years. Survival in field soil varies greatly in response to depth of burial, soil moisture and temperature, and perhaps other factors. Teliospore survival is relatively unaffected by freezing for several months at 32°F, and survival is reduced only slightly by deep freezing (0°F) in soil for 20 weeks. Subfreezing temperatures required to inhibit spore viability do not occur for sufficient times at any Pacific Northwest location where wheat is produced. For instance, at Pocatello, the coldest wheat-producing location in the region, temperature records indicate that 0°F is attained for only two days each year (averaged over 54 years of records), and that the length of freezing below 32°F averages 68 days per year. At Corvallis, the mildest climate in the region, air temperatures are below 32°F an average of six days per year and never reach 0°F.

Humidity during heading appears to be the most important environmental factor for Karnal bunt occurrence. Spores and mycelium presumably dehydrate, and infection is reduced or prevented, if humidity declines and solar radiation is high for even short periods during the day. Under experimental conditions at 25°F, secondary sporidia have survived 2 and 12 hours at 25 and 95 percent relative humidity, respectively. Droplets of condensation or guttation trapped in wheat heads would be expected to extend the effective wetting period when humidity is low. Humidity inside the leaf sheath also remains high for unemerged heads and portions of emerging heads.

Minimal climatic and plant growth requirements for Karnal bunt to occur are not well defined. There are, however, numerous published reports describing conditions in which the disease did or did not occur. The consensus of reports indicate that for infection to occur, measurable rain (>0.1 inch) or irrigation must occur on each of two or more successive days, at least one-third inch must be collected within the 2-day interval, and/or average daily relative humidity above the plant canopy must exceed 70 percent during both days.

The goal of this study was to estimate the environmental risk for Karnal bunt to occur if soils become contaminated by the Karnal bunt pathogen at 13 Pacific Northwest locations. We analyzed historical data to determine the frequency at which climatic requirements for infection, as described above, were satisfied during heading.

METHODS

Historic temperature records were examined to identify weather conditions favorable for infection shortly before and during heading in areas where wheat is produced in the Pacific Northwest. The National Climatic Data Center's daily temperature and precipitation records were evaluated for 13 locations; Moscow and Pocatello in Idaho, Corvallis, La Grande, Moro, Nyssa, Pendleton (experiment station and airport), and Pilot Rock in Oregon, and Lind, Moses Lake, Quincy, and Spokane in Washington.

Humidity was estimated as the ratio of saturation vapor pressures at the average and minimum daily temperatures. Saturation vapor pressure was computed from temperature records; minimum temperature was assumed to be the dew point. Numbers and percentages of years with at least one potential "infection period", based on periods in which the average relative humidity exceeded 70 percent over a 2-day period, were determined for each of four potential heading intervals.

Four possible heading intervals were selected to represent those that occur during heading of spring- and fall-planted wheat. In the Pacific Northwest, heading occurs from early May to late June, depending on location and planting date. Four time intervals were examined: May 1 to June 30 (60 days), May 7 to June 22 (45 days), May 15 to June 15 (31 days), and May 22 to June 7 (16 days). The longest interval slightly exceeds the range of heading dates, and the shortest interval is shorter than the range of heading at all sites.

For locations with a 50 percent or greater probability of infection during the longest heading interval tested, the frequency of possible infection events was re-evaluated under two more conservative estimates of humidity. The conservative estimates were made because humidity calculated from daily average temperature does not adequately reveal the duration of low humidity which can dehydrate fungus spores and hyphae. The most conservative (driest) estimate used maximum daily temperature. An intermediate estimate used the minimum and one degree lower than maximum daily air temperature. Humidity computed from maximum daily temperature indicates the minimum humidity for the day, but the interval of time for that maximum temperature and minimum humidity may be brief. The interval of time that daily temperature is at or above one degree less than the daily maximum will almost always exceed two hours in the Pacific Northwest. Humidity computed from the maximum temperature minus one degree would occur for a sufficient time (at least two hours) to determine the presence or absence of free moisture on heads of non-irrigated wheat.

Temperature was not used as a limiting factor because temperatures during heading in the Pacific Northwest were always well within the limits of optimum and minimum temperatures when Karnal bunt occurs in other regions.

RESULTS AND DISCUSSION

Environmental conditions appear favorable for *T. indica* to cause Karnal bunt in high humidity and irrigated wheat producing regions of the Pacific Northwest. Table 1 presents the percentage of years in which at least one potential infection period occurred at each location. These data include many years that were favorable for multiple or prolonged infection events. Based on the second shortest heading interval, May 15 to June 15, six of the 13 locations have possible infection periods at least half of the time. The five driest locations (Lind, Moro, Moses Lake, Nyssa, and Quincy) have possible infection periods in only two or three of every 10 years. Teliospores survive in some soils for up to four years. Since there are intervals of four years or more in the weather records from the dry locations when no weather conditions that produce a possible infection event occur, they would not be expected to be favorable habitats for *T. indica* to survive without irrigation.

Predicted infection periods are markedly influenced by the method used to calculate relative humidity (Table 2). The estimate of relative humidity considered most realistic in this study was the one based on the average of the minimum and maximum minus one degree daily temperature. Using this criterion, all except two locations had less than one year in five for naturally occurring infection opportunities between May 15 and June 15 (Table 2). In these locations, conditions for potential infection events occur infrequently enough that the pathogen would not be expected to sustain itself in nonirrigated cropping systems. However, at two locations, Corvallis and Spokane, the potential for naturally occurring infection occurs with a probability of about one year in three. If a more liberal estimate of humidity is used at these two locations, the predicted potential for infection exceeds six of every ten years. Possible infection events at these two locations occur frequently enough that the pathogen would be expected to sustain itself in rotations that include wheat at least every third year. Wheat is a major crop in these locations and is often produced during alternate years. For instance, the Willamette Valley produces 16 percent of the wheat and 95 percent of the ryegrass in Oregon.

Atmospheric conditions required for Karnal bunt appear to closely parallel those for wheat head scab and potato late blight. In Arizona, where wheat and potatoes are watered by furrow irrigation, the area of Karnal bunt occurrence during 1995 coincided with that of late blight. Head scab and late blight both occur in the Pacific Northwest. Head scab occurs in irrigated wheat and in high mountain valleys. Late blight occurs in irrigated fields.

Irrigation is known to favor the occurrence of Karnal bunt. Providing that soils are contaminated, an opportunity for infection appears to occur every year at all Pacific Northwest locations when overhead irrigation water is applied during heading. Approximately 20% of wheat in Oregon and Washington is produced with sprinker irrigation. More than half the production in Idaho is irrigated, with sprinkler irrigation being dominant in eastern Idaho. Most wheat near Moses Lake, Nyssa, Quincy, and Pocatello is irrigated. It is common for water to be applied at each location until the plant is mature.

This analysis was limited to climatic conditions required for spore survival, release, and infection. However, the potential for disease to occur also depends on the population of teliospores in soil, and their survival over time, depth of burial, and synchronization of germination with wheat heading. For instance, some teliospores survive for shorter periods in irrigated than non-irrigated soils, are less germinable when buried by tillage rather than left at the soil surface, and may germinate under favorable conditions at times when wheat is not heading. It is also probable for wheat to be produced less frequently in irrigated than in nonirrigated fields. Collectively, these conditions could reduce the risk associated with favorable infection periods in irrigated soils of the Pacific Northwest.

ACKNOWLEDGEMENTS

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Table 1. Percentage of years with favorable weather events[a] for infection of wheat by *Tilletia indica* during heading at 13 locations in the Pacific Northwest, based on 28-65 years of records for these locations.

Location	May 1 to June 30	May 7 to June 22	May 15 to June 15	May 22 to June 7
Corvallis, OR	96	85	74	54
LaGrande, OR	93	90	70	43
Moscow, ID	81	70	57	34
Spokane, WA	91	77	60	34
Pocatello, ID	79	71	55	26
Pendleton Airport, OR	70	72	53	32
Pendleton Exp Stn, OR	63	61	47	29
Pilot Rock, OR	61	56	39	17
Moro, OR	48	43	34	22
Nyssa, OR	40	33	29	24
Quincy, WA	33	29	27	13
Lind, WA	42	38	25	17
Moses Lake, WA	46	43	25	11

[a] Favorable weather conditions defined measurable rain (>0.1 inch) occurred on each of two or more successive days, at least 0.3 inch was collected within the 2-day interval, and average relative humidity above the plant canopy exceeded 70% during both days.

Table 2. Percentage of years with favorable weather events[a] for infection of wheat by *Tilletia indica* during four heading intervals at eight locations in the Pacific Northwest USA, based on calculations of minimum humidity at average daily temperature ("ave"; the least conservative estimate), maximum temperature minus 1° ("max-1"; the most likely estimate), or maximum daily temperature ("max"; the most conservative estimate).

Location	May 1 to June 30			May 7 to June 22			May 15 to June 15			May 22 to June 7		
	(ave)	(max-1)	(max)	(ave)	(max-1)	(max)	(ave)	(max-1)	(max)	(ave)	(max-1)	(max)
Spokane, WA	92	55	30	77	51	30	60	36	23	34	17	17
Corvallis, OR	96	45	23	85	34	15	74	30	11	54	19	4
Pendleton Airport	68	23	13	68	19	11	53	19	11	32	9	4
Pilot Rock, OR	61	32	12	56	20	10	39	15	7	17	5	2
Moscow, ID	81	19	11	70	19	11	57	11	6	34	6	2
Pocatello, ID	79	28	11	72	21	6	55	13	2	26	4	0
La Grande, OR	93	27	10	90	23	10	67	17	7	47	10	3
Pendleton Exp Stn	63	16	8	61	11	3	47	8	3	29	5	3

[a] Favorable weather conditions defined as: 1) measurable rain (0.1 inch) occurred on each of two or more successive days, 2) at least 0.3 inch was collected within the 2-day interval, and 3) average relative humidity above the plant canopy exceeded 70% during both days.

Addendum on
Karnal Bunt

Karnal bunt is a fungal disease of wheats, triticales, and rye. Individual cultivar reaction to this disease varies widely. Barley and oats are not susceptible. Karnal bunt is one of five known smut diseases of wheat -- common bunt, dwarf bunt (TCK), flag smut, loose smut, and Karnal bunt. While generally unfavorable for Karnal bunt, some environments in the Pacific Northwest are quite favorable for development and survival of other smuts. All of the other smuts except for Karnal bunt are already present in the Pacific Northwest, but are generally controlled through cultivar resistance, seed treatments, and cultural practices.

Karnal bunt was first described in Karnal, India in 1931. It has now been identified in all major wheat producing regions of India, Pakistan, Iraq, and Afghanistan. It was likely brought into Mexico on seed in the late 1960s, and is now well established in northwestern Mexico.

Like all smuts, the Karnal bunt fungus (*Tilletia indica*) has a complex life cycle with several spore stages. Teliospores are the initial inoculum. Teliospores can be brought into a field on infested seed, straw or chaff, in contaminated soil, on contaminated harvesting or transportation equipment, or by the wind. Infested seed is the most likely mode of long distance transport. Once in the area, soilborne teliospores are the principal inoculum source. These spores are thick walled and can survive for long periods of time and under adverse conditions.

Teliospores germinate at or near the soil surface in response to moisture. Unlike other smuts, Karnal bunt teliospore germination is delayed until late in the growing season when wheat plants are flowering. Each germinating teliospore produces other spores, called primary sporidia, which in turn produce secondary sporidia that are forcibly ejected under cool, moist conditions. Each sporidial stage is wind- or insect-dispersed. Secondary sporidia that land on moist foliage can germinate and produce additional secondary sporidia or hyphae that produce secondary sporidia. Hyphae from secondary sporidia infect through stomates in glumes of emerged wheat spikes, causing infection of the ovule. Sporidia may also be washed down into the flag leaf sheath, onto unemerged or emerging heads. Survival of sporidia and infection are favored by intermediate temperature (60-80°F optimum, 45-52°F minimum) and either high humidity (>70%) or rainfall that produces high humidity during several successive days at the time of heading. Once in the ovule, the fungus grows, develops, and ultimately produces teliospores.

Karnal bunt usually causes only partial smutting of the kernel. The disease is rarely detected in the field, and it is very difficult to find smutted kernels in harvested grain. The spores are easily released at harvest and teliospores are released to contaminate seed, soil, equipment, and handling facilities. The spores do not present a health risk to consumers of infested grain or grain products. Control of teliospores is the key to restricting further spread of the disease. Regulations in most countries, including the United States, prohibit importation of wheat seed, plants, unprocessed straw, chaff, and mill products, from countries or areas where Karnal bunt is known to occur. Likewise, movement of contaminated transportation equipment is restricted, and contaminated handling facilities are required to eradicate the fungus. Crops planted with contaminated seed are likely to be destroyed under current regulations for quarantines and eradication procedures.

Karnal bunt does not generally reduce the productivity of wheat. Economic losses from production *per se* are unlikely, and control measures are available for use in areas where the disease develops significantly. However, stringent export regulations, currently placed at zero tolerance for any detectable teliospores in any size shipment, impose huge consequences for marketing contaminated wheat. Until international sanctions against the Karnal bunt pathogen have been removed, all available means must be taken to prevent contamination of Pacific Northwest wheat crops.

Adapted from: R. Karow, R. Line, and D. Smiley. 1996. Karnal bunt: cereal disease causes worry. Oregon Wheat 47(4):6-9.

LIGHT FRACTION SOIL ORGANIC MATTER IN LONG-TERM AGROECOSYSTEMS

Stephan L. Albrecht, Heather L.M. Baune, Paul E. Rasmussen, and Clyde L. Douglas, Jr.

INTRODUCTION

Soil organic matter (SOM) includes plant, animal, and microbial material in all stages of decay. The most decomposed SOM consists of a mixture of organic compounds closely associated with clay and silt in the soil. Soil organic matter is one of several criteria including bulk density, nitrogen, aggregation, and microbial activity which is used to estimate soil quality.

Soil organic matter plays a major role in maintaining soil structure, soil water infiltration, root development, and decreased soil erosion. It is a repository for crop nutrients, such as nitrogen, sulfur, phosphorus, and numerous minor elements. It gives color to the soil, increases water holding capacity, and resists changes in soil pH. It is not surprising that the amount and depth of SOM greatly impacts the productivity of both cultivated and uncultivated soils.

Soil organic matter accumulation is dependent on the balance between primary productivity (i.e. production of stems, roots and leaves) and biological decomposition of residue in the soil. Soil organic matter accretion is influenced by moisture and temperature. The rate of carbon accumulation is higher in moist temperate climates. The amount of SOM is inversely related to the amount of silt and clay in that soil (Christensen and Sorensen, 1985; Christensen, Bertelsen and Gissel-Nielsen, 1989). Nutrients, such as minerals in volcanic ash or in fertilizers, help to increase SOM by increasing vegetative productivity. Under similar climatic and edaphic conditions, grassland soils have higher SOM levels than do cultivated farmlands, even though residue input may be substantially less in the grassland. Crop management practices such as moldboard plowing, residue burning, and fallowing all decrease SOM.

Soil organic matter quality can be evaluated by several different methods. Density fractionation is utilized to isolate SOM that is not firmly associated with the mineral part of the soil. Soil is dispersed in dense organic liquids or inorganic salt solutions to separate different density fractions. The light fraction (LF) of SOM (predominantly the least decomposed material) is usually separated from whole soil by density fractionation in a liquid medium with a density between 1.6 and 2.2 grams per cubic centimeter (g/cm^3). The remaining SOM, or heavy fraction, consists of extensively decomposed organo-mineral complexes. The LF is generally considered to be a transitory SOM pool dominated by decomposing plant and animal residues (Greenland and Ford, 1964). It is relatively large in size compared to other soil organic matter components and insoluble in water. It contains organic material not recognizable as residue, but not yet highly decomposed. The LF may include micro-organisms and microfauna, but Ahmed and Oades (1984) suggested that total microbial biomass in the LF is insignificant.

The carbon-to-nitrogen (C:N) ratio in the LF is usually greater than C:N ratio for whole soil, indicating the significant influence of plant residues in this SOM pool (Greenland and Ford, 1964). The LF is also enriched in carbohydrates relative to whole soils (Oades, 1972). It has been suggested by Christensen (1992) that the proportion of LF in the SOM provides a better and earlier indication of the consequences of soil management than SOM levels in whole soils. Cultivation of virgin sites greatly reduced the SOM LF in Australia (Dalal and Mayer, 1987).

We hypothesize that SOM LF is likely to be affected by land use, tillage, and other factors such as burning and fallow, in the Pacific Northwest. The objectives of this investigation were to isolate SOM LF from the soil of several long-term experiments at the Pendleton Agricultural Research Center and evaluate the relationship of SOM LF to long-term management practices.

EXPERIMENTAL

Soil samples were collected from long term experiments located on the Columbia Basin Agricultural Research Center 10 miles northeast of Pendleton, OR. These experiments have a documented history of tillage, cultivar, seeding date, soil amendments and yield. In addition, many soil parameters, including nitrate, ammonia, pH, extractable phosphorus, carbon and total nitrogen, are determined at regular intervals. Rasmussen and Smiley (1994) recently published a comprehensive description of the plots.

Samples were taken from the following experiments:

Grass Pasture (GP) - Maintained as permanent pasture since 1931, it is periodically reseeded with introduced grass cultivars, and occasionally fertilized. It was grazed until 1985. It has not been grazed since, but it is clipped once or twice a year. The clippings remain in the field.

Residue Management (CR) - Established in 1931, it is the most comprehensive of the experiments. The rotation is winter wheat/fallow, the tillage is moldboard plow and residue is burned in the spring. Nitrogen fertilizer treatments (0 or 80 lbs. N per acre) are applied about 10 days before seeding.

No-Till (SF) - Started in 1982, then modified in 1983 and 1988, it was cropped annually in wheat from 1982 to 1988, then converted to winter wheat/fallow. Wheat stubble is flailed and left in the field. There is no tillage, except fertilization. We selected two of five N rates (0 and 80 lbs. N per acre) for sampling.

Soil samples were collected in eight inch increments (0-8 and 8-16 in.), air dried, crushed and sieved (9.0 mesh screen). Plant residues and rocks were removed from the sample by hand. Soil moisture content was determined on a subsample.

We isolated the LF by the method of Gregorich and Ellert (1993). A weighed portion of soil sample was transferred to a polypropylene centrifuge tube and sodium iodide (NaI) solution (density = 1.7 g/cm^3) was added. The tubes were placed on a reciprocating shaker at 275 rpm for one hour at room temperature (72°F). After shaking, soil on the cap and tube walls was washed into the tube with NaI solution. The tubes were centrifuged at 1000 x gravity for 15 minutes at 60°F. The NaI solution and the LF were separated by filtration. The supernatant, with the suspended LF, was decanted into a glass vacuum filtration apparatus and rinsed with a dilute solution of calcium chloride followed by distilled water. The LF was gently washed from the filter into an aluminum weigh boat using distilled water. The resulting slurry was dried at 140°F for 24 hours, or until dry, then weighed.

The soil was extracted a second time with another aliquot of NaI solution. The additional LF was collected by filtration as described above and added to the first LF isolated to give the total weight. Total C and N in the soil samples and in the extracted LF were determined by combustion in a Fisons CNS analyzer.

RESULTS AND DISCUSSION

The proportion of LF recovered from whole soils ranged from 0.04 percent in the CR soil (Table 1) to 0.61 percent in the GP soil. Light fraction isolated from an array of Australian soils ranged from 0.03 to 8.2 percent of the soil dry weight (Greenwood and Ford, 1964). Janzen (1987) found the LF to account for less than 0.4 percent of the soil weight in cultivated Canadian soils. In course, sandy German soils the LF made up 0.1 to 0.4 percent of the whole soil weight (Leuschner et al, 1981, reported by Christensen, 1992)

Table 1. Light fraction SOM in soil as affected by long-term crop management. Columbia Basin Agricultural Research Center, Pendleton. Soil samples taken 1994.

Depth (in)	Nitrogen (lbs/acre)	LF[1] (%)	C:N (LF)	C:N (whole soil)	N in LF[2] (%)	C in LF[3] (%)
Residue Management Experiment (CR) Soil						
0-8	0	0.05	12.3	12.3	1.56	2.57
8-16	0	0.04	9.0	9.7	1.14	1.92
0-8	80	0.07	12.7	12.4	3.90	6.80
8-16	80	0.06	9.7	9.4	0.95	6.67
NoTill Experiment (SF) Soil						
0-8	0	0.23	22.2	13.5	2.97	4.87
8-16	0	0.14	17.7	10.3	1.11	1.82
0-8	80	0.28	23.2	13.3	2.71	4.70
8-16	80	0.19	22.9	10.5	0.96	2.11
Grass Pasture Experiment (GP) Soil						
0-8	0	0.61	15.4	10.9	5.17	7.31
8-16	0	0.43	17.7	9.8	4.35	7.86

[1] Percent LF in whole soil.
[2] Percent N in LF to total N in whole soil.
[3] Percent C in LF to total C in whole soil.

Accumulation of LF is favored by continuous vegetation. Whitehead and coworkers (1975) reported LF amounts of 0.4 percent and 5.4 percent of the soil weight in cultivated and in permanent pasture soil respectively. Garwood et al (1972) found that a temperate grazed grassland was able to maintain twice as much LF as under arable tilled soils. In our study, LF concentration in the grass pasture soil is more than twice that of any cultivated soil (Table 1).

The amount of LF decreased with depth in all management practices. The LF also increased with N addition. Undoubtedly, this increase is because of increased plant growth, due to N fertilizer additions, and to increased residue production.

The C:N ratio in the LF ranged from almost 10 to slightly over 23 and was generally higher than in native soil (Table 1). Carbon to nitrogen ratios of LF isolated by Greenland and Ford (1964) ranged from 12 to 30. Plant residues greatly influence the C:N ratio which causes it to be greater than that found in whole soil. This may explain why C:N ratios in the CR experiment were relatively low. Wheat stubble in this experiment is burned which greatly reduces the amount of residue available for the formation of SOM. In summary, we found that the concentration of SOM LF is distinctly different between cropping systems and a key indicator of management practices that will improve soil quality. The main relationships were: (a) continuous grassland has greater LF accumulation than does cultivated soil; (b) no-till management results in greater LF accumulation than does plowing and burning; and (c) there is an inverse relationship between LF and soil depth and a positive relationship between LF and N fertilization.

ACKNOWLEDGMENTS

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MAJOR FACTORS INFLUENCING WHEAT YIELD IMPROVEMENT DURING THE LAST THIRTY YEARS

William A. Payne, Paul E. Rasmussen and Roger Goller

INTRODUCTION

Long-term experiments maintained at the Columbia Basin Agricultural Research Center provide invaluable information on historical trends in crop production, yield stability, sustainability of cropping systems, and crop response to climate. Analyses of historical data allow scientists to make predictions for the future, and to draw conclusions on the viability and soundness of various aspects of cropping systems.

We have begun analyses of thirty years' yield data from five long-term experiments. The purpose of this report is to present preliminary conclusions on major factors influencing wheat yield during the last thirty years, and to make tentative predictions on their future viability. The factors discussed in this report are new varieties, N fertilizer addition, fallowing to maintain yield stability in winter and spring wheat cropping systems, and precipitation.

MATERIALS AND METHODS

Yield and precipitation data were taken from five long-term experiments for the years 1967 to 1996. The experimental treatments selected for these analyses were:

1. Wheat/fallow rotation, using improved varieties and the old Kharkov variety from annual variety testing trials;
2. Wheat/fallow rotation, using modern winter wheat varieties with and without N fertilizer addition, from long-term crop residue trials;
3. Wheat/pea rotation, with N fertilizer addition;
4. Continuous winter wheat, with fertilizer addition;
5. Continuous spring wheat, with fertilizer addition; and

Wheat/fallow rotation with spring wheat and fertilizer addition.

Yield and precipitation data were plotted against time for all years. Simple linear regression was used to characterize long-term trends for yield and stability trends.

RESULTS AND DISCUSSION

Winter (Sep 1 - Mar 31) precipitation was highly variable from year to year (Figure 1).

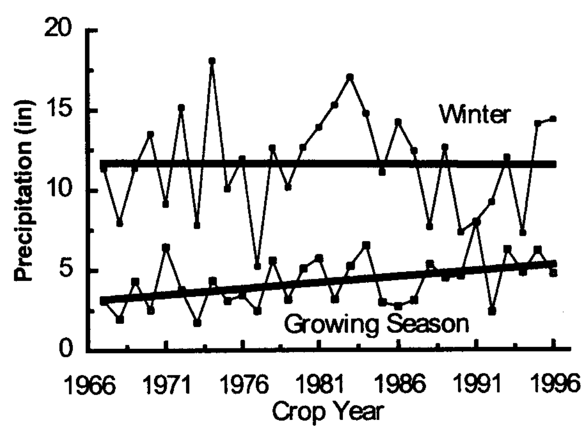


Figure 1. Winter (Sep 1 - Mar 31) and growing season (Apr 1 - Jun 30) precipitation at the Pendleton research center from 1967 to 1996.

There were successive wet years in the early eighties, and successive dry years in the early nineties, but there were no apparent long-term trends. More sophisticated analyses and larger data sets would be required to identify any periodic tendencies in winter rainfall patterns.

Growing season (Apr 1 - Jun 30) precipitation, on the other hand, has tended to increase slightly since 1967 (Figure 1), with an average increase of 0.07 inches per year. Whether this is a truly sustained trend or simply part of a short to medium term cycle would have profound consequences for cropping system strategies.

Yield data allow us to make qualitative inferences about the influence that improved varieties, fertilizer addition, fallowing, and precipitation have had on long-term yield trends in the different cropping systems.

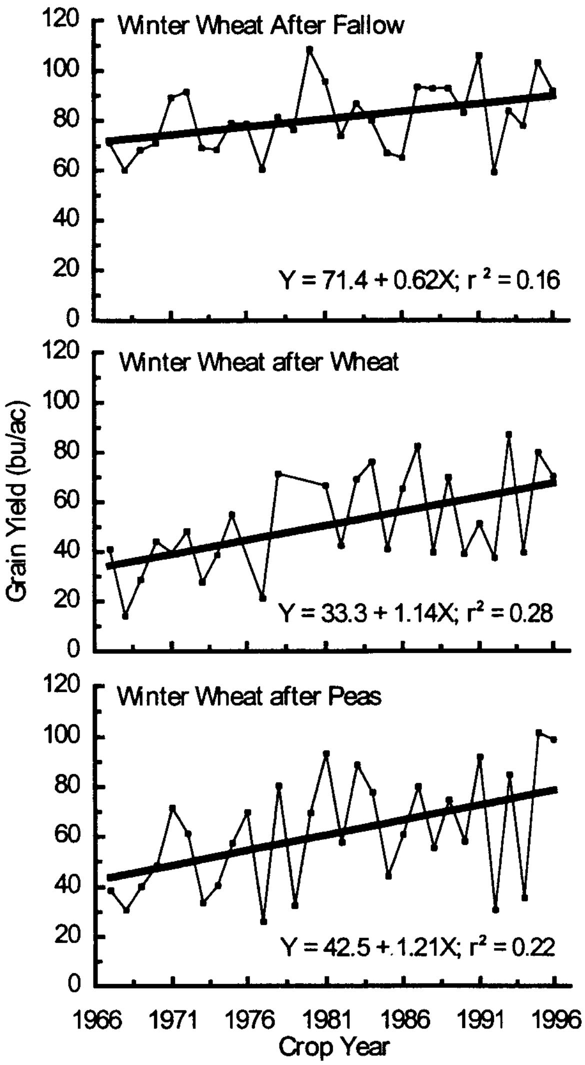


Figure 2. Long-term yield trends at the Pendleton research center from 1967 to 1996 for three N-fertilized winter wheat cropping systems.

Winter wheat yields in the wheat/fallow rotations were erratic, but generally increased during the 30 year period (Figure 2). This increase averaged more than 0.6 bushels per year for plots where improved varieties were grown with N fertilizer (Figure 3). Data from the annual variety trials suggest that part of this increase is dependent upon the use of

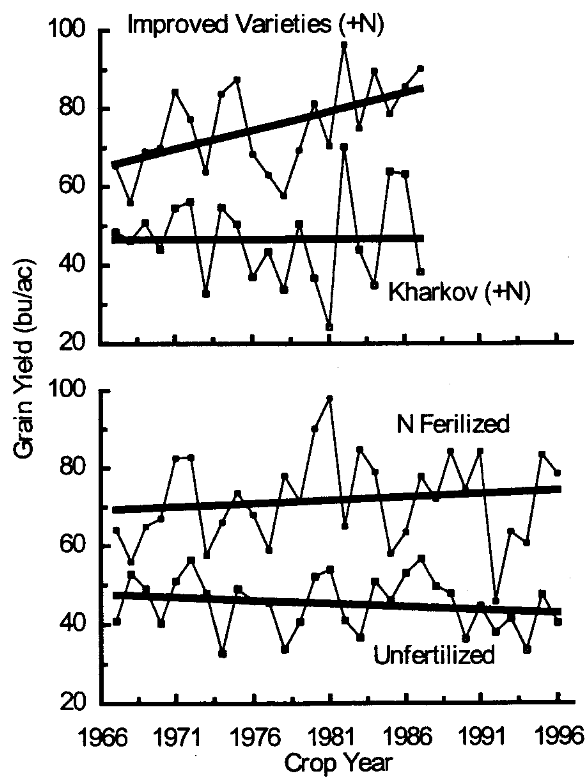


Figure 3. Long-term yield trends due to improved varieties and N fertilization at the Pendleton research station from 1967 to 1996.

improved varieties that have the ability to respond to favorable weather conditions. Average yield of the best varieties has gradually increased, whereas yield of the discontinued Kharkov variety has shown no increase despite generally increasing rainfall during the growing season (Figure 1).

The role of N fertilizer in increasing winter wheat yield can be clearly seen in Figure 3. Yields of unfertilized plots were remarkably stable (but low) compared to fertilized plots. Unfertilized plots have gradually declining yields, presumably due to depletion of soil fertility. This illustrates the importance of having sufficient soil fertility to allow the wheat crop to take full advantage of additional soil moisture in favorable rainfall years.

Winter wheat yields have also increased when grown annually or in rotation with peas (Figure 2). Average yearly yield increase is 1.2 bushels/acre in annual cropping compared to 0.6 for winter wheat following fallow. However, the data show clearly that annual cropping greatly decreased yield stability of winter wheat, because of the absence of fallow to stabilize crop water supply. For example, from 1994 to 1995, winter wheat yield varied from 30 to 100 bushels in the wheat/pea rotations, and from about 35 to 75 bushels in the continuous wheat plots, but only from 70 to 90 bushels in the wheat/fallow system. These data serve to point out why risk management must be a major consideration when annual cropping winter wheat.

Overall, the effect of fallowing upon stabilizing yield was less apparent for spring wheat when compared to annual cropping (Figure 4). There were, however, some very dry years, such as 1992, during which fallowing helped maintain yields compared to annual cropping. Spring wheat yield in both annual and fallowed systems has been steadily increasing over the past 30 years. The similar yield stability of annual spring wheat compared to wheat/fallow rotation, combined with the trend of yield gains, suggest that annual spring wheat is an increasingly attractive cropping system for growing conditions similar to ours. However, our analysis suggests that increased yield has been associated with increased growing season rainfall (Figure 1).

Under present rainfall patterns, spring cropping has the potential to compete more favorably with winter wheat than was the case 20 to 30 years ago. An added advantage of spring cropping is that it provides opportunities for better control of grassy weeds such as downy brome, wild oats, and goatgrass.

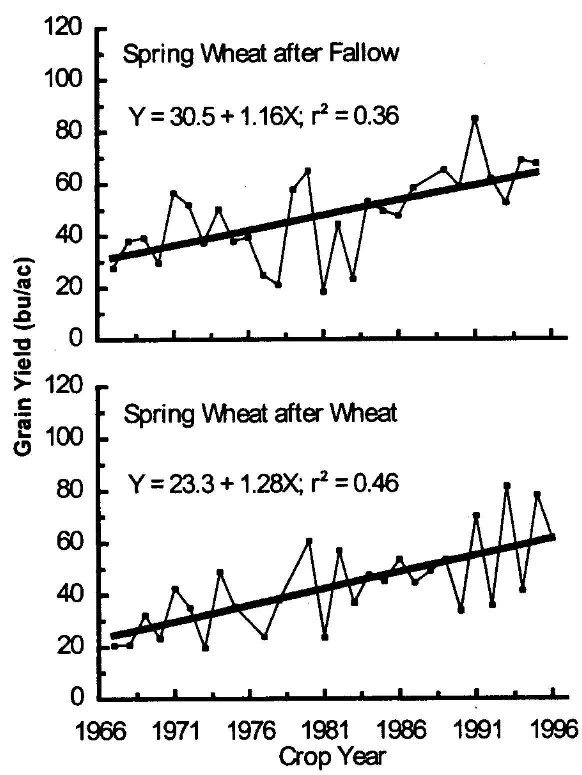
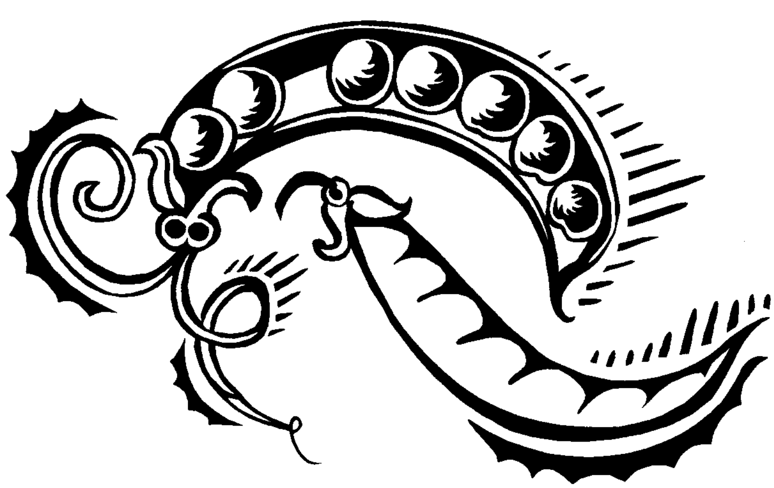


Figure 4. Long-term yield trends for two spring wheat cropping systems receiving adequate N-fertilizer additions at the Pendleton research center from 1967 to 1996.

A primary drawback to spring cropping, however, remains the difficulty of seeding large areas because of too few sufficiently dry days for cultivation, seeding, etc.

Obviously, a return to drier spring weather, such as was seen in 1992 or 1994, would render spring cropping much less attractive.



OREGON'S CLUB WHEAT PROGRAM THE NEXT STEP

Mike Moore, Karen Morrow,
Vicky Correa, and Warren Kronstad

Since the departure in 1994 of Dr. Pamela Zwer, the OSU club wheat breeder at the Columbia Basin Agricultural Research Center (CBARC), the program has gone through a transition. Efforts and obligations have continued relatively unchanged, however the breeding methods were modified to be more in keeping with the OSU common wheat breeding program directed by Dr. Warren Kronstad. An additional testing site was established at the Rugg farm northeast of Pendleton. Dr. Jim Anderson, USDA-ARS geneticist at Pullman, WA, assumed responsibility for the regional club wheat breeding efforts after he arrived during July, 1996. At that time, the Oregon and USDA-ARS programs were combined. The Oregon Wheat Commission continued to support the club wheat program through September, 1996. Federal funds were approved for the 1996-1997 USDA fiscal year.

Karen Morrow became coordinator of the OSU component of the program when Mike Moore and Vicki Correa resigned during the winter. Mrs. Morrow is supervised by Drs. Jim Anderson and Richard Smiley, Superintendent of CBARC. Karen Morrow utilizes seasonal labor as needed to perform all activities associated with the program. Current funding is by USDA-ARS and the Oregon Agricultural Experiment Station.

In the fall of 1996, Dr. Anderson planted all of the early generation germplasm previously produced by the OSU program. These materials were planted at Pullman to allow Dr. Anderson to closely monitor all plantings. Karen Morrow and her seasonal staff, at Pendleton, made club wheat crosses for the regional program. Screening for resistance to stripe rust and Russian wheat aphid, previous areas of emphasis for the OSU club wheat program at Pendleton, were tabled during 1996. Aphid testing was shifted to the University of Idaho.

In the continued search for club wheat varieties that are improvements over current lines, the club wheat program conducted trials on CBARC's stations at Pendleton and Moro, and at the Rugg site. In 1996, seeding conditions were excellent at each location, and weed competition was minimal. Excellent growing conditions produced high yields.

With moisture being exceptionally good for the year, nitrogen became an issue. Grain proteins in the trials on both stations were low, even with additional nitrogen applied in the spring at Pendleton. The Pendleton trials typically had proteins in the 7 to 8 percent range, and some as low as 6 percent. Protein at Moro was typically in the 6 to 7 percent range. Protein below 9 percent is an indication that the crop was under-fertilized; however such protein levels are satisfactory for club wheat.

Listed in the following tables are data for several promising club lines, including 92CL0049 and 92CL0054. These two lines were approved by a pre-release committee in 1995. Data to support a decision to release one or both lines are being compiled. Yield data from Pendleton are given for 1995 in Table 1 and for Pendleton and Moro for 1996 in Table 2. Data for Moro were not reported in Table 1 due to severe erosion and mixed stands resulting in unreliable information. Stephens and Rohde data are included as yield benchmarks for each trial. Lines in bold in Table 2 rank in the top ten for both Pendleton and Moro. The poor performance of 92CL0054 in the 1996 Pendleton trial was due to lodging. Generally regarded as tolerant to strawbreaker foot rot, further evaluation as to the reaction of this selection must be made. The CV for 92CL0054 was 23 percent in this trial, indicating a high degree of variability between the four replications of that line. Table 3 is a summary of yield data from the Rugg site grown in 1996. 92CL0049, with a yield of 128 bushels ranked number 1, with 92CL0054 yielding 108. Two other selections, 94CL0033 and 92CL0003 also provided high yields.

Tables 4 and 5 contain quality data for the same trials and years as Tables 1 and 2. Flour yield, mill score, and cake volume are the three major club wheat quality characteristics considered when looking at club wheat quality. Each entry is compared to Paha, the industry standard for club wheat quality. In all categories, the larger number is superior. Flour yield and mill score are important to the milling industry, and cake volume is important to the end product producer. Cake volumes at or above 1300 cubic centimeters are preferred.

Some lines do very well one year, but are mediocre the next for yield and quality. However, other lines do well across years and locations, i.e. 92CL0003, 92CL0006, and 93CL0080 in 1995 and 1996 for yield. 93CL0080 also looks good for quality both years, and appears promising.

Headrows were planted for all of the numbered lines in Table 1 in the fall of 1996. Efforts to purify 92CL0049, one of the lines approved by the OSU Pre-release Committee, are ongoing. Headrows planted in the fall of 1995 were from individual heads selected from purification blocks the previous crop. This is the normal protocol for such efforts, and by this stage the headrow population should be fairly uniform. This was not the case in 1996, as 20 percent of the rows were removed from purification blocks due to a common wheat contaminant that has been an issue throughout the testing and purification efforts for this line. It would appear that one of the parents is causing severe problems at the chromosome pairing stage, thus it may be impossible to achieve the desired uniform club type. Additional rows were removed for various and more subtle reasons as the season progressed. Heads were selected from the remaining rows and were seeded in the fall of 1996. 92CL0054 is the second line approved by the pre-release committee, has been purified and breeder's seed could be made available. Additional advanced lines are planted, in the event one of those is approved for pre-release.

The club wheat program staff also cooperate with Dr. Russ Karow, coordinator of the Statewide Cereal Testing Program. They manage five locations where fall and spring wheat, barley, and triticale are planted. Sites are located at the research stations at Pendleton, Moro, and Hermiston, and at Charlie Anderson's farm near Heppner and John Cutherbert's farm near La Grande. Dr. Karow's program provides the pre-packaged seed for planting. This program interacts with experiment station personnel and growers to coordinate field requirements, sowing and maintaining the plots throughout the growing season, and harvesting the trials. Data and discussion of the trials are presented at field days and county crops tours. The harvested material is returned to Dr. Karow for processing, statistical analysis, and summarization of the data.

This program also plants the Western Regional White Winter Wheat Nursery, coordinated by Dr. Jim Anderson. The purpose of this trial is to test potential new varieties in locations throughout the tri-state area. The Columbia Basin Ag Research Center is responsible for establishing these regional trials at the research stations at Pendleton and Moro.

These efforts were made possible with funds from the Oregon Wheat Commission and the support of the wheat farmers of Oregon.

Table 1. 1995 Pendleton Elite Yield Trials

Trial Name	ID Number or Variety	Pendleton Rank	Bushels per acre	Trial average bushels per acre
Club Elite 1			LSD 15.2	85.2
	93CL0080	1	110.3	
	92CL0049	2	108.1	
	92CL0006	5	104.1	
	Stephens	13	93.3	
	92CL0007	15	90.4	
	Rohde	16	88.7	
	92CL0054	17	88.5	
Club Elite 2			LSD 17.7	85.2
	93CL0012	10	91.6	
	Stephens	17	86.0	
	Rohde	31	76.5	
Club Elite 3			LSD 16.0	70.4
	92CL0003	3	92.4	
	Stephens	4	87.9	
	93CL0133	5	81.9	
	Rohde	21	61.4	

*Data for Moro not reported due to severe erosion and mixed stands resulting in unreliable information.

Table 2. 1996 Top Ten Lines for Moro and Pendleton Elite Yield Trials

ID Number or Variety	Moro Rank	Moro Bu/Acre		Pendleton Rank	Pendleton Bu/Acre	
93CL0132	1	82.7		14	79.1	
92CL0006	**2**	**80.9**		**3**	**92.1**	
Stephens	3	79.2		12	79.4	
93CL0196	4	78.4		33	65.0	
93CL0080	**5**	**78.3**		**2**	**94.3**	
94CL0100	6	77.9		40	60.2	
94CL0040	7	77.2		23	70.2	
94CL0104	8	76.8		11	79.9	
92CL0003	**9**	**76.7**		**4**	**90.4**	
94CL0033	**10**	**76.5**		**7**	**87.0**	
94CL0018	29	67.2		1	94.5	
94CL0025	37	65.9		5	89.0	
94CL0076	36	66.1		6	87.5	
92CL0049	20	70.4		8	86.8	
93CL0081	24	68.4		9	82.1	
93CL0094	15	72.5		10	79.9	
Rohde	26	67.9		37	61.7	
92CL0054	35	66.2		41	59.2	
92CL0007	18	71.3		18	75.1	
Trial average		68.3			68.5	
Trial maximum and minimum bushels/acre		High	Low		High	Low
		82.7	39.2		94.5	33.9

Table 3. 1996 Elite Lines located at the Rugg Site

ID Number or Variety	Rank	Bushels per acre
92CL0049	1	127.8
92CL0003	3	121.6
Stephens	5	117.5
92CL0006	6	114.4
93CL0080	7	113.5
92CL0054	9	108.2
Rohde	20	75.6

$LSD_{0.10} = 13.6$
C.V. = 13.7%

Table 4. 1995 Pendleton Club Wheat Quality Data

Trial Name	ID Number or Variety	Flour Yield[1]	Milling Score	Cake Volume[2]
Club Elite 1				
	92CL0006	74.1	87.9	1275
	92CL0007	71.9	83.1	1275
	92CL0049	73.1	84.1	1295
	92CL0054	77.5	90.8	1235
	93CL0080	74.9	85.8	1325
	Stephens	75.5	88.4	1265
	Rohde	74.1	84.2	1350
	Paha	76.1	87.3	1355
Club Elite 2				
	93CL0012	76.8	91.2	1310
	Stephens	75.6	89.2	1280
	Rohde	74.5	86.7	1225
	Paha	76.4	88.9	1340
Club Elite 3				
	92CL0003	73.3	85.2	1265
	93CL0133	75.9	88.4	1340
	Stephens	77.1	87.2	1235
	Rohde	74.8	84.1	1245
	Paha	76.8	85.7	1335

[1]Flour Yield is the percent of flour returned compared to whole grain that is milled.
[2]Cake volume is measured in cubic centimeters.

Table 5. 1996 Club Wheat Quality Data for Pendleton and Moro

Location	ID Number or Variety	Flour Yield[1]	Milling Score	Cake Volume[2]
Pendleton	92CL0003	69.3	89.6	1300
	92CL0006	67.5	88.1	1245
	92CL0007	68.5	88.1	1235
	93CL0012	66.3	87.7	270
	92CL0049	67.4	86.6	1265
	92CL0054	67.7	85.7	1295
	93CL0080	68.8	87.1	1350
	Stephens	66.5	83.5	1200
	Rohde	65.6	84.3	1250
	Paha	70.2	88.9	1315
Moro	92CL0003	68.8	85.8	1290
	92CL0006	69.2	88.2	1265
	92CL0007	67.5	86.7	1280
	93CL0012	65.3	85.2	1300
	92CL0049	67.9	84.1	1345
	92CL0054	68.3	85.2	1290
	93CL0080	69.1	87.3	1315
	Stephens	66.3	54.5	1290
	Rohde	65.6	51.1	1295
	Paha	69.4	85.9	1330

[1]Flour Yield is the percent of flour returned compared to whole grain that is milled.
[2]Cake volume is measured in cubic centimeters.

RHIZOCTONIA DISEASES AND THEIR MANAGEMENT IN CEREALS

Richard W. Smiley

INTRODUCTION

Rhizoctonia root rot has been one of the major impediments to the adoption of minimum- and no-till planting of wheat and barley in the Pacific Northwest and elsewhere. New information on the epidemiology of *Rhizoctonia* species affecting cereals has led to the development of management strategies with the potential to effectively control this disease.

Wheat and barley can be infected by several species of *Rhizoctonia,* including *R. solani*, *R. oryzae*, *R. zeae*, *R. cerealis*, *Rhizoctonia* (W-AK), and many "binucleate" types. The *Rhizoctonia* genus is highly variable. For example, the species *R. solani* is composed of more than a dozen sub-groups of closely related fungi that differ in many physical and behavioral characteristics including: temperature preference, species of plants attacked, types of plant tissue attacked, and regions of occurrence. Symptoms caused by species of *Rhizoctonia* include seed rot, preemergence damping-off, root rot, and foliar blight. Root rot usually has a greater impact on plant health than diseases of other plant tissues.

CAUSAL AGENTS AND SYMPTOMS

Root Diseases

Root diseases caused by *Rhizoctonia* species have been given names such as Rhizoctonia root rot, Rhizoctonia patch, bare patch, stunted patch, barley stunt, purple patch, and crater disease. Different names are used in different countries and regions. Rhizoctonia root rot and bare patch are names used in the Pacific Northwest.

R. *solani* AG-8 is generally considered the primary causal agent of root rot in the Pacific Northwest, South Australia, New South Wales (Australia), and the United Kingdom. *R. oryzae* can also cause significant damage in the Pacific Northwest. Species and groups that cause root rot of wheat and barley in other regions include *R. solani* AG-4 and AG-5 in Texas, *R. zeae* in Minnesota, and *Rhizoctonia* (W-AK) in Alaska. In West Australia the disease is caused by a complex of fungi composed of multiple types of *Rhizoctonia* spp., including *R. solani* AG-2-1, AG-2-2, and AG-8, other *Rhizoctonia* species, and other fungi. A complex of fungi, as opposed to a single pathogen, is thought to cause the bare patch phase of this disease. *Rhizoctonia* is considered a transient species in a rapidly evolving succession of root infecting and colonizing fungi. Australian scientists reported that combinations of fungi in the succession caused more severe root disease than the same fungi used singly. This complexity complicates our ability to manage this disease.

Severe root rot is characterized above ground by the development of circular patches of stunted and/or chlorotic plants that produce little or no grain. This is called the "bare patch" phase of Rhizoctonia root rot. When disease pressure is high, patches may coalesce to create uniform disease development across the entire field. Plants in these fields have uniformly poor vigor and density. Where this occurs the term

Rhizoctonia root rot seems most descriptive, because there are no bare patches to suggest that root disease may be causing the poor performance of the crop. Low disease pressure results in individual stunted plants interspersed within rows of productive plants, or minor root rot characterized by infections that do not cause stunting or other symptoms of reduced plant vigor. Moderate root damage can delay crop maturation up to three weeks without stunting plants.

Symptoms on roots depend on the type of *Rhizoctonia* attacking the roots. Infection by *R. solani* AG-8 results in the development of sunken brown lesions, and as growth of the fungus progresses, roots may be girdled and severed with the remaining root stub having a "spear-tip" appearance. This is most prevalent on crown (secondary) roots. Some isolates of *R. ozyzae* also cause these symptoms at high soil temperatures (>70°F), but at lower temperatures (<60°F) cause yellowing and necrosis (death) of the cortex (tissue between the root's vascular system and outer surface) without severing the vascular system. As such, *R. ozyzae* is most damaging to crown roots at high temperatures. *R. oryzae* and *R. cerealis* can also retard or prevent development of seminal (primary) roots and lateral branches off main roots, a phenomenon that is not caused by *R. solani* AG-8.

Damage to wheat and barley roots is often dependent on interactions among the specific fungal isolates and temperature. A distribution in disease severity, from none to severe, was observed for 19 isolates of *R. oryzae* tested separately on wheat seedlings at Pullman. Some isolates were more damaging at high temperature and others were equally damaging at all temperatures tested. Similar results were found with 21 isolates of *Rhizoctonia* (W-AK) on barley seedlings. Isolates of *R. solani* AG-8 were all pathogenic on wheat, and seedling stunting and root rot were usually more severe at lower than at higher temperatures. An Australian scientist found that the virulence of *R. solani* AG-8 was higher on barley than wheat. In the Pacific Northwest, root rot is more damaging to barley than to wheat in side-by-side plantings. Studies continue to demonstrate that relationships are complex between soil temperature and specific isolates of each species and group of *Rhizoctonia*.

Seed Rot, Seedling, and Stem Diseases

Seed rot and preemergence damping-off of wheat and barley are caused by *R. oryzae* and *R. cerealis*. Isolates of *R. cerealis* from wheat following bluegrass seed crops reduce wheat emergence as much as 40 percent in greenhouse experiments. In contrast, isolates of *R. solani* AG-4, AG-5, and AG-8, that cause severe root rot of cereals, do not affect seedling emergence.

Sharp eyespot, caused by *R. cerealis,* is characterized by development of circular to elliptical lesions on the leaf sheath near the base of wheat and barley stems. Symptoms are very similar to those by strawbreaker foot rot (also named "eyespot"), caused by *Pseudocercosporella herpotrichoides*. Sharp eyespot becomes more prevalent and recognizable as fungicides and resistant cultivars are introduced to control strawbreaker foot rot. Although sharp eyespot typically results in minimal yield loss, infections that extend through the stem tissue can result in blight of seedlings or lodging of mature plants. Severe damage from sharp eyespot has been observed on winter wheat following bluegrass harvested for sod in New York state.

R. cerealis can be particularly damaging when wheat follows grasses in a rotation. Winter wheat cultivars appear to differ in susceptibility to infection by *R. cerealis*, but reliable guidelines are not available.

MANAGEMENT OF ROOT ROT

Cultivation and Crop Residue Management

Rhizoctonia root rot of wheat and barley is usually more severe when the crop is sown directly into cereal stubble ("direct drill" or "no-till") than when planted into a seedbed prepared using conventional cultivation practices. Conventional primary tillage, either with a moldboard or chisel plow, has been the primary means used to control Rhizoctonia root rot of cereals. The incidence and severity of root infection is often inversely correlated with intensity and depth of cultivation. In Oregon, root rot on wheat after summer fallow increased with the amount of residue on the soil surface at the time of planting, and was reduced by burning wheat stubble before planting. Interestingly, root rot was unaffected by amounts of residue or tillage in a wheat-pea rotation that had a much higher microbial diversity and biomass than is present in wheat-summer fallow rotations.

Inoculum of *Rhizoctonia* in fields planted without tillage is concentrated in the upper four inches of the soil profile. Moldboard plows can bury the fungus propagules so the seedling wheat or barley roots do not encounter a high density of inoculum until the seedling has established an extensive root system. Burial of residue deeply and completely may be very beneficial for reducing root rot. Shallow or incomplete inversion of soil may be ineffective because some residue is placed in the zone where seedling roots from the next crop will contact the inoculum soon after the seed germinates.

Seed drills differ greatly in the amount of soil disturbance created during direct drilling. Increasing the depth and intensity of soil disturbance under the seed placement zone while drilling can increase wheat yields even in the absence of *Rhizoctonia.* However, disease can be particularly prevalent and damaging when root growth is inhibited by dense soil structure. Deep disturbance while planting appears to be as effective as pre-planting cultivations for reducing damage from Rhizoctonia root rot. It is now accepted that direct drilling with openers that disturb soil below the seed reduce damage from Rhizoctonia root rot and take-all. Similar benefits are achieved by installing either a chisel point or coulter in front of each drill opener to loosen soil and move infested residue away from the narrow zone where seedlings will establish.

Crop Rotation and Disease Decline

Isolates of *R. solani* pathogenic to wheat also infect crops such as peas, lentils, lupins, and canola. Despite the broad host range of these fungi, crop rotation is an effective means to reduce the incidence of root rot of wheat and barley. Reduced root rot in wheat-pea rotation, compared to wheat-fallow or wheat-canola rotations, is thought to occur in response to greater microbial biomass and/or diversity in the wheat-legume rotation, thereby limiting the inoculum potential of the pathogen. Although crop rotation may afford some protection against Rhizoctonia root rot by lowering the inoculum potential of the pathogen, rotation can only provide significant control of this disease when wheat or barley follows several years of plant-free fallow.

While rotations often reduce severity of Rhizoctonia root rot in short-term experiments, there is growing evidence that disease severity also declines under long-term cereal monoculture (e.g., annual cropping). A disease decline phenomenon for root rot caused by *R. solani* AG-8 was described at Pendleton. Similar observations have been made for take-all of annual spring- or fall-planted wheat and barley, and for *Rhizoctonia* diseases of sugarbeets or radishes grown continuously. Studies at two Umatilla County locations showed that productivity of barley in *Rhizoctonia*-infested soil increased with number of years of no-till management. When the annual no-till system was initiated there was a sharply defined initial increase in root rot severity and a concurrent decline in yield, followed by a return to "normality" as the numbers of years of annual cropping increased. Studies with continuous cropping elsewhere have shown that the decline in disease and increase in yield occurs when all plant residue is re-incorporated into the soil, but not when the residue has been removed, as by burning or straw removal. Suppression of Rhizoctonia root rot has been associated with an abundance of earthworms in some studies, and earthworms are known to be most active in conservation tillage systems.

Disease decline phenomenon appear to be associated with increased biological activity in the soil, resulting from annual inputs of organic matter from cereals. The factor responsible for suppressing the disease in long-term monocultures can be transferred from one soil to another by simply transferring small amounts of soil from the disease-suppressive soil (e.g., the monoculture) to the nonsuppressive soil (e.g., soils cropped as rotations). The suppressive activity is eliminated when soil is partially sterilized by pasteurization or irradiation, suggesting that the suppressive factor is associated with living soil microorganisms. As such, this is a biological control system for root diseases.

Management of Volunteer Cereals and Weeds

Volunteer cereals and grass weeds serve as hosts of *R. solani* between the harvesting of one crop and the planting of the next. Root rot in no-till wheat and barley is most severe if planting is within 3 days after herbicides have been applied. Application of glyphosate (Roundup®) or paraquat at least 2 or 3 weeks before planting greatly reduces the severity of Rhizoctonia root rot and increases the yield of no-till wheat and barley. Compared to an application three days before planting spring barley, yields have been improved up to 20 percent by spraying three weeks before planting, and up to 50 percent by spraying in the fall as well as the spring. The longer interval between herbicide application and planting apparently allows additional time for saprophytic microorganisms to displace *Rhizoctonia* in the dying roots of treated plants, resulting in lower inoculum levels of the pathogen. Similar benefits also occur with root diseases caused by other pathogens.

Damage from Rhizoctonia root rot has been amplified on wheat and barley in soils treated with pre-plant or post-emergence applications of sulfonylurea herbicides such as chlorsulfuron (Glean®). These herbicides can cause plant stress, which enables *R. solani* to cause greater damage to wheat and barley roots in treated soils.

Seed Treatment

Many chemical and biological seed treatments have been evaluated for controlling Rhizoctonia root rot. Triadimenol (Baytan®) is effective in controlling infection of wheat by *R. solani* AG-4 but not *R. solani* AG-8. Tolclofos-methyl (Rizolex®) and flutolanil (Moncut®) are toxic to *R. solani* AG-8 and *R. oryzae,* and reduce the incidence of Rhizoctonia root rot on winter wheat seedlings, but seldom improve grain yields. Difenoconazole (Dividend®) in combination with the biocontrol agents *Pseudomonas fluorescens* Pf-5; *Pseudomonas chlororaphis* 30-84, or *Bacillus* sp. L324 reduce damping-off and root rot of wheat seedlings caused by several *Rhizoctonia* species, but are more active against *R. oryzae* and *R. cerealis* than *R. solani* AG-8. Development of consistently effective seed treatments will be difficult due to the multiple species of *Rhizoctonia* capable of causing disease on cereals, the differential sensitivity of these pathogens to fungicides and antibiotics produced by biological control agents, and the prolonged period during which winter cereals remain susceptible to damage by *Rhizoctonia* species. Disease protection and positive yield responses to fungicide seed treatments are more prevalent for spring- than fall-planted cereals, presumably because protection remains higher over a longer proportion of the plant growth cycle for spring- than fall-planted cereals.

Plant Nutrition

There are numerous reports of plant growth responses to application of nitrogen fertilizer in *Rhizoctonia*-infested soils. Results have varied from suppression to no effect, or even increased damage. Inorganic sources such as ammonium nitrate have led to higher amounts of damage than from organic sources (pea vines or cow manure) in long-term (60-year) experiments at Pendleton. Elaborate evaluations of wheat responses to nitrogen in soils infested with *R. solani* AG-8 at other locations have led to the conclusion that nitrogen alone has no effect on root damage. Zinc deficiency in Australia reduces host resistance to *R. solani* AG-8 and increases damage to roots of wheat and barley, but this is not known to occur in the Pacific Northwest.

Strong advantages are usually achieved when balanced fertilizers are banded directly below the seed, and sometimes when mixed with the seed. The placed fertilizer is immediately available and improves seedling vigor much more than when fertilizer is broadcast or injected prior to planting. Banding a balanced starter fertilizer is particularly well suited for use with drills that loosen soil below the seed zone.

Host Plant Resistance or Tolerance

Wheat and barley cultivars tolerant to Rhizoctonia root rot are not available even though cultivars and breeding lines vary significantly in tolerance to root damage. For example, at both Pendleton and Moro, five of 216 lines yielded nearly as well in soil artificially inoculated with *R. solani* AG-8 as in adjacent plots where the pathogen had not been added. Unfortunately, development of cultivars with acceptable levels of tolerance is still impeded by high season-to-season and field-to-field variability.

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STATE-WIDE CEREAL VARIETY TESTING PROGRAM TRIALS

Russ Karow, Ernie Marx, Helle Ruddenklau, and Mike Moore

INTRODUCTION

This article reports results from cereal variety trials conducted in the Columbia Basin during 1996. These trials were conducted as part of a state-wide testing program initiated in 1992 to provide growers with local data on cereal variety performance. The program is coordinated by Russ Karow, OSU Extension Cereals Specialist, and Ernie Marx and Helle Ruddenklau, Dept. of Crop and Soil Science Research Assistants. Seed is packaged in Corvallis and distributed to trial coordinators across the state. Coordinators plant, manage and harvest trials, in some instances in cooperation with growers. Information on trial locations, coordinators and grower cooperators is given in Table 1. The Corvallis research team processes harvested grain, analyzes results and provides summary data to extension agents, seed dealers, field reps, and growers across the state and region.

Winter and spring barleys, triticales, and wheats of several market classes were tested at the 11 sites statewide, five in the Columbia Basin. Only Columbia Basin data are included in this report. Grain yield, test weight, protein, and lodging were determined for all varieties at all sites. Heading date, height, disease reactions, and other quality factors were determined as time, labor, and equipment allowed.

MATERIALS AND METHODS

Dryland plots (5 x 20 feet) at Heppner, Pendleton, and Moro were seeded at 20 seeds per square foot. Irrigated plots at LaGrande (5 x 20 feet), Hermiston (5 x 20 feet) and all other locations were seeded at 30 seeds per square foot. Seeding rates for dryland plots ranged from 46 to 114 pounds per acre, depending on variety, to attain the desired 20 seeds per square foot seeding rate. Irrigated plot seeding rates ranged from 69 to 171 pounds per acre. All trials were laid out as randomized complete block designs with three replications. Plots were seeded using small plot drills. Seeding, harvest and production practices were typical for each location.

Harvested grain was cleaned with a Pelz rub-bar cleaner. Plot yield, test weight, protein, and moisture were all determined on cleaned grain samples. Cleaned barley samples had few awns, hence test weights were atypically high, but variety to variety comparisons are valid. Yields are reported on a 10 percent moisture basis and in 60 pound bushels for wheats and triticales and in pounds per acre for barleys. Proteins are reported on a 12 percent moisture basis and were determined using a Tecator Infratec 1225 whole grain analyzer.

In addition to small-plot variety tests, large-scale winter wheat drill strip trials have been conducted across the state the last four years. Cooperating growers were provided with 50 to 80 pounds of seed of each variety to be tested. Seed for 1996 trials was donated by Eric and Marnie Anderson, Pendleton Grain Growers, and Corvallis Feed and Seed. 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. Table 2 lists sites, grower cooperators, and background information about 1996 winter wheat drill strip test plots.

RESULTS AND DISCUSSION

Small plot winter grain data are presented in Tables 3 through 6. Data from winter wheat drill strip plots are presented in Table 7. Data for spring grains are presented in Tables 8 through 11. Over-site averages are provided for dryland sites (Heppner, Moro, Pendleton). You will also find values labeled "percent of average" associated with most yield data. Percent of average data are generated by dividing a variety's yield by the trial average yield. A variety with a calculated value greater than 100 has performed better than average while a variety with a value less than 100 is below average. Calculating yield performance in this manner allows easy variety comparison across diverse environments and over years. Multi-year, percent of average yield data are presented in Tables 4 through 5 for winter grains and 9 through10 for spring grains.

Winter wheats and triticales Over the three year period 1994-1996 across three dryland locations, the soft white wheats Stephens, Madsen, Rod, and Gene exhibited the highest yield levels (Table 5). Celia, a winter triticale, had the highest overall average. Differences among varieties, however, are not statistically significant. The top yielding wheats differed by only one percent. The yield range for the 14 winter wheats and triticales shown in Table 5 is only 15 percent or roughly 9 bushels per acre. Given that the yield potential of these varieties appears to be similar, variety selection can be based on other criteria such as disease resistance, lodging potential, plant maturity, etc.

Average test weight was below 60 pounds per bushel at all sites except Hermiston (Table 6). Gene consistently had lower test weights than other soft white winter varieties. Otherwise, there were few differences between varieties within market classes.

Protein levels were low at Pendleton and extremely low at Moro indicating that plots may have been nitrogen deficient (Table 6). The LaGrande site has consistently had high protein levels in all years of testing.

Drill strip test data are presented in Table 7. Six varieties were included in the 1996 standard set - Gene, MacVicar, Madsen, Rod, Rohde, and Stephens. For the third consecutive year, Rod had the highest yield averaged across sites and was also the highest yielding variety at seven sites. Gene also performed well at many sites, especially those with high yield potential. Rohde club wheat has shown excellent yield potential across environments, even under high rainfall and irrigated conditions.

Winter barleys Winter barley data are shown in the bottom sections of Tables 3 and 5. Kold, Hesk, and Hundred had the highest yields. Kold outperformed Hesk and Hundred in terms of test weight (Table 6). Kold has resistance to barley stripe rust, which may be a consideration in variety selection. Steptoe, Hesk, and Scio, traditionally grown winter barleys, showed average performance. These results are consistent with trials in previous years (see

OSU Special Report 775, "Winter Cereals for 1997").

Spring wheats and triticales Spring grain data are presented in Tables 8 through 11. Alpowa (a Washington State University release intended to replace Penawawa), ID377S (a hard white released by University of Idaho breeder Ed Souza), and Penawawa were the highest yielding varieties across sites in 1996 (Table 8). Treasure, which has performed well in the past, performed poorly at Heppner and Moro in 1996. Seed supplies for Alpowa are increasing, but are still limited. In 1997, ID377S will only be grown in Idaho under contract with a growers cooperative specifically formed to manage production and marketing of this variety. Production throughout the Pacific Northwest is anticipated in 1998. Wawawai is a Wakanz replacement, both having Hessian fly resistance. Wawawai continues to perform well in the Pendleton area, but has been inconsistent at other sites. This variety should be considered for use where Hessian fly has been a problem.

Spring barleys Spring barley data are presented in Tables 8, 10 and 11. Baronesse, a two-row feed barley, continues to yield well across environments and years. Steptoe, with yields close to those of Baronesse, tends to have lower test weight and protein levels. BSR45, a barley stripe rust resistant line, is being released as "Icaro". Icaro was developed by Dr. Pat Hayes in cooperation with co-workers at ICARDA - the International Center for Agricultural Research in Dry Areas. Icaro performed well at LaGrande and Heppner, with better than average yield and test weight, and should be considered where barley stripe rust is a problem. Two hulless, waxy barleys (WPB-BZ4899-74 and Waxbar) were once again included in trials to get a better idea of hulless barley performance across environments. Percent of average yield for Waxbar was 65 percent across the five sites. WPB-BZ4899-74, grown at just two sites, yielded slightly better than Waxbar but still below trial averages.

Seed treatments Gaucho (imidacloprid), an insecticidal seed treatment for aphid and Hessian fly control, was evaluated in both winter and spring wheat trials. The active ingredient in Gaucho is different than that in currently used insect seed treatments and could play a valuable role in resistance management. It offers another alternative to growers who prefer using a seed or in-furrow treatment in place of sprays for insect control.

For winter wheat, Russian wheat aphid and aphid control to prevent barley yellow dwarf virus infestation are needed. Neither was a problem in 1996 plots and Gaucho did not improve winter grain yields. In spring trials, wheat yields increased slightly with the Gaucho treatment at all sites, but the increase was statistically significant only at Heppner. Gaucho will be evaluated again in 1997.

Baytan, a fungicidal seed treatment, was evaluated in winter and spring barley trials. Baytan differs from other seed treatments in that it helps suppress barley stripe rust and take-all. While stripe rust was detected at all sites in 1996, disease pressure was extremely low. In the winter trials, Hesk (6RF) was the treated variety. Baytan resulted in slightly increased yields at all five Columbia Basin sites, but the increase was statistically significant at only one site. In the spring trials, Steptoe (6RF) was treated with Baytan. Baytan treated seed resulted in increased yield at four of five sites, but the increase was statistically significant at only one site.

Dividend is a fungicidal treatment that controls dwarf bunt in wheat in addition to the diseases commonly controlled by other seed treatments. There was no dwarf bunt in any of the trials and no measured benefit to the Dividend treatment.

Raxil is similar to Vitavax with improved control of common bunt. Raxil treated wheat did not perform differently from other treatments in the Columbia Basin.

CONCLUSIONS

Data for 1996 once again show that there are few statistical differences among winter or spring grain varieties. Whether tested in small or large plots, newer varieties show a similar yield potential. It appears that factors such as available moisture, disease, and insect stress are capping yields in each environment, not the genetic yield potential of varieties *per se*. Our data suggest that growers should carefully assess those environmental factors that limit yield in each of their fields and grow newer varieties with tolerance or resistance to those stresses or to investigate other means of control. The yield potential is there; we need to allow for expression.

FOR MORE INFORMATION

Use more than one years data to make variety selection decisions. For more information, contact your local county office of the OSU Extension Service and ask for a copy of Special Report 755, "Winter Cereal Varieties for 1997," or Crop Science Report 105R, "Spring Grain Varieties for 1997." These publications contain current year and historic variety performance data for wheats, barleys, triticales, oats, and even cereal rye. Your county agent may have other data as well.

Variety trial data and other grain production information is posted on the OSU Cereals Extension Web Page (http://www.css.orst.edu/crops/cereals/home.htm). We expect the web page to become an important tool for supplying information to people in the grain industry. Please help us by telling us what information you would like to see posted.

The state-wide 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).

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Table 1. 1996 state-wide Oregon cereal variety testing program locations, site coordinators and grower cooperators.

Trial name	Trial type	Trial location	Trial coordinator	Grower cooperator
Corvallis	all grains - dryland	Hyslop Farm	Russ Karow, Helle Ruddenklau	
Morrow Co. (Heppner)	all grains - dryland	Anderson Farm	Mike Moore	Charlie Anderson
Hermiston	all grains - irrigated	Hermiston Expt. Station	Mike Moore	
Klamath Falls	all grains - irrigated	Klamath Expt. Station	Randy Dovel	
LaGrande	all grains - irrigated	Cuthbert Farm	Mike Moore	John Cuthbert
Madras	all grains - irrigated	Central OR Expt. Station	Steve James, Mylen Bohle	
Medford	all grains - dryland	Southern OR Expt. Station	Rich Roseberg	
Moro	all grains - dryland	Sherman Expt. Station	Mike Moore	
North Valley (Cornelius)	winter grains - dryland	Goetze Farm	Russ Karow, Helle Ruddenklau	Norm Goetze
North Valley (Sheridan)	spring grains - dryland	Moritz Farm	Russ Karow, Helle Ruddenklau	Sandy & Mike Moritz
Ontario	all grains - irrigated	Malheur Expt. Station	Clint Shock, Mike Barnum	
Pendleton	all grains - dryland	Pendleton Expt. Station	Mike Moore	

Table 2. Growers, locations, and cooperating county agents for 1996 winter wheat drill strip test plots in eastern Oregon and Washington.

Grower	City	County	Irrigation	County Agent
Mary Ann Hill	Pendleton	Umatilla	No	Mike Stoltz
Dean Nichols	Dayton, WA	Columbia, WA	No	Roland Sherman
Mark Hale	Pendleton	Umatilla	No	Mike Stoltz
Sandy Macnab/Erling Jacobsen	Moro Expt. Station	Sherman	No	Sandy Macnab
Gary Brown	Wasco	Sherman	No	Sandy Macnab
Bill Miller	Dufur	Wasco	No	Sandy Macnab
Larry and Chris Kaseberg	Wasco	Sherman	No	Sandy Macnab
John Rietmann	Ione	Morrow	No	Mike Stoltz
Alan Klages	Joseph	Wallowa	Yes	Gordon Cook
Ben Holdman	Pendleton	Umatilla	No	Mike Stoltz
Mike Weimer	Clem	Gilliam	No	- -
Art Buether	Kent	Sherman	No	Sandy Macnab
Russ Erickson	Condon	Gilliam	No	Mike Stoltz

Table 3. 1996 variety testing program winter grain yields across five Columbia Basin locations.

Variety/ line	Market class	Hermiston	LaGrande	Moro	Heppner	Pendleton	3 site* average	Hermiston	LaGrande	Moro	Heppner	Pendleton	3 site* average
Winter wheats and triticales		Yield (60 pound bu/a; 10% moisture)						Yield as a percent of trial average					
Daws	SW	97	33	64	46	79	63	101	93	95	88	99	94
Gene	SW	86	11	76	37	86	66	90	32	113	69	108	97
Hill 81	SW	104	79	65	54	86	68	108	220	97	101	107	102
Hiller	Club	93	20	75	58	89	74	96	57	112	110	112	111
Hyak	Club	69	24	74	54	88	72	71	68	111	102	110	107
Lewjain	SW	103	62	65	56	80	67	107	173	98	106	101	101
MacVicar	SW	95	34	74	38	72	61	98	96	110	72	90	91
Madsen	SW	93	51	70	57	81	69	97	143	104	107	101	104
Madsen+Stephens	SW	99	34	69	49	76	65	103	96	103	93	95	97
Malcolm	SW	93	39	67	33	66	55	96	109	100	63	83	82
Rely	Club	90	40	59	51	78	63	94	111	88	96	98	94
Rod	SW	108	63	79	57	89	75	112	177	118	108	112	113
Rohde	Club	94	19	67	55	71	64	98	53	100	105	88	98
Stephens	SW	100	36	76	46	75	65	104	99	113	86	94	98
Stn with Gaucho**	SW	97	36	77	45	76	66	100	102	114	85	95	98
Stn with Dividend**	SW	89	43	73	43	78	64	92	120	109	80	97	96
Stn with Raxil**	SW	90	35	82	43	76	67	93	98	122	80	96	99
W301	SW	91	38	69	42	75	62	94	105	103	79	93	92
Celia	Triticale	93	27	58	51	92	67	96	76	87	96	115	99
WA7752	Club	97	23	63	54	92	69	100	63	94	102	115	103
ID8614502b	SW	90	36	67	52	84	67	93	99	99	98	105	101
ID467	HR	86	36	59	49	84	64	89	100	88	93	105	95
OR929049-CLB	Club	92	24	61	43	82	62	95	67	91	82	103	92
OR92054-CLB	Club	68	16	61	55	70	62	71	44	91	104	87	94
RS87-123	Triticale	131		54	87	85	75	135		80	165	106	117
RS87-183	Triticale	123		56	80	71	69	127		83	151	89	108
RS87-202	Triticale	137		51	91	78	73	142		76	173	98	116
Trial average		97	36	67	53	80	67						
PLSD (5%)		18	10	12	10	10	NS						
PLSD (10%)		15	8	10	9	8	NS						
CV		12	17	11	12	8	16						
P-VALUE		0.00	0.0	0.00	0.00	0.00	0.94						
Winter barleys		Yield (lb/a; 10% moisture)						Yield as a percent of trial average					
Gwen	6RF	1478	3386	2994	5125	4185	4101	36	118	72	96	77	82
Hesk	6RF	4498	2605	4403	5849	5757	5336	110	90	105	109	106	107
Hesk with Baytan**	6RF	4649	2842	5389	6011	5851	5750	114	99	129	112	108	116
Hundred	6RF	3730	2112	4663	5007	5731	5134	91	73	111	94	106	104
Kold	6RF	5186	4153	4357	5470	5940	5255	127	144	104	102	110	105
Scio	6RF	4715	2599	4575	5180	5131	4962	115	90	109	97	95	100
Steptoe	6RF	3456	2080	3486	5226	4492	4401	85	72	83	98	83	88
Strider	6RF/M	4990	3272	3623	4928	6252	4934	122	114	87	92	115	98
Average		4088	2881	4186	5350	5417	4984						
PLSD (5%)		1012	930	1042	NS	502	845						
PLSD (10%)		831	764	855	NS	412	694						
CV		14	18	14	11	5	10						
P-value		0.00	0.00	0.00	0.01	0.00	0.02						

*Does not include Hermiston and LaGrande due to hail and frost damage, respectively.

** Gaucho is a seed treatment insecticide. Baytan, Dividend, and Raxil are a seed treatment fungicides.

Table 4. 1994-96 winter grain yields across four Columbia Basin locations.

Variety/ line	Market class	LaGrande	Moro	Heppner	Pendleton	3 site* average
		Yields expressed as percent of average				
1994						
Celia	Triticale	99	133	113	124	123
Daws	SW	104	100	87	103	97
Gene	SW	99	107	119	114	113
MacVicar	SW	102	98	114	109	107
Madsen	SW	112	98	107	102	102
Malcolm	SW	94	95	127	111	111
Rod	SW	109	123	100	91	105
Rohde	Club	106	129	95	102	108
Stephens	SW	97	105	128	116	116
W301	SW	100	108	123	117	116
Average yield (bu/a)		91	37	65	76	
1995						
Celia	Triticale	98	103	92	128	108
Daws	SW	120	107	104	96	103
Gene	SW	113	107	115	110	111
MacVicar	SW	93	93	78	101	91
Madsen	SW	88	102	128	111	114
Malcolm	SW	124	110	121	94	108
Rod	SW	104	111	109	90	104
Rohde	Club	99	104	107	83	98
Stephens	SW	90	108	109	114	110
W301	SW	104	104	112	104	107
Average yield (bu/a)		85	52	44	84	
1996						
Celia	Triticale	76	87	96	115	99
Daws	SW	93	95	88	99	94
Gene	SW	32	113	69	108	97
MacVicar	SW	96	110	72	90	91
Madsen	SW	143	104	107	101	104
Malcolm	SW	109	100	63	83	82
Rod	SW	177	118	108	112	113
Rohde	Club	53	100	105	88	98
Stephens	SW	99	113	86	94	98
W301	SW	105	103	79	93	92
Average yield (bu/a)		36	67	53	80	
1994-96						
Celia	Triticale	91	108	100	122	110
Daws	SW	106	101	93	99	98
Gene	SW	81	109	101	110	107
MacVicar	SW	97	100	88	100	96
Madsen	SW	114	101	114	105	107
Malcolm	SW	109	102	103	96	100
Rod	SW	130	117	106	98	107
Rohde	Club	86	111	102	91	101
Stephens	SW	95	108	108	108	108
W301	SW	103	105	105	105	105
1994-96 average yield (bu/a)		71	52	54	80	

*Averaged across Moro, Morrow and Pendleton locations.

Table 7. 1996 winter wheat variety drill strip trials across eastern Oregon and Washington locations.

Variety	Hill Pendleton	Nichols Dayton,WA	Hales Midway	Macnab Moro	Brown Wasco	Miller Dufur	Kaseberg Wasco	Rietmann Condon	Holdman Pendleton	Klages Joseph	Weimar Clem	Buether Kent	Ericksen Condon	Average
Gene	123	123	107	95	86	92	78	73	67	59	69	52	15	87
MacVicar	117	105	104	83	91	79	70		65	55	63	63		
Madsen	108	118	102	82	75	95	67	68	61	72	65	52	35	85
Rod	128	130	97	93	91	68	102	75	74	81	65	60	20	90
Rohde	104	100	94		64	63	61	63	70	48	56	58	20	
Stephens	115	116	107	86	85	68	67	72	59	61	61	56	16	82
Eltan		103												
Lambert		117												
Mac1	114	110	99						63	82				
Mix				96		92					63			
W301	116		103		73		95	72	64	48	63			
Average	116	115	102	88	82	77	74	70	66	63	63	57	21	86

A site at Lyle Peck's was lost to hail damage.

Macnab evaluated 10 two-way mixtures. The mix reported, Madsen-Gene, was the highest yielding.

The Miller mix is a Madsen-Rod combination. A Crew-Hyak mixture tested in the same trial yielded 95 bu/a.

The Weimar mix is a W301-MacVicar combination.

Table 5. 1994-96 winter grain yields across three Columbia Basin locations.

Variety	Market class	Moro	Heppner	Pendleton	3 site average
		Yields expressed as percent of average			
Winter wheats and triticales					
Daws	SW	101	93	99	98
Gene	SW	109	101	110	107
Hill 81	SW	97	101	105	101
Hyak	Club	106	96	106	103
Lewjain	SW	100	92	99	97
MacVicar	SW	100	88	100	96
Madsen	SW	101	114	105	107
Malcolm	SW	102	103	96	100
Rely	Club	99	92	95	95
Rod	SW	117	106	98	107
Rohde	Club	111	102	91	101
Stephens	SW	108	108	108	108
W301	SW	105	105	105	105
Celia	Triticale	108	100	122	110
1994-96 average yield (bu/a)		52	54	80	62
Winter barleys					2-site average
Gwen	6RF	—	97	86	92
Hesk	6RF	—	110	107	108
Hundred	6RF	—	103	115	109
Kold	6RF	—	106	118	112
Steptoe	6RF	—	95	94	94
1994-96 average yield (lb/a)		—	4222	4763	4532

Table 6. 1996 variety testing program winter grain test weight and protein data across five Columbia Basin locations

Variety/ line	Market class	Hermiston	LaGrande	Moro	Heppner	Pendleton	3 site* average	Hermiston	LaGrande	Moro	Heppner	Pendleton	3 site* average
Winter wheats and triticales		Test weight (lb/bu)						Protein percent (12% moisture)					
Daws	SW	63.5	60.7	59.1	60.1	60.1	59.8	11.3	14.3	6.1	8.2	7.6	7.3
Gene	SW	62.0	57.4	57.1	55.1	56.7	56.3	12.0	14.8	6.7	8.5	8.6	7.9
Hill 81	SW	63.7	62.2	58.1	59.4	59.9	59.1	11.6	13.5	6.7	8.7	8.0	7.8
Hiller	Club	61.2	58.0	56.4	58.2	56.8	57.1	11.1	14.6	6.1	9.9	7.3	7.7
Hyak	Club	62.0	58.6	56.5	58.1	58.7	57.8	12.0	15.0	6.5	11.2	7.2	8.3
Lewjain	SW	63.2	60.2	58.5	60.6	60.5	59.9	11.1	13.1	5.6	6.9	7.9	6.8
MacVicar	SW	63.1	59.5	58.7	57.8	58.6	58.3	11.2	13.1	6.3	8.6	8.2	7.7
Madsen	SW	63.0	60.9	57.8	59.7	60.3	59.3	12.1	14.5	6.1	10.1	8.7	8.3
Madsen+Stephens	SW	62.6	58.9	56.4	60.3	58.9	58.5	11.3	13.9	5.9	11.2	8.2	8.4
Malcolm	SW	62.9	60.1	59.4	58.9	59.3	59.2	11.4	13.2	6.2	8.6	7.6	7.5
Rely	Club	62.0	60.2	56.3	58.9	58.7	58.0	11.0	14.4	6.0	7.5	7.0	6.9
Rod	SW	61.2	60.5	58.4	59.9	59.7	59.4	10.6	13.1	6.0	7.9	7.4	7.1
Rohde	Club	63.2	58.0	56.7	60.5	60.0	59.0	11.8	14.3	6.5	7.7	7.5	7.2
Stephens	SW	62.4	59.7	57.9	58.9	58.6	58.5	11.5	14.2	7.1	8.3	8.0	7.8
Stn with Gaucho**	SW	62.9	58.8	57.8	59.1	58.2	58.3	11.1	14.0	7.1	8.9	8.0	8.0
Stn with Dividend**	SW	61.7	59.0	57.9	58.0	58.6	58.2	11.2	13.6	7.1	11.2	8.1	8.8
Stn with Raxil**	SW	62.4	59.2	58.2	57.7	58.4	58.1	11.5	13.9	7.7	12.1	8.5	9.4
W301	SW	63.2	59.4	57.7	59.5	58.5	58.6	11.4	13.8	6.3	9.9	8.7	8.3
Celia	Triticale	59.7	57.0	58.5	56.3	57.9	57.6	10.6	13.3	4.9	9.0	7.3	7.1
WA7752	Club	63.0	61.1	57.0	60.1	61.1	59.4	11.9	15.3	5.8	11.9	8.1	8.6
ID8614502b	SW	63.4	59.6	57.4	59.7	60.1	59.1	12.1	13.9	5.7	9.3	8.0	7.6
ID467	HR	63.0	60.3	58.8	60.7	60.2	59.9	11.4	14.1	6.4	10.7	7.8	8.3
OR929049-CLB	Club	60.8	58.4	56.9	59.3	57.5	57.9	10.2	12.7	5.1	10.5	7.7	7.7
OR92054-CLB	Club	62.9	60.6	56.4	60.0	59.1	58.5	12.7	15.0	5.8	7.7	7.6	7.0
RS87-123	Triticale	59.2		53.7	56.5	57.0	55.7	11.0		7.3	8.2	8.3	8.0
RS87-183	Triticale	58.8		54.5	55.9	56.9	55.8	11.1		7.4	8.3	8.4	8.0
RS87-202	Triticale	58.5		54.2	56.9	56.4	55.8	11.3		6.9	8.8	8.2	8.0
Trial average		62.1	59.5	57.3	58.8	58.8	58.3	11.4	14.0	6.3	9.2	7.9	7.8
PLSD (5%)		1.0	1.4	2.0	1.5	1.1	1.5	0.8	0.4	1.3	NS	0.8	NS
PLSD (10%)		0.9	1.2	1.7	1.3	0.9	1.2	0.7	0.3	1.1	2.6	0.6	NS
CV		1	1	2	2	1	2	4	2	13	21	6	11
P-VALUE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.01	0.06	0.00	0.11
Winter barleys		Test weight (lb/bu)						Protein percent (12% moisture)					
Gwen	6RF	41.2	38.3	53.2	54.4	53.4	53.7	10.7	12.4	7.0	8.8	9.3	8.4
Hesk	6RF	47.5	37.4	51.2	49.5	51.3	50.7	11.4	13.2	5.1	7.3	7.2	6.5
Hesk with Baytan**	6RF	47.2	35.3	51.2	48.3	51.1	50.2	11.3	12.9	5.5	8.4	8.1	7.3
Hundred	6RF	45.1	34.4	50.6	49.1	50.3	50.0	12.3	13.0	5.5	9.1	8.0	7.5
Kold	6RF	50.5	44.0	53.0	50.8	51.7	51.8	12.4	13.3	4.8	8.2	7.9	7.0
Scio	6RF	46.6	29.7	51.1	49.7	51.6	50.8	11.3	12.2	5.5	7.9	8.3	7.3
Steptoe	6RF	46.5	30.1	52.7	50.4	52.7	51.9	10.8	11.1	5.2	7.6	7.6	6.8
Strider	6RF/M	48.3	42.5	51.9	48.8	52.4	51.0	11.3	12.6	5.4	7.6	8.1	7.0
Average		46.6	36.5	51.9	50.1	51.8	51.3	11.4	12.6	5.5	8.1	8.1	7.2
PLSD (5%)		2.1	3.0	0.6	2.8	0.6	1.7	1.1	0.6	0.7	NS	0.6	0.6
PLSD (10%)		1.7	2.4	0.5	2.3	0.5	1.37	0.9	0.5	0.5	NS	0.5	0.5
CV		3	5	1	3	1	4	5	3	7	12	4	5
P-value		0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.36	0.00	0.00

*Does not include Hermiston and LaGrande due to hail and frost damage, respectively.

** Gaucho is a seed treatment insecticide. Baytan, Dividend, and Raxil are a seed treatment fungicides.

Table 8. 1996 variety testing program spring grain yields across five Columbia Basin locations.

Variety/ line	Market class	Hermiston	LaGrande	Moro	Heppner	Pendleton	3-site** average
Spring wheats and triticales		Yield (60 pound bu/a; 10% moisture)					
Alpowa	SW	68	84	54	30	39	41
Alpowa with Gaucho**	SW	83	84	55	44	45	48
Centennial	SW	77	56	47	29	34	36
Dirkwin	SW	77	88	44	23	34	
ID377S	HW	81	75	48	33	41	41
ID462	HR	83	65				
ID488	SW	87	67	51	26	45	40
Klasic	HW	74	23	47	22	43	37
OR4895181	HW	76	72	47	23	38	36
Penawawa	SW	84	67	54	32	39	42
Pomerelle	SW	81	80	44	23	43	37
RSI310	Triticale		105			37	
SDM405S	SW	77	75	50	26	34	37
Sunstar Promise	SW	76	68	51	24	38	38
Treasure	SW	84	95	37	17	40	31
Trical 2700	Triticale	78	87	37	20	37	31
WPB881	Durum		29		25	29	
WPB926R	HR	75	38	46	28	37	37
WPB936R	HR	72	60	49	28	43	
Wawawai	SW	80	61	50	22	43	38
Whitebird	SW	76	79	52	21	39	37
Yecora Rojo	HR	73	24	50	31	38	40
Trial average		78	67	48	26	39	38
PLSD (5%)		NS	14	10	8	NS	6
PLSD (10%)		NS	12	8	6	NS	5
CV		9	13	13	18	15	10
P-VALUE		0.21	0.00	0.03	0.00	0.13	0.00

Variety/ line	Market class	Hermiston	LaGrande	Moro	Heppner	Pendleton	3-site** average
Spring barleys		Yield (lb/a; 10% moisture)					
Baronesse	2RF	5443	4028	3700	1976	3523	3066
Bear (WA11045-87)	6R hulless	4001	2712	3019	1225	3080	2441
Colter	6RF	3802	5190	4029	1277	2615	2640
Crest	2RM	4349	3167	3359	1380	3264	2667
Galena	2RM	4685					
Icaro (BSR 45)	2RM		5463		2201		
Idagold	2RF	4110					
Maranna	6RF	4468	5645	3783	1329	3101	2738
Payette	6RF	3686	5435	3586	1407	2336	2443
Russell	6RM	3947	5440	3853	1983	2864	2900
Steptoe	6RF	4526	2774	3777	1661	3287	2908
Steptoe with Baytan*	6RF	4648	3960	4104	2099	2692	2965
WPB-BZ489-74	6R hulless			2878		2401	
Waxbar	6R hulless	3343	2758	2549	766	2062	1792
Trial average		4251	4234	3512	1573	2839	2641
PLSD (5%)		554	1463	600	412	828	546
PLSD (10%)		458	1210	496	341	685	451
CV		8	20	10	15	17	12
P-VALUE		0.00	0.00	0.00	0.00	0.03	0.01

* Gaucho is a seed treatment insecticide. Baytan is a seed treatment fungicide.

**Does not include Hermiston nor LaGrande (irrigated sites)

Variety/ line	Hermiston	LaGrande	Moro	Heppner	Pendleton	3-site** average
Spring wheats and triticales	Yield as a percent of trial average					
Alpowa	87	125	113	114	100	109
Alpowa with Gaucho**	106	125	115	168	115	133
Centennial	99	84	98	110	87	98
Dirkwin	99	131	91	88	87	89
ID377S	104	112	100	125	107	111
ID462	106	97				
ID488	112	99	106	97	115	106
Klasic	95	34	98	83	110	97
OR4895181	97	106	98	87	99	95
Penawawa	108	99	112	123	100	111
Pomerelle	104	119	92	86	111	96
RSI310		156			96	
SDM405S	99	111	105	99	89	98
Sunstar Promise	97	101	106	92	97	98
Treasure	108	142	76	66	103	82
Trical 2700	100	128	77	75	94	82
WPB881		43		95	74	
WPB926R	96	56	96	108	96	100
WPB936R	92	89	101	107	110	106
Wawawai	103	90	104	82	110	99
Whitebird	97	117	109	79	101	96
Yecora Rojo	94	35	104	119	97	107

Variety/ line	Hermiston	LaGrande	Moro	Heppner	Pendleton	3-site** average
Spring barleys	Yield as a percent of trial average					
Baronesse	128	95	105	126	124	118
Bear (WA11045-87)	94	64	86	78	108	91
Colter	89	123	115	81	92	96
Crest	102	75	96	88	115	99
Galena	110					
Icaro (BSR 45)		129		140		
Idagold	97					
Maranna	105	133	108	84	109	100
Payette	87	128	102	89	82	91
Russell	93	128	110	126	101	112
Steptoe	106	66	108	106	116	110
Steptoe with Baytan*	109	94	117	133	95	115
WPB-BZ489-74			82		85	
Waxbar	79	65	73	49	73	65

Table 9. 1994-96 spring grain yields across five Columbia Basin locations.

Variety	Market class	Hermiston*	LaGrande	Moro	Heppner	Pendleton	3-site** average
			Yields expressed as percent of average				
1994							
Alpowa	SW	117	122	107	104	108	106
Centennial	SW	126	97	115	77	91	94
Dirkwin	SW	97	91	90	15	44	50
ID 377S	HW	125	97	109	169	116	132
Klasic	HW	105	119	103	155	106	121
Penawawa	SW	92	88	102	36	76	71
Treasure	SW	118	100	106	108	87	100
Wawawai	SW	122	96	103	60	147	103
WPB926R	HR	105	95	109	160	152	140
Yecora Rojo	HR	99	131	121	163	89	125
Average yield (bu/a)		60	40	40	14	43	32
1995							
Alpowa	SW	–	112	98	115	120	111
Centennial	SW	–	106	104	109	97	103
Dirkwin	SW	–	109	101	114	93	102
ID377S	HW	–	114	103	113	109	108
Klasic	HW	–	89	96	110	69	92
Penawawa	SW	–	108	97	96	103	99
Treasure	SW	–	104	101	89	122	104
Wawawai	SW	–	125	101	109	115	108
WPB926R	HR	–	92	93	108	93	98
Yecora Rojo	HR	–	94	102	116	100	106
Average yield (bu/a)			55	51	35	56	47
1996							
Alpowa	SW	87	125	113	114	100	109
Centennial	SW	99	84	98	110	87	98
Dirkwin	SW	99	131	91	88	87	89
ID377S	HW	104	112	100	125	107	111
Klasic	HW	95	34	98	83	110	97
Penawawa	SW	108	99	112	123	100	111
Treasure	SW	100	142	76	66	103	82
Wawawai	SW	108	90	104	82	110	99
WPB926R	HR	96	56	96	108	96	100
Yecora Rojo	HR	94	35	104	119	97	107
Average yield (bu/a)		78	67	48	26	39	38
1994-96 average							
Alpowa	SW	–	120	106	111	109	109
Centennial	SW	–	95	105	98	92	99
Dirkwin	SW	–	110	94	72	74	80
ID377S	HW	–	107	104	136	111	117
Klasic	HW	–	81	99	116	95	103
Penawawa	SW	–	98	104	85	93	94
Treasure	SW	–	115	94	87	104	95
Wawawai	SW	–	104	103	84	124	103
WPB926R	HR	–	81	99	125	114	113
Yecora Rojo	HR	–	87	109	133	95	112
1994-96 average yield (bu/a)			54	46	25	46	39

* Hermiston trial lost to hail in 1995 and early varieties hail damaged in 1996.

**Does not include Hermiston nor LaGrande (irrigated sites)

Table 10. 1994-96 spring barley yields across five Columbia Basin locations.

Variety	Market class	Hermiston*	LaGrande	Moro	Heppner	Pendleton	3-site** average
			Yields expressed as percent of average				
1994							
Baronesse	2RM	109	102	100	138	110	116
Colter	6RF	106	100	102	75	99	92
Crest	2RM	102	112	92	108	95	98
Maranna	6RF	115	96	104	72	107	94
Russell	6RM	97	98	94	70	90	84
Steptoe	6RF	82	87	110	151	99	120
Average yield (lb/a)		6393	3707	3010	2124	4944	3359
1995							
Baronesse	2RF	--	115	120	114	114	116
Colter	6RF	--	100	108	98	118	108
Crest	2RM	--	104	104	98	103	102
Maranna	6RF	--	80	103	86	82	90
Russell	6RM	--	99	92	106	83	94
Steptoe	6RF	--	93	108	103	114	108
Average yield (lb/a)			3722	3490	2607	4456	3517
1996							
Baronesse	2RF	128	95	105	126	124	118
Colter	6RF	89	123	115	81	92	96
Crest	2RM	102	75	96	88	115	99
Maranna	6RF	105	133	108	84	109	100
Russell	6RM	93	128	110	126	101	112
Steptoe	6RF	106	66	108	106	116	110
Average yield (lb/a)		4251	4234	3512	1573	2839	2641
1994-96							
Baronesse	2RF	--	104	109	126	116	117
Colter	6RF	--	108	108	84	103	99
Crest	2RM	--	97	97	98	104	100
Maranna	6RF	--	103	105	81	99	95
Russell	6RM	--	108	98	101	91	97
Steptoe	6RF	--	82	108	120	109	113
1994-96 average yield (lb/a)			2647	2174	1232	2594	2000

* Hermiston site lost to hail in 1995 and early varieties hail damaged in 1996.

**Does not include Hermiston nor LaGrande (irrigated sites)

Table 11. 1996 variety testing program spring grain test weight and protein across five Columbia Basin locations.

Variety/ line	Market class	Test weight (lb/bu) Hermiston	LaGrande	Moro	Heppner	Pendleton	3-site** average	Protein percent (12% moisture) Hermiston	LaGrande	Moro	Heppner	Pendleton	3-site** average
Spring wheats and triticales													
Alpowa	SW	61.6	63.4	58.9	53.7	61.1	57.9	11.0	13.5	10.9	13.5	9.0	11.1
Alpowa with Gaucho*	SW	60.7	63.1	58.9	55.0	60.8	58.2	11.3	13.3	10.5	12.9	9.7	11.0
Centennial	SW	62.3	62.5	56.9	54.0	60.5	57.1	11.6	13.7	11.8	13.4	10.0	11.7
Dirkwin	SW	58.4	56.4	52.5	47.8	56.3	52.2	11.2	12.2	11.8	13.9	10.7	12.1
ID377S	HW	63.0	61.8	56.9	53.7	62.6	57.7	11.9	14.8	12.6	14.1	10.7	12.5
ID462	HR	63.1	60.9					12.4	14.5				
ID488	SW	62.3	62.4	56.3	51.5	60.9	56.2	10.8	13.0	10.9	13.7	8.7	11.1
Klasic	HW	65.4	60.4	58.5	55.0	63.4	59.0	11.8	16.2	12.5	14.3	10.6	12.5
OR4895181	HW	60.1	59.5	55.9	49.4	59.0	54.8	12.8	14.0	12.3	14.3	10.7	12.4
Penawawa	SW	62.4	61.4	58.3	54.1	61.1	57.8	11.1	14.1	11.6	13.5	9.2	11.4
Pomerelle	SW	60.9	57.7	54.9	50.1	60.3	55.1	11.4	12.5	12.1	13.9	9.5	11.8
RSI310	Triticale		55.6			54.5			11.4			9.0	
SDM405S	SW	62.5	62.6	58.9	53.7	61.2	57.9	11.1	12.7	11.2	13.8	9.9	11.6
Sunstar Promise	SW	62.6	62.2	59.9	52.8	61.1	57.9	10.7	12.5	10.7	13.8	9.5	11.3
Treasure	SW	58.8	60.7	46.4	49.4	60.5	52.1	11.0	12.4	12.7	15.0	9.2	12.3
Trical 2700	Triticale	50.2	51.2	47.2	42.5	53.1	47.6	11.5	11.7	11.2	13.7	8.9	11.3
WPB881	Durum		59.7		54.0	60.8			15.2		15.0	12.5	
WPB926R	HR	61.3	59.4	58.8	53.3	61.9	58.0	13.1	15.2	13.0	14.7	10.9	12.9
WPB936R	HR	62.5	61.3	58.3	53.4	62.8	58.2	13.3	14.1	12.0	14.3	10.5	12.3
Wawawai	SW	61.5	61.9	56.5	50.2	62.0	56.2	11.5	13.5	11.1	14.5	9.7	11.8
Whitebird	SW	62.6	61.4	58.0	51.2	60.7	56.6	11.3	12.4	11.1	14.2	9.6	11.6
Yecora Rojo	HR	64.3	60.8	60.3	56.4	63.3	60.0	12.6	16.1	12.7	14.4	10.6	12.6
Average		61.3	60.3	56.4	52.1	60.4	56.3	11.7	13.6	11.7	14.0	9.9	11.9
PLSD (5%)		2.0	1.8	6.6	3.2	1.0	2.6	0.8	0.5	0.7	NS	0.7	0.7
PLSD (10%)		1.7	1.5	5.5	2.6	0.8	2.2	0.7	0.4	0.6	NS	0.6	0.6
CV		2	2	7	4	1	3	4	2	4	7	4	4
P-VALUE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00
Spring barleys													
Baronesse	2RF	55.6	52.3	55.1	49.4	54.1	52.9	9.4	13.6	10.9	12.5	9.2	10.9
Bear (WA11045-87)	6R hulless	58.8	56.9	52.6	54.0	57.5	54.7	10.5	15.2	11.3	13.4	9.2	11.3
Colter	6RF	52.6	52.8	51.9	42.8	52.5	49.1	8.6	11.1	9.4	12.2	8.3	10.0
Crest	2RM	55.1	52.5	50.3	46.0	54.1	50.1	9.9	14.0	9.9	12.8	8.9	10.5
Galena	2RM	54.9						9.4					
Icaro (BSR 45)	2RM		54.1		52.0				13.1		13.0		
Idagold	2RF	53.4						9.8					
Maranna	6RF	51.8	51.2	50.3	41.3	52.7	48.1	8.9	13.4	10.5	14.7	9.3	11.5
Payette	6RF	53.2	52.4	52.6	42.4	52.5	49.2	9.9	13.5	10.4	13.8	9.0	11.1
Russell	6RM	53.5	53.0	52.9	46.6	54.0	51.2	9.3	12.0	9.2	11.3	8.8	9.8
Steptoe	6RF	51.6	45.1	48.3	42.6	55.6	48.8	9.3	12.9	9.3	12.2	9.7	10.4
Steptoe with Baytan*	6RF	51.4	46.6	50.3	40.9	52.4	47.9	9.1	12.4	9.0	12.0	9.1	10.0
WPB-BZ489-74	6R hulless			59.0		58.3				12.7		10.6	
Waxbar	6R hulless	58.2	56.3	53.8	42.7	55.9	50.8	10.0	17.2	12.2	16.3	10.4	13.0
Average		54.2	52.1	52.5	45.5	54.5	50.8	9.5	13.5	10.4	13.1	9.3	10.9
PLSD (5%)		1.1	2.2	3.1	3.7	NS		0.7	1.0	1.1	1.5	NS	
PLSD (10%)		0.9	1.8	2.6	3.0	NS		0.6	0.8	0.9	1.3	NS	
CV		1	3	4	5	6		4	4	6	7	14	
P-VALUE		0.00	0.00	0.00	0.00	0.40		0.00	0.00	0.00	0.00	0.64	

* Gaucho is a seed treatment insecticide. Baytan is a seed treatment fungicide.

**Does not include Hermiston nor LaGrande (irrigated sites)

WINTER EROSION IN FOUR RESIDUE MANAGEMENT SYSTEMS: PRELIMINARY REPORT

J.D. Williams, D.E.Wilkins,
C.L. Douglas Jr., and R.W. Rickman.

INTRODUCTION

About 86 percent of the erosion in the dryland cropping areas of the Pacific Northwest occurs during low intensity rainfall on frozen soil, snow melt on frozen soil, or rain and snowmelt on frozen soil (Zuzel et al. 1982). Soil loss is greatest from the approximately 4.5 million acres (Smiley 1991, McCool et al. 1993) that are planted to winter wheat following summer fallow. Soil loss from the more erodible of these fields will range from 10 to 150 t yr^{-1}.

Although rills produce an estimated 90 percent of the eroded material (Zuzel et al. 1993), erosion begins as sheet flow, unconcentrated flow across the soil surface, before flow concentrates to form rills. A number of factors reduce or nearly eliminate sheet erosion. In fallowed fields, a roughly plowed soil surface produces many detention dams to store water from small impermeable runoff areas and provides open pathways to subsurface soil that is not frozen. Alternatively, residue stubble can be left standing to provide residue cover and intact root structure. In fall planted winter wheat, cover provided by either residue or green crops reduces the soil erosion by raindrop splash and sheet flow. Zuzel and Pikul (1993) suggest that less than 25 percent cover is ineffective for erosion control.

Obtaining 30 percent cover with moldboard plowing and two to three tillage operations is not always possible. Residue must be managed not only to provide erosion control, but to overcome equipment limitations, assure disease and weed control, and improve seedbed preparation. Residue can be in excess of 15,000 lb ac^{-1} in fields with 90 to 150 bu ac^{-1} wheat yield. These residue levels are generally incorporated completely with a moldboard plow or burned, which leaves little or no cover residue. Chisel plowing in these levels of residue often results in a combination of weed, disease, equipment, and seedbed preparation problems.

We developed a mow-plow residue management system to solve heavy residue, weed, and seedbed preparation problems. We mounted a harvester-header on the front of a tractor to cut and sidecast residue onto adjacent moldboard plowed surface. The moldboard plow was pulled with the same tractor. Thus, each circuit of the field placed residue on the previous moldboard pass. Some residue was incorporated into soil by subsequent rodweeding and seed drill disturbance. Header height can be adjusted to vary the amount of residue turned under by the moldboard plow. Research conducted to date (Wilkins, unpublished data) suggests this system does not increase soil-borne disease problems and provides effective weed control.

We conducted this research to determine the soil and water conservation effectiveness of the mow-plow system relative to moldboard and chisel plowing.

METHODS

Duff (3D) Ranch and Reeder Farms provided plot sites for this research approximately 10 miles north of Pendleton and within agronomic zone 3 (Douglas et al. 1990). The analysis of data reported here is preliminary.

We simulated rainfall using a newly developed rainfall simulator to mimic rainfall on frozen soil (Williams et al. 1996). Rainfall was simulated during warming periods following periods sufficiently cold to freeze the soil 6 - 18 in. deep in January and February of 1996 and 1997. Rainfall intensity was 0.32 in. hr^{-1} and maintained for 90 minutes after runoff began. We simultaneously simulated rainfall onto four residue tillage treatments in individual plots. The treatments were:

(1.) chisel plow,
(2.) moldboard plow,
(3.) mow-plow low residue (l), and
(4.) mow-plow high residue (h).

Residue levels after primary tillage were 1,880 lb. ac^{-1} for the mow-plow (l) at and 5,440 lb. ac^{-1} for the mow-plow (h) treatments. Residue rates represent the amount of residue needed for 30 percent cover after secondary tillage, fertilizing, and seeding and all the residue from fallowed stubble, respectively.

We measured residue and plant cover, depth of frozen soil, time to ponding, time to runoff, and runoff amounts every 10 minutes for 90 minutes after runoff began. We collected runoff in 1 liter bottles in 10 minute intervals and weighed, dried, and reweighed the bottles to determine both runoff rate and soil loss. We calculated erosion rates by regressing accumulated ten minute increment soil loss against time.

RESULTS

Runoff rates did not differ significantly between treatments. Small rills developed in each of the treatments, but were not quantified. Erosion rates differed between dates and treatments. For example, soil erosion averaged across treatments was 1,550 lb. ac^{-1} and 470 lb. ac^{-1} with no snow or 1 inch snow, respectively. A general pattern emerges the average of two days erosion rates onto bare soil (Figures 1 & 2). The most effective erosion control treatment was the chisel plow, followed closely by the mow-plow (h). The mow-plow (l) treatment was not distinguishable from either high residue treatments or the moldboard plow treatment. The erosion rate in the moldboard plow treatment was significantly greater than either of the high residue treatments at the end of one hour.

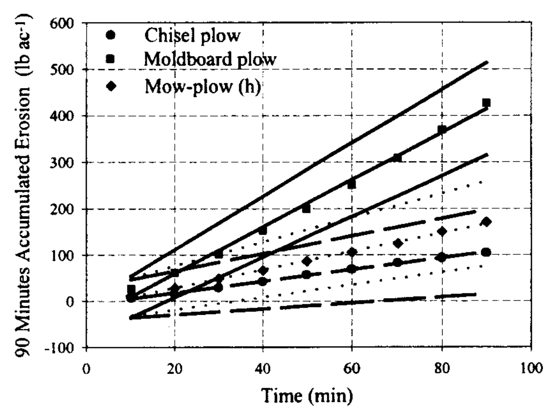

Fig. 1. Relationship of moldboard plow, mow-plow (h), and chisel plow erosion rates from eroded material accumulated for 90 minutes after runoff began. Means of two simulations and confidence intervals (95 percent) shown for fitted relationship.

DISCUSSION

The mow-plow system provides an alternative to chisel plowing for leaving surface residue cover. It also provides the opportunity to examine, in the following discussion, the differences in erosion protection provided by anchored residue, crown, and root material versus residue left on the surface. Moldboard and chisel plowing represent the two extremes of residue cover for cover and erosion (Fig. 3).

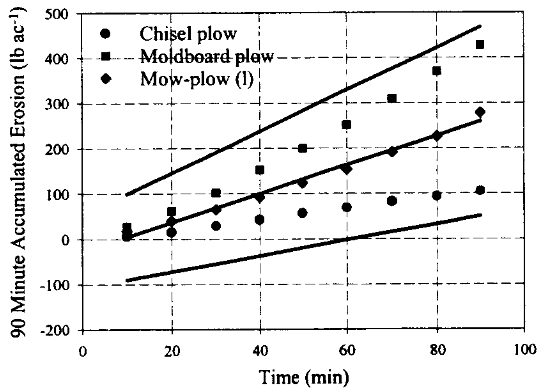

Fig. 2. Relationship of moldboard plow, mow-plow (l), and chisel plow erosion rates from eroded material accumulated for 90 minutes after runoff began. Means of two simulations and confidence intervals (95 percent) shown for fitted relationship of mow-plow (l) demonstrating variability of low residue application.

Mow-plow cover erosion values fall between these extremes. High variability in the mow-plow (l) treatment suggests that sparse residue cover alone might not provide adequate erosion protection, because of either insufficient surface residue or lack of residue incorporation. In the mow-plow (h), nearly half of the applied residue was incorporated in the soil surface by subsequent tillage. Erosion in the mow-plow (h) treatment was 40 percent of that for the moldboard treatment, but nearly double that of the chisel plow.

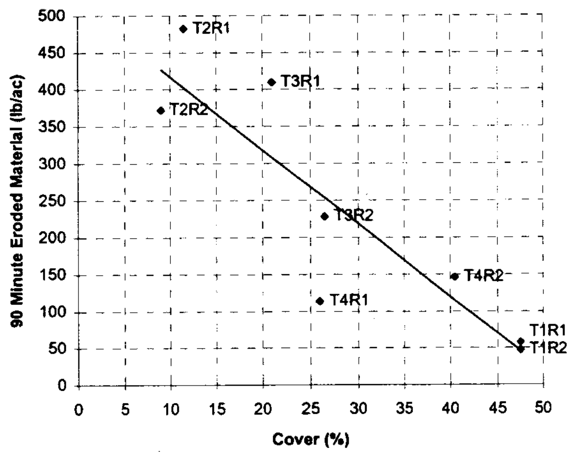

Fig. 3. Total eroded material from two runs versus residue cover. Treatment designations are: Chisel plow (T1), moldboard plow (T2), mow-plow (l) (T3), and mow-plow (h) (T4).

CONCLUSION

The mow-plow system did not influence infiltration rates. A light application of residue using the mow-plow system had no apparent influence on soil erodibility. A heavy application of residue significantly lowered the rate of erosion relative to the moldboard plowing. We demonstrated the importance of incorporated residue by comparison of the two mow-plow treatments with the chisel plow. Considering the relative erosion responses by the mow-plow (l) and (h) treatments, incorporating residue might be as important as surface cover alone. The presence of the root and crown structure in the chisel plow treatment appears to contribute additional protection against soil erosion. This research is preliminary in that it dealt with the onset of a thaw event producing only raindrop and sheet erosion. Additional research is required to determine effectiveness of the mow-plow system through an entire thawing event with rill development.

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WINTER WHEAT RESPONSE TO NITROGEN, SULFUR, PHOSPHORUS, AND MICRONUTRIENTS

Paul E. Rasmussen and Roger H. Goller

INTRODUCTION

Winter wheat responds readily to fertilizer application throughout much of the Pacific Northwest dryland cereal production area. But fertilizer response and recommended rates of application are strongly affected by adequacy of moisture, crop rotation, landscape position, the rate of other elements applied, and past fertilizer practices (Leggett, 1959; Rasmussen and Rohde, 1991; Fiez et al., 1994).

Nitrogen (N) normally dominates fertilizer needs, and because of its almost universal response has received the most attention. It is perceived as the element where the rate is most accurately established, but this is an erroneous perception because of significant effects of drought stress on crop yield and N response (Rasmussen and Rohde, 1991). Available phosphorus (P) levels are normally adequate for dryland cereals, but responses are becoming more frequent as yields increase, tillage decreases, and portions of the landscape become eroded (Pan and Hopkins, 1991; Rasmussen and Douglas, 1992). The decision to apply P generally depends on type of tillage and expected yield (Rasmussen and Douglas, 1992). Sulfur (S) is frequently applied, often to ensure against deficiency because diagnostic criteria for its need are not highly accurate. Sulfur is generally applied in relation to the rate of N applied. The need for micronutrients in dryland cereals is not well established, and they are infrequently applied to ensure against deficiency.

We conducted this experiment to evaluate fertilizer response across the major climatic zones, evaluate the soil contribution to N needs, and investigate yearly effects on nutrient response. The 1992 crop-year had low spring rainfall and substantial drought, while the 1993 crop-year had abundant spring rainfall.

MATERIALS AND METHODS

A series of fertilizer experiments was set out in 1992 and 1993 in four climatic zones. Different sites were selected in each zone each year. Fertility treatments consisted of rates of N from 0 to 129 lbs/acre (0 to 111 at wheat/fallow sites in 1992), and included comparisons to measure P, S, and micronutrient response (Table 1).

Table 1. Fertilizer treatments applied to eight experiment sites. Umatilla county, Oregon 1992-1993.

Treatment	Nutrient Applied			
Number	N†	P	S	Micromix‡
	lbs/acre			
1	0	0	0	No
2	43	4	6	No
3	86	8	12	No
4	129	12	18	No
5	86	0	12	No
6	86	8	0	No
7	86	8	12	Yes

† N rates for wheat/fallow sites in 1992 were 0, 37, 74, and 111 lb/acre.

‡ Micromix (Zn, Mg, Mn, Fe, Cu, B, Mo, Co); spring foliar spray ; 2 qt/acre of Bushel Builder (McGregor Co.)

The experimental design consisted of a randomized block with three replications. Individual plots were 10 by 100 feet.

Experiments spanned average rainfall amounts and rotations ranging from 10-inch winter wheat/fallow to 19-inch winter wheat/spring pea (Table 2). One of eight sites (the 1993 19-inch wheat/fallow) contained elevated levels of residual N similar to that found in some annual cropping systems in the Palouse (Sowers et al., 1994).

Sites were located on gentle backslope landscape positions, with slope ranging from 1 to 9 percent. All sites had been routinely fertilized with N for many years. All sites had a history of S fertilization, but only the wheat/pea rotation sites had a history of P fertilization. Only the 1992 wheat/pea site had a Zn application within the previous four years. Sites generally had moderate levels of available P and S and low levels of available Zn in the upper 8 inches of soil, based on Oregon soil test guidelines (Marx et al., 1996).

Table 2. Climate, soil, and agronomic data for eight experiment sites. Umatilla county, Oregon 1992-1993.

		Rainfall and Crop Rotation†			
Component	Year	10WF	13WF	16WF	19WP
Soil series		Shano	Walla Walla		Athena
Soil organic matter (%)		0.9	1.1	2.1	2.7
Spring (April-May-June) rainfall (inches)	1992	2.8	2.6	2.4	3.2
	1993	3.3	6.3	7.8	10.3
Available N at seeding (lb/ac)	1992	66	90	-	80
	1993	62	78	84	156
Soil pH	1992	6.8	6.1	6.5	5.9
	1993	6.9	6.3	6.1	6.0
Soil test P (ppm)	1992	16	22	14	23
	1993	20	15	21	23
Soil test S (ppm)	1992	3.1	3.8	3.3	3.7
	1993	4.1	2.0	2.3	4.8
Soil test Zn (ppm)	1992	0.5	0.7	0.6	1.1
	1993	0.6	0.7	0.6	0.8

† Rainfall: average in inches/year; Crop rotation: WF = Wheat/Fallow, WP = Wheat/Pea.
Soil test pH, P, S, and Zn for 0-8 inch depth; Soil tests by Agricheck, Inc., Umatilla, OR.

Fertilizer was applied in mid-summer on fallow rotations and in early fall when following peas. Nitrogen was applied as a non-pressure solution of urea ammonium nitrate (32-0-0-0S), P as ammonium polyphosphate (11-37-0-0S), and S as ammonium thiosulfate (12-0-0-26S) shanked 5 inches deep on 10-inch spacing. Micronutrients were applied as a foliar application of Bushel Builder in the spring of the crop year.

Winter wheat was seeded by each farmer uniformly across the entire plot. Grain yield was determined by harvesting a 5 by 90 foot section with a plot combine. Winter and spring precipitation were measured at each site.

RESULTS AND DISCUSSION

Winter wheat responded to N fertilization very differently between 1992 and 1993 (Table 3). In 1992, a year with low spring rainfall, N response was minimal in all agronomic zones, and higher rates of application decreased yield in some instances. The reverse was generally true in 1993, a year with substantially greater than normal spring precipitation. Nitrogen increased wheat yield substantially in 1993, with the optimum rate not attained in some instances. This illustrates the dilemma of attempting to apply N to achieve high efficiency of use because N, to be effective, must be applied before spring rainfall is known. When spring rainfall is high, wheat is very responsive to N and a substantial yield penalty incurs when inadequate fertilizer is applied. The general tendency is to apply sufficient N to ensure adequacy for high yield situations. But in years with low spring rainfall, yield is restricted and considerable N either ends up as elevated grain protein or remains in soil where it is subject to leaching and denitrification.

Winter wheat did not respond to P, S, or micronutrient application either year. Sodium bicarbonate extractable-P levels were between 14 and 23 ppm. These levels generally reflect the P status of the more fertile loess soils of the Columbia Plateau where P response in dryland cereals seldom occurs. None of the sites had a history of P application. None of the sites responded to S application, but this was not unexpected. All of the sites except the low rainfall one had a history of S application. Sulfur has substantial residual carryover, and S is applied more frequently than necessary in many instances because of the poor record of definitive plant and soil tests. None of the sites responded to micronutrient application, again suggesting adequate availability for dryland cereal production. Soil tests for zinc, the element most suspected of being deficient, tested low for available Zn (<1ppm) at all sites.

SUMMARY

The optimum N application rate in dryland regions of the Pacific Northwest depends to a large degree on yield level achieved which in turn is dependent on the amount of spring rainfall received. Predicting grain yield and N need before spring rainfall is known has considerably less accuracy than is desirable. But there are no easily-defined solutions to the problem since late-season N additions tend to increase grain protein more than yield. The lack of winter wheat response to P, S, and micronutrients indicates that these elements are either in adequate supply in soil or, in the case of S, are met by residual from past fertilizer practices where soils are not severely eroded.

Table 3. Winter wheat yield response to N, P, S, and micronutrients in 1992 and 1993. Umatilla county, Oregon.

N Rate†		Rainfall and Crop Rotation‡			
		10WF	13WF	16WF	19WP
lbs/acre		--- 1992 Grain Yield, *bushels/acre* ---			
0		27 *a*	66 *b*	57 *a*	43 *a*
37		29 *a*	69 *b*	62 *ab*	49 *a*
74		27 *a*	65 *b*	64 *b*	43 *a*
111		29 *a*	60 *a*	64 *b*	45 *a*
		--- 1993 Grain Yield, *bushels/acre* ---			
0		27 *a*	60 *a*	44 *a*	107 *a*
43		41 *b*	76 *b*	63 *b*	116 *b*
86		40 *b*	89 *c*	74 *c*	120 *c*
129		42 *b*	96 *d*	86 *d*	117 *bc*
Nutrient Added		Yield Response			
Phosphorus	1992	No	No	No	No
	1993	No	No	No	No
Sulfur	1992	No	No	No	No
	1993	No	No	No	No
Micronutrients	1992	No	No	No	No
	1993	No	No	No	No

† N rates for 19WP were 0, 43, 86, and 129 lb/acre

‡ Rainfall: average in inches/year; crop rotation: WF = Wheat/Fallow, WP = Wheat/Pea; numbers within each column with the same letter are not different at probability = 0.05.

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YELLOW MUSTARD PRODUCTION IN SEMIARID OREGON

Don Wysocki, Michael Stoltz, Sandra Ott

INTRODUCTION

Mustard (*Sinapis alba*) is a cool season, spring annual, tap-rooted, broadleaf plant. It is presumed to have its origins in the Middle East region. Mustard has been cultivated for at least 4,000 years as an oil, spice, and medicinal plant. It was introduced into Western and Northern Europe in the early Middle Ages and has been cultivated not only for seed, but also used as a forage, green manure, and garden crop.

Three types of mustard: yellow, brown and oriental are grown as a cash crop. Yellow mustard is the most common type grown in North America. It is used for condiment or "hot-dog" mustard, while brown and oriental are used for oil and spices. Mustard is typically grown under contract because the market demand is small and consequently prices can range widely. Contracts assure producers a market source at an established price.

Mustard is adapted to fertile, well drained soils and yields best when water and fertility are adequate. It is tolerant to salinity and similar to barley in productivity on saline soils. Varieties of yellow mustard mature in about 85-90 days. Mustard is an excellent rotation crop with small grains because it disrupts many weed and disease problems common to cereals.

GROWTH HABIT

Yellow mustard is a spring annual broadleaf with a well defined tap root. Mustard emerges rapidly (5-10 days) and grows quickly under favorable moisture and temperature conditions. Crop canopy will completely cover the ground about 30 days after planting. At approximately 35-40 days after sowing, plants begin to bud and 5-7 days later flowering begins. Full bloom is reached 7-10 days after flower initiation. Adequate water and cool temperatures (<85^o F) favor a long bloom period (>15 days). Seed yield is directly related to length of bloom. Mature plants vary in height from 30 to 45 inches depending on genetic potential and environmental conditions. Small grain crops following mustard generally yield better than following small grains because of rotation benefits. Crops such as sunflower, Canola, safflower, crambe, dry bean and soybean are not recommended in close rotation with mustard, as they are all susceptible to Sclerotinia (white mold).

SOWING CONSIDERATIONS

Several factors must be considered and/or adjusted to establish a vigorous stand of yellow mustard. These include herbicide history, seedbed preparation, choice of seeding equipment, row spacing, seeding depth, seeding rate and seeding date.

Herbicide History A major consideration in growing yellow mustard is residual effects of soil-active sulfonyl-urea herbicides. This includes products such as Finesse®, Amber®, Glean® and Ally®. These products have fairly long plant back periods for broadleaf crop such as yellow mustard. Check your field records and consult your supplier and the label of the specific product for plant back restrictions.

Seedbed Preparation Generally, seedbeds for mustard are similar to those required for small grains. The soil should be firm and fairly level. Tillage should be just deep enough to kill weeds, but keep soil moisture close to the surface and leave a firm seedbed. It may be necessary to roll or pack the seedbed (before or after sowing) if the soil is loose or uneven or if soil moisture is variable.

Sowing Depth, Seed Placement and Row Spacing Seed depth depends on seedbed, soil and weather conditions and type of seeding equipment available. Ideally, mustard should be sown no deeper that necessary to achieve good seed soil contact and placement into firm moist soil with a minimum of soil cover. When sowing with a disk or hoe drill, place seed 1/2 to 1 inch deep into moist soil and press over the row. Uniform seed depth will assure even, vigorous emergence. Mustard can be successfully planted into small grain stubble, provided seed makes good contact with moist soil and is not more than 1.5 inches deep. Disk and hoe drills or air seeders can be used to seed mustard but uniform depth control is critical for seed placement. Soil crusting prior to seedling emergence can cause problems. If mustard stands are poor (<4-5 plant/ft^2 ,10 days after planting), replanting should be made rapidly.

As with all spring crops, uniform competitive stands are important. For this reason it is best to plant mustard at narrow (6-7 inch) row spacing. However, row spacings up to 12 inches wide can be used, but canopy closure will not occur as quickly. Therefore weed competition and evaporative water loss may be greater. Row spacings wider than 12 inches are not recommended.

Sowing Rate and Date Yellow mustard has about 100,000 seeds per pound and should be sown at a rate of 8-12 pounds per acre. Higher rates should be used where seedbed conditions are poor or emergence may be a problem. In research trials, we have consistently achieved adequate stands with 7 lb/acre. Mustard should be sown promptly when the soil temperature in the seedbed consistently exceeds 40° F. Generally, at Pendleton, 40° F is reached about mid March. Delayed plantings can run into problems with shortened flowering periods because of late season heat stress.

PLANT VARIETIES

Commercially available varieties of yellow mustard include Gisilba, Ochre, and Tilney. Generally, variety selection is determined by the contractor. There are quality considerations that are important to processors that make certain varieties more desirable than others. Needing a uniformity and consistent supply, contractors offer contracts to grow specific varieties. Varietial information derived over the 1995-1996 growing seasons appears in Table 1. Mustard was grown after fallow and after a previous crop of winter wheat at both the Sherman and Pendleton research farms in 1995 and 1996. The trials included 27 and 12 varieties respectively in each year. These experiments were part of a regional mustard variety testing and breeding program operated by Dr. Jack Brown from the University of Idaho. Varieties not shown in Table 1 are experimental breeding lines, which are not commercially available.

FERTILIZATION

Mustard responds to nitrogen, phosphorus and sulfur fertilizer in a manner similar to small grains or spring Canola. As with small grains, nitrogen is the nutrient needed in the greatest quantity. Because yellow mustard is a new crop in this area little information is available on nitrogen

Table 1 Yield of yellow mustard at Pendleton and Moro under fallow and annual crop. 1995-96

	Pendleton				Sherman				Average All Sites	
	annual crop		fallow		annual crop		fallow			
Gisilba	Rank/27	Yield lb/acre	Rank/27	Yield lb/acre	Rank/27	Yield lb/acre	Rank/27	Yield lb/acre	Rank/27	Yield lb/acre
1995										
	8	1565	4	1465	9	1264	20	1129	6	1356
Kirby	1	1789	1	1712	5	1308	1	1480	1	1572
Ochre	7	1579	6	1387	1	1471	15	1180	3	1404
Tilney	27	1347	20	1098	27	1077	2	1365	21	1222
Trial Average		1507		1162		1222		1256		1371
1996										
	Rank/12		Rank/12		Rank/12		Rank/12		Rank/12	
Gisilba	2	859	3	1148	6	579	8	1110	4	924
Kirby	7	730	1	1218	2	621	2	1220	1	947
Ochre	8	684	4	1119	7	577	9	1047	9	857
Tilney	3	815	7	1083	5	584	3	1155	5	909
Trial Average		717		1058		563		1075		

fertility rates. The fertilizer guide *SF 718 Fertilizing Mustard, Canola and Crambe* Dahnke, et al. 1992) from North Dakota (a mustard producing area) recommends 6.5 lb N/100 lb of expected seed yield. Table 2 is based on the North Dakota recommendation.

Phosphorus and sulfur should be added according to the recommendations for spring wheat. Spring crops respond to these nutrients particularly in an annual crop rotation. A general recommendation or maintenance application is 20 lb P2O5 and 10 lb S/acre. Mixing low rates of phosphorus fertilizer (<100 lb/acre 16-20-0-14) with mustard seed and planting them together has been used effectively. However, the combination must be thoroughly mixed and remain unseparated to assure uniform seeding.

Table 2. Nitrogen fertilization rates for yellow mustard in North Dakota (Dahnke, et al. 1992)

Expected Yield lb/acre	Soil N-NO3 + Fertilizer N lb/acre
1000	65
1500	100
2000	130
2500	165

WEED CONTROL

Weed control must be based on clean field selection and shallow seeding for quickand uniform emergence to obtain a uniform stand. Weeds have not been a serious problem in mustard production. However weed seeds of similar size and shape as mustard can cause cleaning losses and market grade reductions. Such losses reduce profits to the grower. Weeds growing as an understory in a mustard crop do not reduce yield. However they may contribute seed to perpetuate the weed problem. Mustard plants are sensitive to herbicides such as 2,4-D, Banvel, and MCPA. Spray drift must be avoided.

INSECTS

Insects have not caused serious problems on yellow mustard in this region. However as acreage of mustard increases fields should be monitored for potential problems. Flea beetles and diamondback month caterpillars are the most likely insects to cause damage. Adult flea beetles feed on the cotyledons and first true leaves, causing a shot holed appearance. Severely damaged seedlings may die, while less seriously damaged plants often suffer a reduction in vigor and stamina. Hot, sunny weather is conducive to feeding activity, while cool, damp weather slows feeding and favors crop growth. Once the crop advances beyond the seedling stage, serious damage is rare because mustard can outgrow the beetle defoliation.

Diamondback moth caterpillars attain a length of ½ inch and are light yellowish green to green. The larvae eat leaves, flowers and green pods and are extremely active when touched.

DISEASES

Mustard grown in rotation with small grains is relatively free of disease. Sclerotinia stalk rot (white mold) is the only disease that has been observed on mustard in this area. It has only been present at very low levels. However, mustard should not be grown in short rotation with Canola, dry edible bean, crambe, or safflower. These crops have a similar problem with white rot and the problem could build to economic levels. Mustard grown in rotation with small grain is a preventative of serious disease problems and provides an excellent biological break for cereal root diseases.

HARVESTING AND SEED QUALITY

Wind, rain, and normal drying generally does not cause mustard to shatter before cutting. Yellow mustard can be direct combined, if the field is not weedy and the crop is uniformly ripe The harvest operation can cause some shatter if the crop is overripe or extremely dry. When direct combining, wait until the crop is mature and dry. The reel can be removed or lifted above the crop if the stand is good. If the reel is needed, it should be operated at a reduced speed.

The combine should be adjusted so that the seeds are completely threshed while using the lowest possible cylinder speed. Cylinder speed should be set at approximately 600 RPM. Careful adjustment of the cylinder speed and cylinder opening is important to avoid cracking. To test for cracking, run your hand into the threshed seed. If cracked mustard is present, it will adhere to the hair on the back of your hand, indicating the need for further combine adjustment. Cracked seed is considered dockage and is a loss to the producer. Cylinder speed may need to be varied during the day as crop moisture content varies. Fan speed should be reduced to limit seed loss, yet maintain sufficient air to ensure clean seed.

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PRECIPITATION SUMMARY - PENDLETON [1]

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
67 Year Average	**.72**	**1.31**	**2.02**	**2.06**	**1.94**	**1.51**	**1.71**	**1.54**	**1.48**	**1.24**	**.35**	**.50**	**16.38**
1976-77	.44	.53	.47	.59	.90	.57	1.72	.46	1.70	.31	.12	2.21	10.02
1977-78	1.54	.69	1.79	3.19	2.27	1.71	1.40	3.50	.81	1.27	.59	1.37	20.13
1978-79	1.61	0	1.68	2.28	1.31	1.54	1.74	1.82	1.15	.18	.12	2.08	15.51
1979-80	.17	2.56	2.31	1.05	2.85	1.55	2.12	1.20	2.45	1.42	.23	.18	18.09
1980-81	1.24	2.96	1.81	1.99	1.26	2.31	2.30	1.29	2.30	2.12	.40	.02	20.00
1981-82	1.51	1.62	2.41	3.27	2.61	1.86	1.99	1.54	.48	1.12	1.02	.50	19.93
1982-83	1.68	2.68	1.46	2.69	1.63	2.97	3.90	1.23	2.08	1.92	1.00	.68	23.92
1983-84	.82	.91	2.79	3.44	.99	2.56	3.23	2.37	2.11	2.05	.05	1.25	22.57
1984-85	.98	1.18	3.43	1.96	.69	1.49	1.33	.65	.89	1.42	.05	.98	15.05
1985-86	1.54	1.34	2.66	1.27	2.38	3.04	1.94	.83	1.79	.09	.61	.19	17.68
1986-87	1.87	.91	3.41	.95	2.08	1.31	1.85	.83	1.63	.62	.47	.06	15.99
1987-88	.04	0	1.44	1.61	2.60	.32	1.65	2.59	1.79	.94	0	0	12.98
1988-89	.40	.08	3.65	1.10	2.86	1.55	2.95	1.94	2.19	.33	.15	1.19	18.39
1989-90	.24	1.00	1.65	.49	1.43	.63	1.89	1.77	2.14	.70	.37	.76	13.07
1990-91	0	1.37	1.73	1.18	1.15	.86	1.71	1.01	4.73	2.22	.15	.24	16.35
1991-92	.03	.89	4.18	.97	.96	1.34	.85	1.29	.20	.90	1.74	.78	14.13
1992-93	.58	1.70	2.61	1.30	2.43	1.04	2.32	2.67	1.58	2.01	.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						
20 Year Average	**.82**	**1.18**	**2.33**	**1.77**	**1.92**	**1.60**	**1.96**	**1.67**	**1.82**	**1.12**	**.40**	**.78**	**17.38**

[1] All units are in inches

PRECIPITATION SUMMARY - MORO [1]

CBARC - Sherman Station - Moro, Oregon

(Crop year basis, ie; September 1 through August 31 of following year)

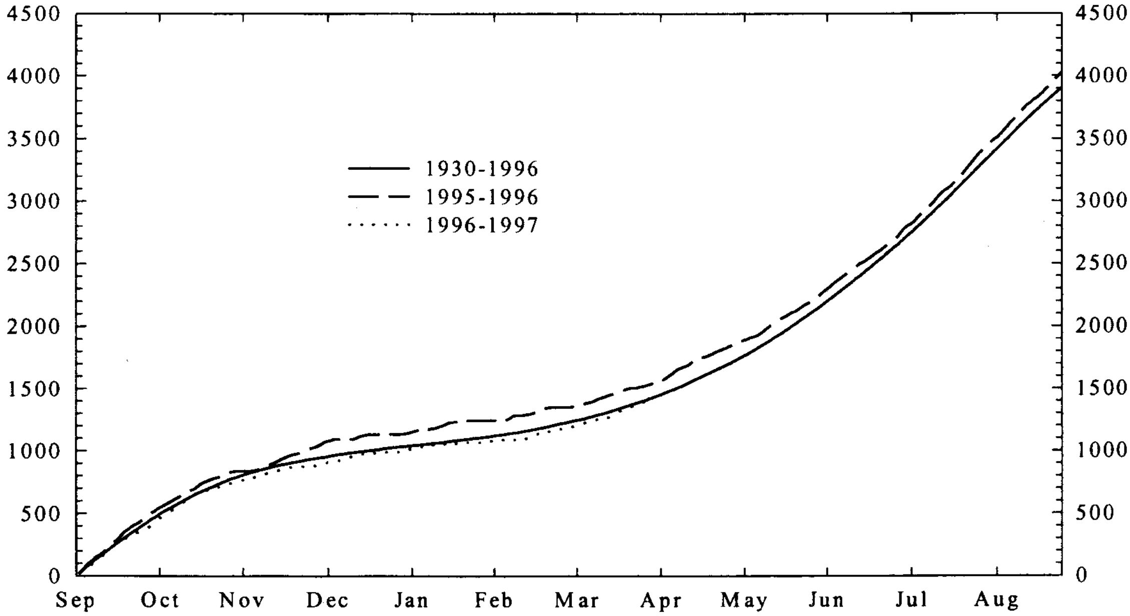
Crop Yr	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
87 Year Average	**.59**	**.91**	**1.71**	**1.64**	**1.63**	**1.17**	**.98**	**.80**	**.82**	**.70**	**.23**	**.28**	**11.47**
1976-77	.04	.10	.43	.20	.18	.63	.50	.08	2.70	.28	.37	.90	6.41
1977-78	.88	.22	2.00	3.22	2.80	1.31	.74	1.42	.43	.44	.59	1.32	15.37
1978-79	.33	.01	.79	.69	1.59	1.54	.99	1.06	.28	.10	.07	1.05	8.50
1979-80	.53	2.59	2.23	.65	3.41	1.83	.94	.89	1.27	1.37	.16	.11	15.98
1980-81	.42	.79	1.73	2.95	1.52	1.22	.65	.41	1.06	1.15	.20	0	12.10
1981-82	.92	.82	1.99	4.73	1.10	.72	.55	1.45	.37	1.15	.21	.40	14.41
1982-83	1.42	1.96	1.08	1.89	1.40	2.43	2.74	.61	1.96	.39	.80	.60	17.28
1983-84	.52	.62	2.45	2.31	.17	1.07	2.34	1.32	.97	1.09	.17	0	13.03
1984-85	.53	.86	3.18	.41	.27	.97	.44	.14	.63	.92	.05	.14	8.54
1985-86	1.11	1.09	1.19	1.12	1.84	2.39	.98	.34	.35	.06	.54	.07	11.08
1986-87	1.52	.45	1.53	.78	1.68	1.10	1.54	.28	.99	.29	.78	.11	11.05
1987-88	.07	.01	.66	3.23	1.60	.21	1.25	2.21	.55	1.02	.04	0	10.85
1988-89	.56	.02	2.51	.22	1.33	.77	1.91	.84	.91	.08	.11	.50	9.76
1989-90	.07	.59	.96	.48	1.91	.17	.76	.79	1.36	.39	.15	1.43	9.06
1990-91	.29	1.27	.61	.74	.87	.60	1.43	.40	.77	1.27	.33	.16	8.74
1991-92	0	1.40	2.57	1.02	.47	1.64	.64	2.38	.04	.28	.81	.02	11.27
1992-93	.68	.85	1.50	1.68	1.42	1.47	1.68	1.22	1.42	.87	.39	.30	13.48
1993-94	.02	.09	.41	.68	1.40	.90	.55	.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													
20 Year Average	**.56**	**.83**	**1.64**	**1.51**	**1.52**	**1.23**	**1.12**	**.99**	**.95**	**.68**	**.36**	**.37**	**11.76**

[1] All units are in inches

CUMULATIVE GROWING DEGREE DAYS

(BASE = 0°C)

PENDLETON



MORO