1995 COLUMBIA BASIN AGRICULTURAL RESEARCH ANNUAL REPORT

Special Report 946
Agricultural Experiment Station • Oregon State University
in cooperation with Agricultural Research Service • USDA

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Agricultural Experiment Station
Oregon State University
in cooperation with
Columbia Plateau Conservation Research Center
the U.S. Department of Agriculture
Agricultural Research Service

In Memory of Les Ekin

This Field Day Report is dedicated to the memory of Leslie G. "Les" Ekin who served this Research Center and the farmers of this area with distinction and loyalty from October 8, 1956 until August 21, 1993: more than 36 years. Les Ekin, born July 25, 1938, was reared and attended school at Pilot Rock, Oregon. He married Mary Sue Henshaw of Pendleton on December 22, 1957. Les and Sue had two sons: Robert, with Micron Technology, Boise, Idaho and Tim, with Pendleton Grain Growers, Pendleton, Oregon. Les died of cancer September 4, 1993.

Les worked as an Agricultural Research Technician for Charles Smith, Bob Ramig, and Clyde Douglas of the USDA Agricultural Research Service during his tenure at the Research Center. His research was in soil and water conservation and soil fertility programs for wheat, barley and peas in continuous cropping and alternate crop-fallow systems. Les assisted in locating plots, tillage, seeding, spraying, fertilizing, harvesting, soil and plant sampling, soil moisture measurements, note taking, and laboratory analyses on research plots in Union, Umatilla, Morrow, Gilliam, Sherman, and Wasco Counties, Oregon and Walla Walla and Columbia counties, Washington. In later years, Les helped train many of the technicians at the Research Center. He assembled many years of research data for statistical analyses and prepared tables and graphic presentations of research data.

Les Ekin was a friendly man of high principles, always willing to help others. His contributions to the research program at this Research Center and to the agricultural industry were numerous and valuable. We salute Les Ekin and dedicate this Field Day Report to him.

CONTENTS

INTRODUCTION

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

PROMOTIONS AND AWARDS

Dan Ball was elected vice-president of the Oregon Society of Weed Science. Richard Smiley was named Fellow of the American Phytopathological Society, elected Councilor for the APS Pacific Division, and appointed APS representative to the Council for Agricultural Science and Technology (CAST).

Within the USDA staff, Dale Wilkins was promoted to GS-14 on June 12, 1994 and Paul Rasmussen was promoted to GS-14 on April 2, 1995. Outstanding Service Awards were given to Betty Klepper, Dale Wilkins, and Phil Dailey. The American Society of Agronomy awarded a Certificate of Excellence for Development of Agronomic Educational Material to Russ Karow, Betty Klepper, Ron Rickman, and Tami Toll (Johlke) for a publication depicting use of wheat seedling morphology in evaluating seedling vigor.

STAFF CHANGES

For the OSU staff, Vicky Correa and Teresa Walenta were employed throughout the year in the wheat breeding program. Cheryl Van Pelt and Julie Bain served during extended periods in the weed science research program. Mike Moore, Senior Faculty Research Assistant, transferred from Corvallis to Pendleton, where he coordinates wheat breeding activities and programs led by Pamela Zwer and Warren Kronstad. Karen Morrow also joined the OSU staff as a Biological Research Technician in the wheat breeding program.

For the USDA staff, John Zuzel retired from his hydrology position after 38 years of government service. Carol Brehaut, research leader secretary, retired after 23 years of service and was replaced by Jacque Grandbois, who transferred to Pendleton when the ARS Laboratory in Fairbanks, AK, was closed. The postdoctoral hydrologist, Deghyo Bae, resigned to return to Korea, his native country. Erin Bailey worked for an 8-week period last summer on a special ARS program for research apprentices in agriculture. Brian Whitten from Pendleton Junior High School worked on a Teacher Research Fellowship in a special ARS program designed to provide more understanding of agricultural research to the students who will become tomorrow's scientists. A summer intern position in soil microbiology was filled by Kimberly Ladd, a junior at Oregon State University with a major in Rangeland Resources. Rebecca Holowecky was hired as a temporary full time technician to operate the Plant Laboratory. Lance Rinker worked for an extended period in the soil quality program.

Seven temporary student employees were hired for the summer field season.

NEW PROJECTS

For the OSU staff, Dan Ball was the recipient of a USDA Special Grant on the development, prediction, and prevention of seed production in jointed goatgrass. Another of Ball's new projects was a grant from ITT Corporation to examine night time tillage to reduce weed seed germination. Don Wysocki was the recipient of a USDA special grant for improving canola seedling establishment under dryland conditions. Wysocki also developed a project for evaluating yield of yellow mustard lines, in cooperation with Jack Brown at the University of Idaho. Richard Smiley received a USDA-Western Region IPM Grant to evaluate the integration of fertilizer practices and fungicide seed treatments for improving wheat production efficiency and reducing nutrient contamination of ground water. Other OSU and USDA-ARS collaborators also participate in these new projects. The new projects complement on-going research funded by the Oregon Wheat Commission, USDA-STEEP II Research Program, agri-business, and other funding agencies.

On the USDA-ARS staff, work by the Teacher Fellow, Brian Whitten, showed that weed seeds are distributed near the soil surface with chisel plowing, but buried with moldboard plowing. This fact led to the development by Dale Wilkins of a new mow-plow system for weed control in a high residue environment. This system involves use of a stripper header at harvest, over-winter tall stubble cover, and a mower/straw management system that is operated in conjunction with a moldboard plow. The mowed residues are distributed behind the plow to provide residue cover. A new post-doctoral position has been assigned to assist in development of this system.

Ron Rickman has initiated a new project to define problems of measuring accurately the residue or canopy cover in a field when the cover is not randomly placed, but occurs in regularly-spaced rows or strips; the work is important for the Natural Resources Conservation Service (NRCS) residue cover measurements in the compliance program. Clyde Douglas and Steve Albrecht have begun a new project to evaluate microbial activity during residue decomposition, evaluate temporal effects on activity, and identify rates of decomposition in relation to residue fraction and type. These two scientists are also collaborating with Dale Wilkins and Ron Rickman to quantify the amount of carbon that is lost during and following different tillage operations.

FACILITIES

The OSU program did not initiate construction projects during the past year. A Kubota tractor was purchased and equipped with an experimental herbicide application system fabricated by our staff. A swather was purchased for use in experiments with canola, grass seed, and legumes. A soil pasteurization system was constructed for the purpose of manipulating populations of soil microorganisms and weed seeds in greenhouse soils. A seed drill was fabricated for experiments requiring deep-furrow planting in small plots. The D2 crawler used in much of the OSU research was replaced by a newer Kamatsu tractor. The Yanmar tractor at the Sherman Station was replaced by a Kioti tractor. A direct communication cable was installed at

Pendleton to improve reliability of on-line accounting and electronic communications.

The USDA office building upgrades included a fire/emergency alarm system for the microbiology laboratory and storage building, roof repair and maintenance, new siding for the equipment shed and solar drying room, and installation of above-ground tanks for heating fuel. Also a satellite dish and receiver was installed to allow on-site training and intra-agency communication via satellite. Major new equipment purchased for the new microbiology program included a high performance liquid chromatograph, a gas chromatograph, a liquid scintillation counter, and a superspeed refrigerated centrifuge.

TRAINING

OSU staff continued to maintain requirements for pesticide application licenses, first aid, and cardiopulmonary resuscitation. Gloria Eidam traveled to Corvallis for training with FIS, the new on-line electronic financial information system, which will become fully implemented during the summer of 1995. Judy Elliott and Gloria Eidam enrolled in a class at Blue Mountain Community College, where they received additional training with word-processing programs. Karl Rhinhart acquired training required to serve as the local trainer for OSU's new Respiratory Protection Program, which involves most OSU staff at the Center.

The following USDA staff attended: Sharron Wart, an advanced field acquisition seminar; Chris Roager and Phil Dailey, laboratory safety and health training; Daryl Haasch, safety training; Steve Albrecht, "Introduction to High Performance Liquid Chromatography" and "Liquid Chromatography Methods Development and Trouble Shooting"; and Craig Cameron, "Introduction to ARC/INFO". Many employees took advantage of one-day courses, including the following: six employees, a one-day course in Microsoft Windows; Betty Klepper and Clyde Douglas, "Pre-retirement Counseling"; Paul Rasmussen and Steve Albrecht, "How to Make Presentations with Confidence and Power"; Paul Rasmussen, "Management Problems of the Technical Person in a Leadership Role"; Larry Baarstad, a chemical applicator's short course; Tami Johlke and Roger Goller, a workshop on "Pesticides and Soil and Water Quality"; and Dale Wilkins, "How to Handle Negativity in the Workplace". Tami Johlke became licensed as a Public Pesticide Applicator for agricultural herbicides. The entire ARS staff received one day of training in "Total Quality Management." Most of the staff attended CPR and/or first aid classes with instructors from Blue Mountain Community College.

VISITORS

Distinguished visitors hosted by staff at the Center included Dick Amerman, Doral Kemper, and Jan Van Schilfgaarde from USDA-ARS, National Program Staff, Beltsville, MD; Bob Reginato, Area Director; Phyllis Johnson, Associate Area Director; Ralph Nave, Assistant Area Director; Chet Reeder, Area Administrative Officer; Martha Steinbock, Technology Transfer Coordinator; and Alvin Humphrey and Brad Baugh, Area Health and Safety Officers, ARS Pacific West Area; Tom Gohlke and Ken Pfeiffer, Natural Resource Conservation Service (NRCS), Western National Technical Center; Keith Saxton, Don McCool and Robert Papendick, (ARS, Pullman, WA); John Byrne, President of OSU; Thayne Dutson, Mike Burke, Kelvin Koong, Van Volk, Bob Witters, and Bruce Sorte, OSU College of Agricultural Sciences; and Ian Tinsley, Sheldon Ladd, and Stella Coakley, Chairs of OSU Departments of Agricultural Chemistry, Crop and Soil Sciences, and Botany and Plant Pathology. Scientists visiting to do joint research with the staff included Ray Allmaras (ARS, St. Paul, MN), Baird Miller (Washington State University), and J. M. Sabatier and Jim Chambers (National Center for Physical Acoustics). Foreign visitors included Tarig Javed from Japan, four Egyptian plant scientists and six scientist-administrators from parts of the former Soviet Union. Also a team of five scientists from other universities visited the station and evaluated staff and facilities, during a Tri-State Wheat Research Review funded by the Wheat Commissions of Idaho, Oregon, and Washington.

SEMINARS

The seminar series at the Center was coordinated by Ron Rickman. Seminars included the following speakers and subjects: Sue Waldman (MODWht3 Validation for Spring Wheat), Don Wysocki (Use of On-Farm Tests to Improve Fertility Management, Fostering the Adoption of STEEP Cropping Systems Technology), Clyde Douglas (Decomposition of Canola Residues), Steve Albrecht (Methanol Effects on Cereal Crop Growth and Yield; Future Direction of the Soil Microbiology Program), Ron Rickman (Soil Water Content Response to Overwinter Tillage for 20 Years of a Wheat-pea Rotation; Predicting the Development of Crown Root Axes of Annual Grasses), Betty Klepper (Root Models: Concepts and Realities), and Paul Rasmussen (Nitrogen Placement and Stubble Burning Effects on Downy Brome Competition in Winter Wheat).

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, industry, 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.

Rotations occurred in the leadership of both committees. John Rea and Steve Anderson are commended for their many years of service and leadership. The Pendleton and Sherman Station liaison committees held a joint meeting on March 2, 1994. The Pendleton Station liaison committee, now led by Chairman Gary Burt (Walla Walla: 509-529-6787), also met on October 18, 1994, and May 3, 1995. The Sherman Station liaison committee, now led by chairman Ernie Moore (Moro: 503-565-3202), met on May 24 and September 6, 1994.

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

1994-95. 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 equipment (David Conlee), funds, seed, soil, and/or chemicals (AGSCO, American Cyanamid, Steve Anderson, Blue Mountain Seed, Blue Mountain Green Pea Growers, CIBA Crop Protection, Connell Grain Growers, E.I. duPont, FMC, Kerley Ag., Lewiston Grain Growers, McGregor Co., Bayer (Miles), Monsanto, Bart Owsley, Pendleton Grain Growers, Premier Edible Oils, Rhone Poulenc, Russell Karow, Sandoz Agro, SeedTec International, United Nations Food and Agriculture Organization, Wilbur-Ellis Co.) or loaned equipment or facilities (John Rea, John Correa, Frank Tubbs, James Moore, Sherman Reese, Bob and Don Zimmerman), USDA-ARS Pullman (Keith Saxton, Don McCool), OSU Dept. of Crop and Soil Sciences, and OSU Hermiston Agricultural Research and Extension Center (George Clough), or provided services (the City of Moro, Robert Powell). Services in field plot tillage and seeding were also provided by Don Meiners, Clint Reeder, Jeff Shaw, Ted Gilliland, Jerry Simpson, Doug Harper, Jay Nowograski, Eric Anderson, Berk Davis, and Leon and Sherman Reese. Collaborators from the NRCS include Harry Riehle (WA), Floyd Bailey (ID), Tom Gohlke (OR), Ken Pfeiffer (Western National Technical Center), Kate Danks (Pendleton), and Bob Adelman (Pendleton).

We also acknowledge those who donated labor, supplies, equipment or funding for the Pendleton Field Day: American Cyanamid, CIBA Crop Protection, Dow-Elanco, E.I. duPont, Farm Credit Services, Farm Equipment Headquarters, First Interstate Bank, FMC Corporation, Huntington-Price, Inland Chemical Service, Inland Empire Bank, Intermountain Canola, McGregor, Main Street Cowboys, Monsanto, Pendleton Bus Company, Pendleton Flour Mills, Pendleton Grain Growers, Pioneer Implement Corp., Rhone-Poulenc, Rohm and Haas, Sandoz Agro, Les Schwab Tire Center, Smith Frozen Foods, Steele's Bar and Grill, Tri-River Chemical, Umatilla County Wheat Growers League, Valent U.S.A., Walla Walla Farmer's Coop, Western Farm Service, Wheatland Insurance, Wilbur-Ellis, and Zeneca.

We also thank donors who provided buses, meals, and other services for the Moro Field Day: Branding Iron Restaurant, Cargill, Cascade Ranchers, Gustafson, Klickitat Valley Grain Growers, Mid-Columbia Bus, Mid-Columbia Producers, Monsanto, Morrow County Grain Growers (Lexington and Wasco), Northwest Chemical, Richelderfer Air Service, SeedTec International, Sherman Aviation, Sherman County School District, Sherman Farm Chemicals, Western Tillage Equipment, and Wilbur-Ellis.

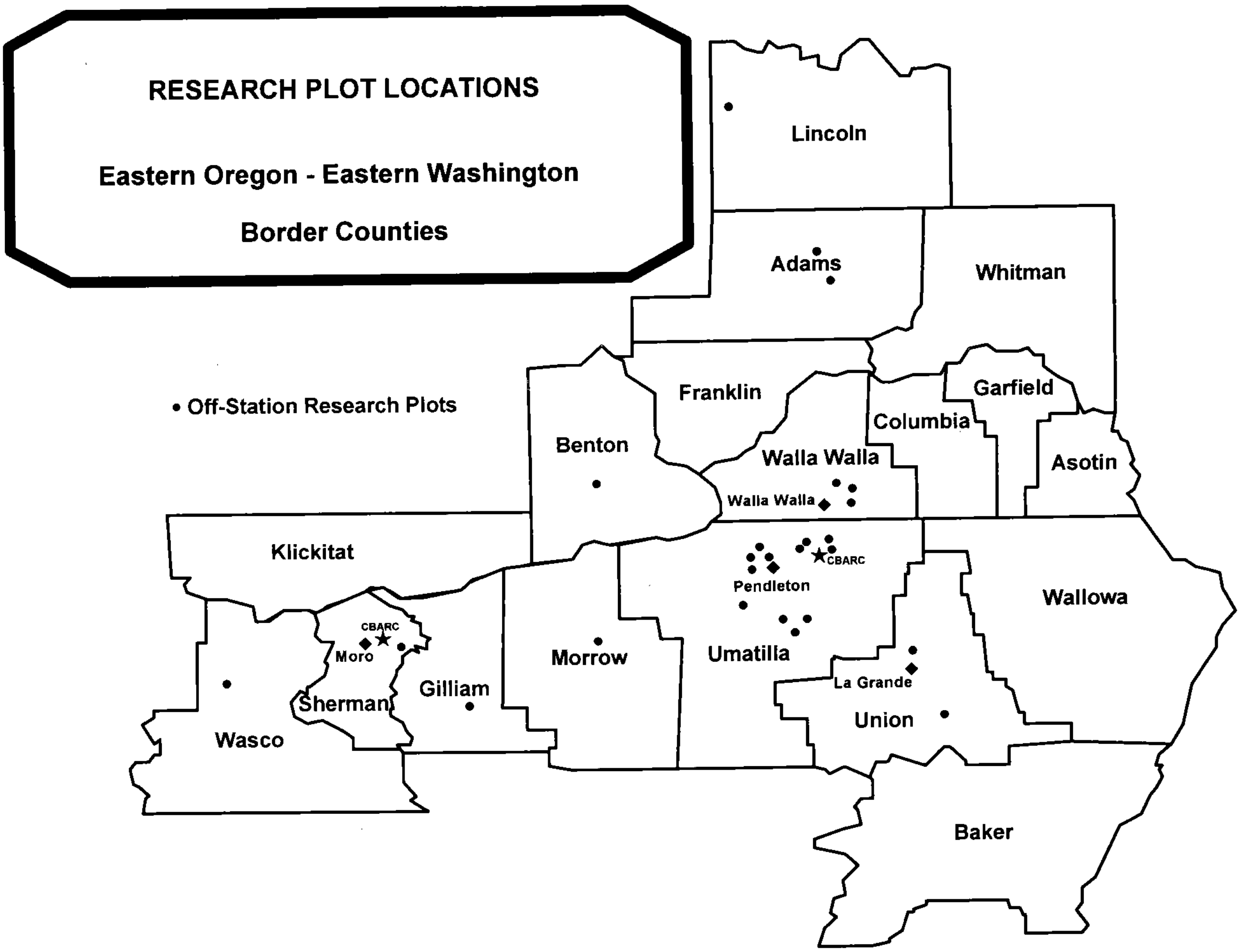
Cooperative research plots at the Center were operated by Warren Kronstad, Patrick Hayes, Chris Mundt, Russ Karow, Jack Brown, and the Natural Resource Conservation Service. Additionally, we are very thankful for the ever-present assistance from the Extension Service personnel in all counties of the region, and especially from Umatilla (Mike Stoltz, Phil Hamm, and Tom Darnell), Union/Baker/Wallowa (Gordon Cook), Sherman/Wasco (Sandy MacNab and Brian Tuck), Morrow/Gilliam (Phil Nesse), and Malheur (Ben Simko) counties in Oregon, and from Columbia (Roland Schirman), Adams/Lincoln (Bill Schillinger), Walla Walla (Walt Gary), Klickitat (John Fouts), Benton (Greg van

Doren), Asotin (Gary Delany), and Whitman (John Burn) counties in Washington.

We also wish to thank over 200 farmers who have allowed us to work on their property during the past year, and who have often gone the extra mile by performing field operations, loaning equipment, donating chemicals, and adjusting their practices to accommodate our plots. The locations of the principal outlying sites are shown on the map that follows.

We truly appreciate the support and encouragement of growers, organizations, and businesses with a mission common to ours: to serve in the best manner possible the 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	Betty Klepper
Superintendent	Research Leader
OSU-CBARC	USDA-ARS-CPCRC



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Don Wellsandt

BENTON, WA
Greg Smith

GILLIAM, OR
Charlie Anderson

LINCOLN, WA
Bob Zimmerman
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CURRENT STATUS OF THE STATEWIDE WHEAT BREEDING PROGRAM

Mike Barnum, Randy Dovel, Erling Jacobsen, Steve James, Russ Karow, Randy Knight, Warren Kronstad, Mike Moore, Richard Roseburg, Mary Verhoeven and Pam Zwer

The two-fold purpose of the wheat breeding program is to provide the grower with wheat varieties that are cost-efficient to produce and to furnish to the industry cultivars with superior quality for various end product uses.

To address the first purpose of the program, varieties must be disease and insect resistant, adaptable to various tillage practices, and withstand abiotic stresses such as pH tolerances and moisture stress. All of the above should be packaged in a cultivar with good yield potential.

The second aspect of the program deals with the ultimate use of the crop. Here quality is of paramount importance, and desirable characteristics differ with different market classes of wheat. The biochemical components of the wheat kernel are influenced by both genetics and the environment, nature, and nurture. The task of the plant breeder is to put the desired genes for quality into the cultivar and the grower to provide the proper environment for the expression of those genes. Of course, mother nature may or may not cooperate with these plans.

To offer the producer management options, the wheat breeding program works on developing cultivars of soft white winter wheat, hard white winter wheat, winter durums, club wheat, and spring wheat. The major effort is on soft white winter wheat development.

Soft White Winter. Several advanced lines are being considered for release. OR908361 and OR908369 carry the VPM/MOS 951 gene for strawbreaker footrot resistance. These lines have excellent flour yield and are on increase for breeder seed this year. OR880494 and OR880510 also have excellent quality and are resistant to the current biotypes of common and dwarf bunt. They have lower yield potential than Stephens or Madsen, but on lower yielding sites they are competitive. Both lines have been submitted for collaborative testing. Lines for collaborative testing are sent to four or five millers and end product manufacturers where that market class of wheat is commonly used. This is normally outside the United States. Four cultivars are currently being tested in the regional nursery. OR870012, OR880172, OR880525 and OR870337 have quality attributes that equal or surpass the current commercial cultivars in at least three areas. OR880172 has been submitted for collaborative testing.

Hard White Winter. Two promising hard white winter selections, OR850513 and OR889176 are being considered as potential varieties. OR889176 has been submitted for collaborative testing. This line has very good milling scores and loaf volume has been equal to or better than the hard red varieties of Hoff and Wanser. Although the hard white wheats are designed for noodle or flat bread end products, good bread baking capability is desirable. They could then be used as blend in the domestic market. OR850513 is not as exceptional in flour yield and loaf volume, but it has outstanding starch pasting viscosity, which is very important to the noodle market.

Perhaps it would be good to digress and explain what is known about the attributes desirable for noodles. There are three major characteristics needed to make a good noodle: color, starch pasting viscosity, and protein. First, most of the Oriental noodles are fresh, and no one likes a gray or green noodle. Many flours, when made into noodles, discolor over a period of 24 to 48 hours. There is genetic variation for this character, and three tests are being employed by the OSU Quality Lab, the Wheat Quality Lab in Pullman, and the Wheat Marketing Research Center Lab in Portland to identify lines with acceptable color.

Second, all three labs are using various instruments to test for starch quality. Starch quality imparts a good "mouth feel" to the noodle. If the quality is not there, the noodles are mushy.

Finally, enough protein must be present to hold the noodle together. At the OSU Quality Laboratory, the early generation material is screened for the aforementioned parameters. Once lines have been entered into yield trials, the material is sent to the Wheat Quality Lab in Pullman for more extensive evaluation. The most advanced material is often tested by the lab in Portland as well, where actual noodles can be made on a pilot scale.

Four other hard white selections besides OR850513 and OR889176 are in regional testing this year.

Approximately 550 hard white lines were received from CIMMYT/ICARDA's Turkey program last year. After a pre-screening at OSU, many of these lines have been sent to Pullman for evaluation. The pedigrees of this material contain lines from the Oregon program, Kansas, Colorado, Nebraska, and from many Eastern European breeding programs.

Spring Wheat. Three hard white spring lines, OR4870255, OR4870279, and OR4870374 have been entered in the collaborative testing program. These lines, when compared with Klasic, are not as good in loaf volume. OR4870255 and OR4870374 are better millers than Klasic, and the former has better color and RVA score, which is a measure of starch pasting viscosity. OR4870279 had the highest RVA score in the nursery.

Four hard red spring selections are in advanced testing. OR4870410, OR4870401, OR4870400, and OR4880189, when compared to McKay, are equal to or superior in milling and baking quality. All of these lines, with the exception of OR480401 have been in regional testing. OR480401 is in the regional nursery this year.

Durums. Work on winter and spring habit durums is in progress. On the winter side, crosses have been made and winter durum lines developed in Oregon are being tested in the advanced and preliminary nurseries. Winter hardiness and quality are the primary goals of this aspect of the program.

The spring durums in the program represent a selection of lines primarily from the CIMMYT program in Mexico. They are suprisingly well adapted to the growing conditions around Pendleton and often out-yield the bread wheats. Testing for durum quality is difficult. The lab at OSU is equipped to analyze seed color for the durums for the desirable deep yellow, but milling to make semolina is beyond its capabilities. Selections are often sent to the USDA/ARS lab in North Dakota for quality analysis. Pendleton Flour Mills also looks at the samples.

Club Wheat. With the requirement for a higher percentage of club wheat in Western Soft White shipments and talk of some markets taking shipments of 100 percent club wheat, the future for club wheat looks bright. This favorable outlook comes at a time of transition for the Club Wheat Breeding Program as the direction of the activities shifts from Dr. Pamela Zwer to Dr. Warren Kronstad. Mike Moore, a senior research assistant with Dr. Kronstad's program, was transferred to the Columbia Basin Agricultural Research Center on September 1, 1994 in an effort to facilitate the transfer of materials and information. The smooth transition for continuing the efforts of the Club Breeding Program, both in breeding efforts and satisfying grant obligations, has been made possible by the professional and cooperative attitude of Pamela Zwer, and the efforts and support of Vicky Correa and Teresa Walenta as well as staff at the Columbia Basin Agricultural Research Center. The overall goal of the program is still to produce club wheat varieties with quality characteristics to meet market requirements and agronomic characteristics to make them profitable for Pacific Northwest wheat producers.

The Club Wheat Breeding Program has ongoing efforts in the following areas:

- Russian wheat aphid screening of program material for resistance.
- Stripe rust inoculation of early generation material in the field at the Columbia Basin Agricultural Research Center.
- Club wheat hybrid production.
- Evaluation of early generation and advanced lines for quality, disease reaction, agronomic characteristics, and yield potential.
- Purification of lines identified as potential releases.
- Cooperation in the Statewide Cereal Testing Program.

Russian wheat aphid (RWA) resistance screening of breeding program material will follow procedures developed by Dr. Zwer using seedlings to predict adult plant responses to RWA. Aphid populations maintained by Vicky Correa will be used. Lines from the elite and advanced nurseries will be assessed for RWA reactions. Lines with RWA resistance will continue to see use as parental material in the crossing program.

Stripe rust inoculation consisted of the use of spores from liquid nitrogen storage mixed with talc, which were dispersed through the F2 materials during weather conditions that favored infection. Plants infected with Tres type stripe rust were also transplanted at intervals in the same fields. Selections will be made at harvest with stripe rust resistance as one of the selection criteria.

Club wheat hybrid production in the greenhouse at the Columbia Basin Agricultural Research Center will utilize about 230 lines planted at two dates approximately one month apart. Some of these lines are currently in the program as potential new varieties, while others are sources of RWA, footrot or stripe rust resistance. Dr. Kronstad will also be making crosses with parental lines as well as F1 materials planted at Corvallis. Crossing priorities are quality, yield, disease resistance, and emergence.

Agronomic notes are of major importance as lines are assessed for their ability to contribute as a new variety or as breeding material in future crosses. Notes on heading date, reaction to numerous diseases, lodging, shattering, and any other items of interest will be taken throughout the growing season.

Dr. Zwer currently has three lines identified as potential new releases. These lines are in the Statewide Cereal Testing Program for the first time this year. These lines have purification blocks planted in an effort to shorten the time between the decision to release and the actual availability of seed to the producer.

The Club Wheat Breeding Program has five sites that it plants, maintains , and harvests in a cooperative effort with Russ Karow and Statewide Cereal Testing Program. Trials are planted at the Columbia Basin Agricultural Research Center, the Sherman County Experiment Station, with Charlie Anderson above Heppner, the Hermiston Agricultural Research and Experiment Center, and with John Cuthbert outside of Island City.

Early generation material is located at the Columbia Basin Agricultural Research Center in a headrow format, with selections to be made this fall by Dr. Kronstad. Notes will be taken throughout the season to assist in the selection of materials. Club yield trials are planted at the Columbia Basin Agricultural Research Center and the Sherman County Experiment Station.

The efforts of the Club Wheat Breeding Program will continue in a manner that assures none of the recent advances are lost and that the program continues to work toward the production and release of new club wheat lines that have the quality characteristics that the market desires and the yield potential to make them profitable for the producers of the Pacific Northwest.

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

Russ Karow, Pam Zwer, Helle Ruddenklau and Mike Moore

INTRODUCTION

This article reports results from cereal variety trials conducted across the Columbia Basin in 1994. These trials were conducted as part of the state-wide cereal variety testing program initiated in 1992 to provide growers with local data on cereal variety performance. This program is coordinated by Russ Karow, OSU Extension Cereals Specialist, and Helle Ruddenklau, Research Assistant, Department of Crop and Soil Science. 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. Russ Karow's research team processes harvested grain, analyzes results, and provides summary data to extension agents, seed dealers, field representatives, and growers across the state.

Winter and spring barleys, triticales and wheats of several market classes were tested at the 11 sites in the testing network (Table 1). Height, lodging, grain yield, and test weight were determined for all varieties. Heading date, disease reactions, protein content, and other quality factors were determined as time, labor, and equipment allowed.

MATERIALS AND METHODS

Dryland plots (5 x 17 feet) at Heppner, Pendleton, and Moro were seeded at 20 seeds per square foot. Irrigated plots at LaGrande (5 x 17 feet) and Hermiston (5 x 20 feet) were seeded at 30 seeds per square foot. Seeding rate for dryland plots ranged from 64 to 108 pounds per acre, depending on variety, in order to attain the desired 20 seeds per square foot seeding rate. 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. Winter and spring wheat and triticale yields are reported on a 10 percent moisture basis and in 60 pound bushels. Wheat and triticale proteins are reported on a 12 percent moisture basis and were determined using a Tecator Infratec 1225 Whole Grain Analyzer purchased for OSU by the Oregon Wheat Commission. Barley protein and moistures have yet to be determined as functional barley software for the whole-grain analyzer is not yet available. Barley yields are reported on an as-is moisture basis.

In addition to small-plot variety tests, large-scale winter wheat drill strip trials have been conducted across the state the last two years. Cooperating growers were provided with 50 to 80 pounds of seed of each variety to be tested. Seed for 1994 trials was donated by Eric and Marnie Anderson and Pendleton Grain Growers. Cooperators, often with assistance of local county agents, established single-replicate drill strip plots on their farms. These drill strips were managed and harvested by the cooperating grower with standard field equipment. Weigh wagons or weigh pads were used to obtain accurate yield data. Table 2 lists sites, grower cooperators, and other background information about 1994 drill strip plot test sites. Two-quart grain samples were saved from each plot and used for test weight and protein analyses.

RESULTS AND DISCUSSION

Yield data for winter and spring grains over all five Columbia Basin test sites are presented in Tables 3-6, along with state-wide averages. Individual site data are presented in Tables 7-25. Data from winter wheat drill strip plots are presented in Table 26.

Winter Wheats and Triticales. Stephens, W301, and Gene were the highest yielding wheat varieties averaged across and within dryland locations (Table 3). These three varieties were also high yielders in 1993, along with Rod and Rohde, suggesting wide adaptation. W301 and Rod were among the highest yielding varieties at LaGrande and Hermiston, while Stephens and Gene showed below trial average performance at these sites. Celia triticale was the highest yielding grain across dryland locations. Growers interested in feed grains should think seriously about triticales as yield and disease resistance are exceptional.

Bonneville, a new hard red winter wheat released by the University of Idaho, was the only variety to consistently lodge across sites (Tables 8, 10, 11). Other varieties showed some lodging, but with no consistency. Grain shattered at Moro (Table 9) with Lambert and Kmor exhibiting highest levels. Protein levels were low at Moro (Table 9) and Heppner (Table 10), suggesting possible nitrogen shortages (Miller and Pan, 1993). Pendleton winter grain proteins (Table 11) were in the desired range with an average of 9.2 percent. Proteins were high at both irrigated sites suggesting surplus nitrogen was present in the soil system. Gene and Madsen (except for Heppner) had above average protein levels across locations, while MacVicar was consistently at or below trial average.

The Moro trial had large numbers of white-heads caused by the dryland root rot complex (*Fusarium graminearum*) and also had a low incidence of flag smut despite the fact that seed was treated with carboxin fungicide. Russian wheat aphids invaded the Heppner plots late in the season but did not appear to have a significant impact on winter grains. Hermiston plots were free of disease and insect pests but did show some winter injury.

Average test weight was below 60 pounds per bushel at all sites but Pendleton. Seeds per pound were also high. Together, these factors suggest that stress late in the season caused small or shrunken seed to be produced at most sites. Test weight performance of wheat varieties varied across sites. Triticale test weights are interesting to compare. Look at the test weights for Bob and Whitman triticales versus that for Celia (Tables 7-11). Bob and Whitman are older-type triticales with wrinkled seed. Celia was selected for improved seed quality and has seed and test weights similar to those of wheat.

Drill strip test data are presented in Table 26. Six varieties were included in the 1994 standard set - Gene, MacVicar, Madsen, Rod, Rohde and Stephens. Rod had the highest yield averaged across sites and was also the highest yielding variety in 9 of the 14 tests. Rod was only mediocre in small-plot performance this year, though it has performed very well in past years. Other varieties were similar in average yield performance.

Winter Barleys. Winter barley data are presented in Table 4 and Tables 12-15. Winter barleys were grown at Moro but harvested grain was lost during processing, hence Moro data is not available. Hesk and Hundred were the highest yielding varieties across dryland locations though their yields are not statistically different from those of Kold or Showin. Kold had better test weights than these other varieties at all locations but Hermiston. Hoody is a hooded, awned variety released for use as a hay. Gwen was released as a dryland variety, but actually performed best this year under irrigated production at Hermiston. Hesk, Hundred, Kold, or Showin appear to be the varieties of choice for the Columbia Basin. Scio has been included in the 1995 variety tests.

Spring Wheats and Triticales. Spring wheat and triticale data are presented in Table 5 and Tables 16-20. Yields at Heppner (Table 19) were significantly impacted by Russian wheat aphid infestation. Triticales and hard wheats were less affected by aphids than soft white wheats. Averaged across dryland locations, Wakanz and Westbred 926R were the highest yielding varieties (Table 5) though they were not statistically significantly different in yield from many other varieties. WB926R has performed well over years. Wakanz is a Hessian fly resistant variety released by Washington State University. It has shown erratic performance over years, but does have excellent yield potential. Wakanz is to be supplanted by Wawawai which also has Hessian fly resistance. Penawawa, the most commonly grown spring wheat in the state (Oregon Agricultural Statistics Service, 1994), was at or below the trial average yield at all Columbia Basin sites and in across site averages. Spring triticales, like their winter counterparts, did extremely well at specific sites and across locations (Table 5 - Victoria or RSI2700).

Spring Barleys. Spring barley data are presented in Table 6 and Tables 21-25. Across dryland sites there were no statistical differences in yield among varieties. Steptoe had the highest yield across dryland locations, as was the case last year, but Baronesse also performed well. As in 1993, Baronesse showed above trial average yield at most sites and exhibited superior test weights. We do not yet know the volunteer potential of these newer varieties in comparison to Steptoe, but our expectation is that there will be less of a problem.

CONCLUSIONS

If you look carefully at the data presented in the accompanying tables, you will discover that there are few, if any, statistical differences in yield among newer varieties. Some would argue that we need to refine our testing program in order to detect differences. I would suggest that our data is adequate (coefficients of variation, a measure of plot-to-plot variability, are not unreasonable) and that varieties are simply similar in yield performance. The drill strip test data presented in Table 26 substantiates this point. When averaged across sites, variety performance tends to be very similar. While high yield is still a goal in all breeding programs, many newer varieties have other attributes that give them an edge over existing varieties. For example, while Baronesse and Steptoe yields are similar, Baronesse has vastly superior test weights.

While Stephens and MacVicar yields are similar, MacVicar consistently has a lower grain protein percentage. As you look through these data and others available to you, remember to think about special variety characteristics that may be of importance to your farming and marketing strategies. Don't judge a variety by it's yield alone.

FOR MORE INFORMATION

Use more than one year's data to make variety selection decisions. For more information, contact your local OSU Extension Service office and ask for a copy of Special Report 755, Winter Cereals for Oregon. This publication contains current year and historic variety performance data for all winter cereals. Your county agent may have other data as well.

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 (503-737-5857).

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Table 1. 1994 state-wide cereal variety testing program locations, stie coordinators and grower cooperators, Oregon

Trial name	Trial type	Trial location	Trial coordinator	Grower cooperator
Corvallis	all grains - dryland	Hyslop Farm	Russ Karow, Helle Ruddenklau	
Heppner	all grains - dryland	Anderson Farm	Pam Zwer, Mike Moore	Charlie Anderson
Hermiston	all grains - irrigated	Hermiston Expt. Station	Russ Karow, Gary Reed, Mike Moore	
Klamath Falls	all grains - irrigated	Klamath Expt. Station	Randy Dovel	
LaGrande	all grains - irrigated	Cuthbert Farm	Pam Zwer, 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	Pam Zwer, Mike Moore	
North Valley	winter grains - dryland	Goetze Farm	Russ Karow, Helle Ruddenklau	Norm Goetze
North Valley	spring grains - dryland	Moritz Farm	Russ Karow, Helle Ruddenklau	Sandy & Mike Moritz
Ontario	all grains - irrigated	Malheur Expt. Station	Mike Barnum, Clint Shock	
Pendleton	all grains - dryland	Pendleton Expt. Station	Pam Zwer, Mike Moore	

Table 2. Growers, locations, and cooperating county agents for 1994 winter wheat drill strip test plots, Oregon and S.W. Washington

Grower	City	County	Irrigation	County Agent
Bruce and Helle Rudde	Amity	Yamhill	No	Susan Aldrich-Markha
Bob Barnes	Salem	Marion	No	Gale Gingrich
Bill Guthrie	Powell Butte	Crook	Yes	Mylen Bohle
Mike Bernards	McMinnville	Yamhill	No	Susan Aldrich-Markha
Alan Klages	Joseph	Wallowa	Yes	Gordon Cook
Mark Hales	Pendleton	Umatilla	No	Mike Stoltz
Mary Ann Hill	Pendleton	Umatilla	No	Mike Stoltz
Bill Miller	Dufur	Wasco	No	Sandy Macnab
Steve Johnson	The Dalles	Wasco	No	Sandy Macnab
Van and Tom Rietmann	Condon	Gilliam	No	Phil Nesse
Dean Nichols	Dayton, WA	Columbia, WA	No	Roland Sherman
Mike Weimer	Arlington	Gilliam	No	Phil Nesse
M & M Ranch	Wasco	Sherman	No	Sandy Macnab
Jim Bird	Grass Valley	Sherman	No	Sandy Macnab

Table 3. 1994 winter wheat and triticale yields for the Columbia Basin and an average over 10 sites in the state-wide variety testing network.

Variety/ line	Market class	Moro	Heppner	Pendleton	Dryland average	Hermiston	LaGrande	10-site average
		(60 lb bushels per acre; 10 percent moisture)						
Cashup	SW	37	64	70	57	131	94	100
Daws	SW	37	56	78	57	121	95	96
Durhiums Pride	SW	33	57	71	53		97	
Gene	SW	39	77	86	68	96	90	98
Hill 81	SW	37	70	81	62	114	92	99
Kmor	SW	27	67	78	57	133	94	
Lambert	SW	22	68	69	53	107		
Lewjain	SW	40	61	75	59	128	78	
MacVicar	SW	36	74	83	64	151	93	105
Madsen	SW	36	69	78	61	118	102	95
Malcolm	SW	35	83	85	67	141	85	102
Nugaines	SW	34	62	65	54	106	95	
Rod	SW	45	65	69	60	140	99	96
Stephens	SW	39	83	88	70	114	88	102
W301	SW	40	80	89	70	128	91	103
Yamhill	SW	26	65	60	50	104	94	85
WA7663	SW	41	64	78	61	138	102	101
Hyak	Club	40	66	85	64	106	81	
Rely	Club	37	55	75	56	119	82	
Rohde	Club	47	62	77	62	121	96	96
Rulo	Club	29	54	70	51		87	
Bonneville	HR	27	34	24	28		56	
Hoff	HR	44	58	71	57	109	93	95
ID426	HR						104	
Celia	Triticale	49	73	94	72	134	90	101
Bob	Triticale	29	62	84	58	105	82	97
Whitman	Triticale	46	69	96	70	119	93	104
Trial average		37	65	76	59	121	91	96
PLSD (5%)		9	10	11	12	21	17	NS
CV (%)		16	9	9	13	10	11	12
P-VALUE		0.00	0.00	0.00	0.00	0.00	0.00	0.07

Trial averages may include some data not shown.

Table 4. 1994 winter barley yields for the Columbia Basin and an average over 9 sites in the state-wide variety testing network. Oregon.

Variety	Market class	Heppner	Pendleton	Dryland average	Hermiston	LaGrande	9-site average
				Yields (lb/a; as is moisture)			
Gwen	6RF	3793	4607	4200	6448	3350	4916
Hesk	6RF	4954	6464	5709	5794	4784	5631
Hoody	6RF	3453	3039	3246	3728	3308	3575
Hundred	6RF	4924	6301	5613	6020	4820	5887
Kamiak	6RF	2481	3254	2868	3767	3059	3671
Kold	6RF	4412	5343	4878	4364	4556	5296
Showin	6RF	4316	5793	5055	6938	4756	5652
Steptoe	6RF	3666	4658	4162	4480	4714	4683
Trial average		4000	4932	4466	5192	4168	4914
PLSD (5%)		968	778	845	1837	831	663
CV (%)		14	9	10	20	11	13
P-VALUE		0.01	0.00	0.00	0.01	0.01	0.00

Table 5. 1994 spring wheat and triticale yields for the Columbia Basin and an average over 11 sites in the state-wide variety testing network. Oregon.

Variety/ line	Market class	Heppner	Moro	Pendleton	Dryland average	Hermiston	LaGrande	11-site average
				Yields (60 lb bushels per acre; 10 percent moisture)				
Alpowa	SW	15	43	46	45	71	49	62
Centennial	SW	11	46	39	43	76	39	67
Dirkwin	SW	2	36	19	27	58	37	52
Owens	SW	8	39	35	37	67	41	59
Penawawa	SW	5	41	33	37	56	35	58
Treasure	SW	16	42	37	40	71	40	61
Wakanz	SW	12	47	69	58	69	42	63
Wawawai	SW	9	41	63	52	73	39	
ID392	SW	17	46	32	39	67	34	58
Calorwa	Club	12	48	43	45	59	48	57
Klasic	HW	22	41	46	43	63	48	61
ID377S	HW	24	44	50	47	75	39	63
Westbred 926R	HR	23	43	65	54	63	38	56
Yecora Rojo	HR	24	48	38	43	60	53	57
Durex	Durum	16	32			40		
Reva	Durum	7	17			12		
Westbred 881	Durum	14	23			41		
D9333	Durum					34		
OR488012	Durum	17	37					
Juan	Triticale	12	41	42	41	79	31	58
Victoria	Triticale	22	43	52	47	76	33	66
RSI 2700	Triticale			60		61		
Trial average		14	40	43	44	60	40	60
PLSD (5%)		6	7	9	13	14	8	7
CV (%)		27	11	13	22	14	12	14
P-VALUE		0.00	0.00	0.00	0.04	0.00	0.00	0.00

Trial averages may include some data not shown.

Table 6. 1994 spring barley yields for the Columbia Basin and an average over 10 sites in the state-wide variety testing network. Oregon.

Variety	Market class	Moro	Heppner	Pendleton	Dryland average	Hermiston	LaGrande	10-site average
				Yield (lb/a; as is moisture)				
Baronesse	2RF	3025	2937	5423	3795	6994	3786	5127
Colter	6RF	3074	1585	4888	3182	6777	3717	4829
Columbia	6RF					6458		
Crest	2RM	2783	2290	4693	3255	6499	4150	4642
Crystal	2RM	2815	1462	5190	3156	5202	3575	4205
Maranna	6RF	3136	1527	5279	3314	7361	3547	5252
Russell	6RM	2822	1479	4452	2918	6198	3629	4694
Steptoe	6RF	3301	3210	4894	3802	5270	3232	4592
Sunstar Bravo	6RF	3121	2500	4730	3450		4017	
Average		3010	2124	4944	3359	6393	3707	4849
PLSD (5%)		NS	565	461	NS	1351	NS	570
CV (%)		10	15	17	13	12	13	13
P-VALUE		0.44	0.00	0.01	0.21	0.04	0.46	0.01

Table 7. 1994 state-wide variety testing program winter wheat and triticale trial on the Hermiston Agricultural Research and Extension Center, Hermiston, OR

Variety/ line	Market class	Plant height (in)	Yield (bu/a)	Test weight (lb/bu)	1000 kernel wgt (g)	Seeds per pound	Protein percent
Hyak	Club	33	105.5	58.8	38.2	11865	12.4
Rely	Club	36	119.1	58.7	34.3	13224	11.7
Rohde	Club	32	121.2	60.2	37.2	12184	11.4
Hoff	HR	35	108.8	62.7	50.5	8982	12.9
Cashup	SW	36	130.5	60.3	39.4	11504	10.7
Daws	SW	34	121.3	58.6	43.7	10373	11.3
Gene	SW	30	95.9	58.6	43.7	10380	12.3
Hill 81	SW	36	114.0	60.5	41.7	10870	11.8
Kmor	SW	35	133.4	57.5	39.1	11601	11.1
Lambert	SW	36	107.1	60.2	51.0	8894	11.6
Lewjain	SW	34	128.3	57.8	36.5	12438	11.6
MacVicar	SW	34	151.4	59.5	49.7	9121	11.0
Madsen	SW	35	117.8	60.4	43.9	10326	12.0
Malcolm	SW	32	141.4	59.7	51.3	8837	11.4
Nugaines	SW	33	105.5	59.5	37.0	12269	11.2
Rod	SW	36	139.7	58.5	42.2	10756	11.0
Stephens	SW	32	113.8	58.6	52.5	8635	11.4
W301	SW	34	128.2	59.8	55.2	8222	11.4
WA7663	SW	35	138.2	57.4	41.1	11045	11.2
Yamhill	SW	37	103.7	57.2	46.5	9761	12.3
Bob	Triticale	45	105.2	51.1	40.8	11126	11.1
Celia	Triticale	38	134.0	58.0	48.4	9372	10.9
Whitman	Triticale	44	119.1	53.9	48.8	9295	10.8
Trial average		35	120.5	58.8	43.6	10404	11.6
PLSD (5%)		3	20.5	1.9	5.4	1288	0.4
CV (%)		5	10	2	7	7	2
P-VALUE		0.00	0.00	0.00	0.00	0.00	0.00

No lodging or shattering was observed Yields adjusted to 10 percent moisture, protein to 12 percent moisture.

Table 8. 1994 state-wide variety testing program winter wheat and triticale trial on the John Cuthbert Ranch, LaGrane, OR

Variety/ line	Market class	Plant height (in)	Lodging percent	Yield (bu/a)	Test Weight (lb/bu)	1000 kernel wgt (g)	Seeds per pound	Protein percent	Moisture percent
Hyak	Club	39	30	81.5	60.4	32.5	13944	11.8	8.3
Rely	Club	42	38	82.4	60.7	33.1	13704	11.5	8.2
Rohde	Club	40	20	96.4	62.8	35.3	12839	12.1	7.8
WA7622	Club	41	3	86.7	57.0	27.8	16317	12.5	8.5
Bonneville	HR	41	53	55.8	62.2	33.1	13692	12.6	8.8
Hoff	HR	36	0	93.1	63.1	39.3	11551	12.1	8.9
Cashup	SW	39	5	93.5	58.6	30.8	14742	12.4	8.3
Daws	SW	40	0	95.1	58.7	31.0	14646	12.8	8.5
Durhiums Pride	SW	40	0	97.2	59.7	35.8	12670	12.1	8.6
Gene	SW	35	0	90.3	58.4	36.5	12417	13.3	8.9
Hill 81	SW	41	0	91.7	60.0	32.3	14043	12.2	8.7
ID426	SW	40	0	104.2	59.4	41.4	10949	12.3	8.9
Kmor	SW	39	7	94.3	58.5	30.5	14858	11.8	8.8
Lewjain	SW	37	13	77.7	57.9	26.6	17033	12.7	8.4
MacVicar	SW	37	0	93.0	58.6	36.5	12427	12.2	8.8
Madsen	SW	38	0	101.9	59.8	37.1	12217	12.6	8.6
Malcolm	SW	36	0	85.5	57.6	35.1	12923	12.5	8.7
Nugaines	SW	36	5	95.4	59.4	30.2	15035	11.9	8.5
Rod	SW	40	7	99.1	57.4	35.8	12681	11.0	8.7
Stephens	SW	36	0	88.1	58.2	39.7	11434	12.2	8.9
W301	SW	36	2	91.2	57.1	37.6	12064	12.8	8.7
WA7663	SW	39	7	102.3	56.6	33.5	13540	11.8	8.7
Yamhill	SW	46	0	94.2	58.6	38.8	11691	12.6	8.9
Bob	Triticale	49	3	82.4	51.1	30.6	14838	12.4	9.3
Celia	Triticale	40	0	90.2	55.4	35.6	12742	12.0	9.0
Whitman	Triticale	48	13	92.9	53.6	41.5	10938	11.3	9.6
Trial Average		40	7	91.2	58.7	34.2	13259	12.3	8.7
PLSD (5%)		3	23	16.7	2.1	5.3	2055	1.1	0.3
CV (%)		6	201	11	2	9	9	5	2
P-VALUE		0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00

Yields adjusted to 10 percent moisture, proteins to 12 percent moisture.

Table 9. 1994 state-wide variety testing program winter wheat and triticale trial on the Sherman Experiment Station, Moro, OR

Variety/ line	Market class	Plant height (in)	Shatter percent	Yield (bu/a)	Test weight (lb/bu)	1000 kernel wgt(g)	Seeds per pound	Protein percent	Moisture percent
Hyak	Club	25	3	39.6	57.8	30.2	15005	8.0	9.1
Rely	Club	26	8	37.1	57.5	27.7	16375	7.4	8.4
Rohde	Club	29	7	47.4	61.1	34.3	13236	7.1	8.7
Rulo	Club	26	3	29.4	57.4	30.9	14694	7.5	8.8
Bonneville	HRW	32	10	26.8	60.6	32.4	14000	8.8	9.7
Hoff	HRW	31	2	43.6	63.0	37.4	12138	7.9	8.9
Cashup	SW	27	2	37.0	60.0	35.2	12875	7.7	9.3
Daws	SW	29	12	36.6	59.2	36.8	12326	7.5	9.3
Durhiums Pride	SW	27	5	32.8	59.7	37.1	12226	7.0	9.1
Gene	SW	27	10	39.4	58.1	40.7	11153	8.2	9.4
Hill 81	SW	28	3	36.8	60.0	33.5	13528	8.2	9.2
Kmor	SW	27	15	26.7	58.9	33.7	13472	7.5	9.3
Lambert	SW	32	20	22.5	55.8	37.5	12086	8.4	10.0
Lewjain	SW	25	5	40.1	61.9	34.1	13302	7.7	8.7
MacVicar	SW	29	12	35.9	59.6	43.5	10428	7.6	9.6
Madsen	SW	27	5	35.9	59.9	38.9	11661	8.6	9.1
Malcolm	SW	27	8	34.8	59.2	37.9	11968	7.6	9.1
Nugaines	SW	26	0	34.1	62.1	32.7	13872	7.6	9.2
Rod	SW	29	3	45.2	58.3	37.4	12119	7.3	9.1
Stephens	SW	28	13	38.6	58.7	42.1	10767	7.9	10.0
W301	SW	29	8	39.8	59.5	40.0	11340	7.8	9.1
WA7663	SW	28	3	41.1	57.9	36.8	12316	6.7	8.7
Yamhill	SW	27	5	26.3	50.9	27.6	16417	9.7	9.8
Bob	Triticale	38	0	29.2	51.0	32.7	13872	7.4	10.3
Celia	Triticale	32	2	48.9	58.0	41.0	11063	6.0	9.1
Whitman	Triticale	36	0	45.8	53.3	39.4	11521	7.0	9.9
Trial average		29	7	36.7	58.6	35.6	12749	7.8	9.3
PLSD (5%)		4	12	9.3	1.4	4.1	1469	0.8	0.8
CV (%)		8	109	16	2	7	7	7	5
P-VALUE		0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00

No lodging was observed.
Flag smut was observed even though seed treatment was used.
Yields are adjusted to 10 percent moisture, protein to 12 percent moisture.

Table 10. 1994 state-wide variety testing program winter wheat and triticale trial on the Charlie Anderson Ranch, Heppner, OR

Variety	Market class	Plant height (in)	Lodging percent	Yield (bu/a)	Test weight (lb/bu)	1000 kernel wgt (g)	Seeds per pound	Protein percent	Moisture percent
Hyak	Club	38	0	66.3	57.8	37.0	12269	8.6	9.0
Rely	Club	38	0	55.4	59.4	39.7	11417	8.9	9.2
Rohde	Club	37	3	61.5	58.8	37.5	12086	8.7	9.0
Rulo	Club	36	0	53.9	58.7	37.4	12128	9.1	10.2
Bonneville	HRW	43	40	33.9	58.9	34.6	13121	10.0	10.6
Hoff	HRW	40	2	57.6	60.4	39.2	11580	9.8	10.1
Cashup	SWW	35	0	63.5	59.5	37.8	12010	10.1	12.1
Daws	SWW	36	0	56.5	57.1	43.3	10476	9.5	12.6
Durhiums Pride	SWW	38	3	56.6	57.1	46.8	9692	9.2	12.9
Gene	SWW	33	0	77.2	56.9	39.5	11475	9.3	9.7
Hill 81	SWW	40	0	69.5	59.1	38.2	11865	9.0	10.7
Kmor	SWW	35	0	67.3	57.8	38.8	11691	7.8	11.5
Lambert	SWW	39	0	67.6	56.8	47.9	9476	8.6	9.9
Lewjain	SWW	35	2	60.9	59.3	35.9	12625	8.8	12.0
MacVicar	SWW	36	0	74.2	62.4	50.9	8912	7.7	10.5
Madsen	SWW	35	0	69.4	60.6	42.0	10792	8.1	12.2
Malcolm	SWW	36	0	82.7	59.2	49.1	9244	8.1	11.5
Nugaines	SWW	32	0	61.6	59.9	38.8	11700	8.2	10.3
Rod	SWW	37	0	65.1	56.4	47.6	9535	8.2	13.3
Stephens	SWW	35	0	82.9	59.4	47.5	9556	8.9	9.8
W301	SWW	34	0	79.9	58.6	46.7	9713	8.6	9.6
WA7663	SWW	33	0	63.8	55.7	47.7	9503	8.4	13.7
Yamhill	SWW	40	7	64.6	58.0	44.2	10269	8.3	9.9
Bob	Triticale	42	0	61.5	49.6	38.6	11751	7.5	13.1
Celia	Triticale	36	0	73.2	58.1	40.7	11137	7.6	10.6
Whitman	Triticale	44	0	69.2	51.4	41.2	11010	8.2	10.8
Trial average		37	2	64.9	57.8	41.5	10941	8.7	10.9
PLSD (5%)		3	14	9.8	4.0	4.8	1265	1.5	1.4
CV (%)		4	445	9	4	7	7	11	8
P-VALUE		0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00

No shattering was observed.
Yields adjusted to 10 percent moisture, proteins to 12 percent moisture.

Table 11. 1994 state-wide variety testing program winter wheat and triticale trial on the Pendleton Experiment Station, Pendleton, OR

Variety/ line	Market class	Heading date	Plant height (in)	Lodging percent	Yield (bu/a)	Test weight (lb/bu)	1000 kernel wgt (g)	Seeds per pound	Protein percent	Moisture percent
Hyak	Club	135	38	0	85.3	61.4	35.8	12670	8.6	6.5
Rely	Club	143	38	8	75.2	61.1	34.4	13198	9.0	6.3
Rohde	Club	140	35	10	77.2	63.2	35.1	12934	8.6	5.9
Rulo	Club	143	37	0	69.6	59.1	32.4	13987	9.2	6.4
Bonneville	HRW	143	39	95	24.1	61.6	34.3	13224	11.5	7.7
Hoff	HRW	133	38	15	71.0	63.6	37.3	12151	9.6	7.7
Cashup	SWW	143	34	0	70.1	60.5	33.2	13675	9.5	6.8
Daws	SWW	141	35	2	78.5	61.4	38.1	11906	9.5	6.8
Durhiums Pride	SWW	142	37	1	70.7	61.9	36.3	12486	8.9	6.7
Gene	SWW	137	34	2	86.4	59.6	34.0	13341	10.3	7.4
Hill 81	SWW	143	38	0	80.6	60.3	31.0	14646	9.0	7.1
Kmor	SWW	144	33	0	77.7	59.9	33.0	13733	8.9	6.6
Lambert	SWW	139	40	0	69.0	60.5	42.9	10566	9.4	7.7
Lewjain	SWW	139	35	0	75.0	61.8	32.5	13944	9.3	6.5
MacVicar	SWW	141	36	0	82.7	61.8	40.2	11292	9.2	7.2
Madsen	SWW	144	36	0	77.8	61.3	35.3	12861	10.8	7.5
Malcolm	SWW	139	36	0	84.6	61.2	39.6	11446	9.0	7.2
Nugaines	SWW	143	34	3	65.1	60.9	30.9	14694	8.6	6.8
Rod	SWW	144	36	30	69.1	59.6	39.3	11551	8.1	7.4
Stephens	SWW	138	34	0	88.0	61.5	43.0	10549	9.5	7.2
W301	SWW	139	35	0	89.2	61.6	42.7	10623	9.5	7.0
WA7663	SWW	145	35	0	78.3	59.5	35.3	12839	8.1	7.0
Yamhill	SWW	142	40	2	59.8	57.9	33.8	13408	10.0	7.9
Bob	Triticale	146	44	0	84.5	53.8	37.3	12161	8.0	7.8
Celia	Triticale	138	39	0	94.2	59.8	38.0	11937	7.8	7.5
Whitman	Triticale	130	48	0	96.3	57.3	44.4	10223	8.2	8.1
Trial average		141	37	6	76.4	60.6	36.0	12600	9.2	7.1
PLSD (5%)		2	3	12	11.3	1.0	3.1	1085	0.7	0.5
CV (%)		1	4	129	9	1	5	5	5	4
P-VALUE		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

No shattering was observed.
Yields are adjusted to 10 percent moisture, proteins to 12 percent moisture.

Table 12. 1994 state-wide variety testing program winter barley trial on the Hermiston Research and Extension Center, Hermiston, OR

Variety	Market class	Stand rating 4-1-94	Plant height (in)	Yield (lb/a)	Test weight (lb/bu)	1000 kernel wgt (g)
Gwen	6RF	2.7	32	6448	51.0	38.0
Hesk	6RF	2.3	33	5794	50.4	42.1
Hoody	6RF	3.7	34	3728	47.3	37.4
Hundred	6RF	4.0	30	6020	48.9	37.2
Kamiak	6RF	4.0	31	3767	52.2	40.5
Kold	6RF	3.0	34	4364	50.7	39.0
Showin	6RF	4.3	29	6938	51.2	38.9
Steptoe	6RF	0.7	35	4480	50.6	53.9
Trial average		3.1	32	5192	50.3	40.9
PLSD (5%)		1.32	NS	1837	1.6	3.9
CV (%)		24	8	20	2	5
P-VALUE		0.01	0.15	0.01	0.00	0.00

Stand rating 1-5 scale (poor to excellent).
No lodging or shattering was observed.

Table 13. 1994 state-wide variety testing program winter barley trial on the John Cuthbert Ranch, LaGrande, OR

Variety	Market class	Plant height (in)	Yield (lb/a)	Test weight (lb/bu)	1000 kernel wgt (g)	Seeds per pound
Gwen	6RF	29	3350	51.0	32.4	13987
Hesk	6RF	30	4784	50.3	37.4	12119
Hoody	6RF	36	3308	46.5	40.2	11275
Hundred	6RF	30	4820	48.0	32.2	14087
Kamiak	6RF	32	3059	51.9	38.2	11865
Kold	6RF	30	4556	52.1	39.5	11484
Showin	6RF	23	4756	49.3	37.7	12022
Steptoe	6RF	30	4714	50.7	48.3	9385
Trial average		30	4168	50.0	38.3	11856
PLSD (5%)		5	831	2.0	5.4	1672
CV (%)		9	11	2	8	8
P-VALUE		0.01	0.01	0.01	0.00	0.00

No lodging or shattering was observed.

Table 14. 1994 state-wide variety testing program winter barley trial on the Charlie Anderson Ranch, Heppner, OR

Variety	Market class	Plant height (in)	Lodging percent	Yield lb/a	Test weight (lb/bu)
Gwen	6RF	37	0	3793	54.5
Hesk	6RF	34	0	4954	52.6
Hoody	6RF	36	17	3453	51.3
Hundred	6RF	33	3	4924	51.0
Kamiak	6RF	37	8	2481	53.0
Kold	6RF	31	0	4412	54.4
Showin	6RF	21	0	4316	51.5
Steptoe	6RF	36	0	3666	52.7
Trial average		33	4	4000	52.6
PLSD (5%)		6	11	968	0.8
CV (%)		10	165	14	1
P-VALUE		0.00	0.05	0.01	0.00

No shattering was observed.

Table 15. 1994 state-wide variety testing program winter barley trial on the Pendleton Experiment Station, Pendleton, OR

Name	Market class	Plant height (in)	Lodging percent	Shatter percent	Yield (lb/a)	Test weight (lb/bu)
Gwen	6RF	37	0	3	4607	52.6
Hesk	6RF	34	0	5	6464	50.8
Hoody	6RF	40	27	0	3039	49.0
Hundred	6RF	31	0	0	6301	49.3
Kamiak	6RF	38	95	17	3254	52.2
Kold	6RF	32	0	13	5343	53.2
Showin	6RF	25	0	0	5793	50.1
Steptoe	6RF	35	3	2	4658	51.9
Trial average		34	16	5	4932	51.2
PLSD (5%)		3	11	9	778	1.1
CV (%)		5	40	100	9	1
P-VALUE		0.00	0.00	0.01	0.00	0.00

No shattering was observed.

Table 16. 1994 state-wide variety testing program spring grain trial on the Hermiston Research and Extension Center, Hermiston, OR

Variety/ line	Market class	Plant height (in)	Yield (bu/a)	Test weight (lb/bu)	Protein percent	Moisture percent
Calorwa	Club	31	59.3	61.3	13.1	10.3
D9333	Durum	31	34.0	61.2	16.0	10.6
Durex	Durum	30	40.4	60.8	15.4	10.9
Reva	Durum	23	11.7	57.0	17.0	10.3
Westbred 881	Durum	30	40.7	59.1	15.8	10.7
Westbred 926R	HR	32	62.9	62.3	14.7	11.0
Yecora Rojo	HR	23	59.7	63.0	15.2	10.3
ID 377S	HW	36	74.9	62.9	14.3	10.8
Klasic	HW	32	63.2	61.4	13.7	10.4
Alpowa	SW	34	70.6	62.2	12.2	9.6
Centennial	SW	32	76.0	61.8	12.4	10.1
Dirkwin	SW	36	58.0	56.2	12.0	11.6
ID 392	SW	36	67.1	61.8	12.0	10.2
ML 042A	SW	31	52.7	61.1	14.2	10.5
Owens	SW	35	67.0	60.4	13.0	10.6
Penawawa	SW	32	55.5	60.5	13.3	9.8
Treasure	SW	32	70.7	59.5	12.3	11.0
Wakanz	SW	36	68.9	59.1	12.4	10.9
Wawawai (WA 7712)	SW	40	73.1	61.5	12.1	10.5
Juan	Triticale	53	78.7	52.8	12.1	11.4
RCI 2700	Triticale	62	61.1	47.5	13.5	11.1
Victoria	Triticale	50	76.5	52.0	12.0	10.8
Trial average		35	60.1	59.3	13.6	10.6
PLSD (5%)		5	14.4	1.9	1.0	1.2
CV (%)		8	14	2	4	7
P-VALUE		0.00	0.00	0.00	0.00	0.00

Yields adjusted to 60 lb bushels and 10 percent moisture.
Proteins adjusted to 12 percent moisture.

Table 17. 1994 state-wide variety testing program spring grain trial on the John Cuthbert Ranch, LaGrande, OR

Variety/ line	Market class	Plant height (in)	Yield (bu/a)	Test weight (lb/bu)	Protein percent	Moisture percent
Calorwa	Club	33	47.8	52.7	14.0	8.3
Westbred 926R	HR	29	38.2	51.3	16.0	9.0
Yecora Rojo	HR	28	52.7	55.2	15.2	8.8
ID377S	HW	31	39.0	51.6	16.3	9.3
Klasic	HW	31	48.0	54.3	15.4	8.8
Alpowa	SW	34	49.0	53.3	14.4	8.4
Centennial	SW	35	38.9	53.9	14.1	8.8
Dirkwin	SW	33	36.8	49.3	14.3	9.7
ID392	SW	34	33.8	51.4	14.2	8.7
Owens	SW	37	41.1	51.2	15.1	8.7
Penawawa	SW	35	35.4	51.9	15.8	8.6
Treasure	SW	33	40.1	51.9	15.7	9.0
Wakanz	SW	35	41.8	49.7	14.5	9.2
Wawawai	SW	38	38.8	53.3	14.1	9.1
Juan	Triticale	34	30.5	44.8	13.4	10.0
Victoria	Triticale	33	32.8	43.7	14.0	9.8
Trial average		33	40.3	51.2	14.8	9.0
PLSD (5%)		NS	8.1	2.2	1.1	0.5
CV (%)		15	12	3	4	3
P-VALUE		0.66	0.00	0.00	0.00	0.00

No lodging or shattering observed.
Yields adjusted to 10 percent moisture, proteins to 12 moisture.

Table 18. 1994 state-wide variety testing program spring grain trial on the Sherman Experiment Station, Moro, OR

Name	Market class	Plant height (in)	Yield (bu/a)	Test weight (lb/bu)	Protein percent	Moisture percent
Calorwa	Club	22	48.1	59.0	12.1	8.6
Durex	Durum	23	31.6	59.5	13.7	9.9
OR488012	Durum	21	37.3	60.1	13.0	9.8
Reva	Durum	18	16.6	57.4	15.9	9.6
Westbred 881	Durum	20	23.1	57.5	14.3	10.0
Westbred 926R	HR	26	43.2	61.6	12.9	9.8
Yecora Rojo	HR	20	48.2	62.4	12.7	9.4
ID377S	HW	27	43.5	58.6	12.9	9.3
Klasic	HW	21	41.1	61.2	13.1	9.4
Alpowa	SW	27	42.6	59.1	11.0	9.2
Centennial	SW	25	45.7	61.4	11.9	8.6
Dirkwin	SW	28	36.0	57.0	12.5	9.2
ID392	SW	28	45.5	59.6	11.5	8.8
Owens	SW	30	39.0	58.2	12.7	9.0
Penawawa	SW	23	40.7	58.7	12.3	9.0
Treasure	SW	25	42.2	58.6	11.9	8.9
Wakanz	SW	25	46.5	56.9	12.4	8.9
Wawawai	SW	30	40.8	58.3	12.0	9.2
Juan	Triticale	37	40.9	50.1	11.2	9.9
Victoria	Triticale	32	42.9	48.7	11.2	9.7
Trial average		26	39.8	58.2	12.6	9.3
PLSD (5%)		3	7.1	1.4	0.7	0.5
CV (%)		7	11	1	3	4
P-VALUE		0.00	0.00	0.00	0.00	0.00

No lodging or shattering observed.

Yields adjusted to 10 percent moisture, proteins to 12 percent moisture.

Table 19. 1994 state-wide variety testing program spring grain trial on the Charlie Anderson Ranch, Heppner, OR

Variety/ line	Market class	Plant height (in)	Lodging percent	Yield (bu/a)	Test weight (lb/bu)	Protein percent	Moisture percent
Calorwa	Club	24	0	12.1	55.3	17.3	9.5
Durex	Durum	21	0	16.1	56.6	17.2	9.9
OR488012	Durum	20	0	17.5	57.5	16.2	10.0
Reva	Durum	18	0	6.6	--	--	--
Westbred 881	Durum	23	3	13.9	55.5	17.5	10.2
Westbred 926R	HR	28	0	23.1	55.1	17.2	9.9
Yecora Rojo	HR	23	0	23.6	57.2	16.8	9.5
ID377S	HW	28	0	24.4	56.3	16.6	10.3
Klasic	HW	20	0	22.3	56.6	16.9	9.8
Alpowa	SW	25	0	15.1	57.9	17.1	9.5
Centennial	SW	24	0	11.1	56.7	16.9	9.9
Dirkwin	SW	25	0	2.1	--	--	--
ID392	SW	27	0	17.2	55.3	16.6	9.6
Owens	SW	25	0	8.3	--	--	--
Penawawa	SW	21	0	5.1	--	--	--
Treasure	SW	27	0	15.5	55.5	17.3	9.6
Wakanz	SW	29	0	12.3	57.1	16.5	9.7
Wawawai	SW	32	0	8.7	--	--	--
Juan	Triticale	37	8	11.6	46.9	14.0	10.8
Victoria	Triticale	42	2	22.0	46.6	13.8	10.5
Trial average		26	1	14.4	55.1	16.5	9.9
PLSD (5%)		4.8	3	6.3	1.7	1.0	0.4
CV (%)		11	330	27	2	4	3
P-VALUE		0.00	0.00	0.00	0.00	0.00	0.00

-- = samples were too small to allow quality testing.
Yields adjusted to 10 percent moisture, proteins to 12 percent moisture.
No shattering observed.
Russian wheat aphid infestation was severe.

Table 20. 1994 state-wide variety testing program spring grain trial on the Pendleton Experiment Station, Pendleton, OR

Variety/ line	Market class	Julian heading date	Plant height (in)	Yield (bu/a)	Test weight (lb/bu)	Protein percent	Moisture percent
Calorwa	Club	147	30	42.9	61.5	10.3	8.7
Westbred 926R	HR	147	30	65.3	62.9	11.4	9.2
Yecora Rojo	HR	148	25	38.4	62.9	11.1	9.1
ID377S	HW	151	32	50.0	61.4	10.4	9.5
Klasic	HW	148	23	45.8	61.9	12.0	9.1
Alpowa	SW	151	30	46.5	60.8	9.0	8.4
Centennial	SW	147	30	39.3	61.1	10.2	8.7
Dirkwin	SW	152	30	18.8	56.0	11.3	10.0
ID392	SW	151	31	32.3	59.0	10.5	8.7
Owens	SW	150	42	35.0	58.4	11.0	8.9
Penawawa	SW	150	30	32.7	58.7	11.2	9.1
Treasure	SW	151	32	37.3	59.1	9.9	8.7
Wakanz	SW	149	35	69.1	59.7	9.9	8.7
Wawawai	SW	150	40	63.1	63.1	9.3	9.2
Juan	Triticale	151	44	42.1	50.0	9.8	9.8
RC12700	Triticale	153	52	60.3	52.2	9.5	9.6
Victoria	Triticale	149	45	52.0	51.3	9.4	9.8
Trial average		150	34	43.0	59.0	10.6	9.1
PLSD (5%)		--	7	9.3	0.9	0.9	0.6
CV (%)		--	19	13	1	5	4
P-VALUE		--	0.00	0.00	0.00	0.00	0.00

No lodging or shattering was observed.
Yields adjusted to 60 lb bushels and 10 percent moisture.
Proteins adjusted to 12 percent moisture.

Table 21. 1994 state-wide variety testing program spring barley trial on the Hermiston Research and Extension Center, Hermiston, OR

Variety	Market class	Plant height (in)	Yield (lb/a)	Test weight (lb/bu)	1000 Seed Weight (g)
Baronesse	2RF	42	6994	55.2	50.9
Colter	6RF	44	6777	55.1	44.7
Columbia	6RF	38	6458	51.5	44.7
Crest	2RM	44	6499	54.8	54.6
Crystal	2RM	44	5202	54.8	55.5
Maranna	6RF	36	7361	54.0	43.9
Russell	6RM	43	6198	55.8	56.2
SDM306	6RF	36	6775	53.5	44.9
Steptoe	6RF	40	5270	53.0	51.5
Trial average		41	6393	54.2	49.7
PLSD (5%)		4	1351	1.4	NS
CV (%)		5	12	2	22
P-VALUE		0.00	0.04	0.00	0.69

Limited lodging and no shattering were observed.
Yields have not been moisture adjusted.

Table 22. 1994 state-wide variety testing program spring barley trial on the John Cuthbert Ranch, LaGrande, OR

Name	Market class	Plant height (in)	Lodging percent	Yield (lb/a)	Test weight (lb/bu)
Baroness	2RF	33	37	3786	49.4
Colter	6RF	38	50	3717	47.5
Crest	2RM	35	35	4150	48.6
Crystal	2RM	36	7	3575	49.7
Maranna	6RF	31	27	3547	43.9
Russell	6RM	34	23	3629	49.3
Steptoe	6RF	36	57	3232	45.3
Sunstar	6RF	38	43	4017	49.4
Trial average		35	35	3707	47.9
PLSD (5%)		NS	NS	NS	2.5
CV (%)		10	96	13	3
P-VALUE		0.20	0.68	0.46	0.00

No shattering was observed.
Yields have not been moisture adjusted.

Table 23. 1994 state-wide variety testing program spri barley trial on the Sherman Experiment Stati Moro, OR

Variety	Market class	Plant height (in)	Yield (lb/a)	Test weight (lb/bu)
Baroness	2RF	23	3025	52.1
Colter	6RF	26	3074	49.6
Crest	2RM	23	2783	50.2
Crystal	2RM	25	2815	52.2
Maranna	6RF	22	3136	49.6
Russell	6RM	27	2822	51.3
Steptoe	6RF	24	3301	50.2
Sunstar	6RF	26	3121	50.6
Trial average		25	3010	50.7
PLSD (5%)		2	NS	NS
CV (%)		5	10	2
P-VALUE		0.00	0.44	0.13

No lodging or shattering observed.

Table 24. 1994 state-wide variety testing program spri barley trial on the Charlie Anderson Ranch, Heppner, OR

Variety	Market class	Plant height (in)	Yield (lb/a)	Test weight (lb/bu)
Baroness	2RF	34	2937	53.3
Colter	6RF	31	1585	49.5
Crest	2RM	35	2290	52.8
Crystal	2RM	29	1462	51.2
Maranna	6RF	25	1527	48.9
Russell	6RM	38	1479	51.2
Steptoe	6RF	35	3210	49.6
Sunstar	6RF	34	2500	50.0
Trial average		33	2124	50.8
PLSD (5%)		NS	565	2.0
CV (%)		16	15	2
P-VALUE		0.14	0.00	0.00

No lodging or shattering observed.

Table 25. 1994 state-wide variety testing program spring barley trial on the Pendleton Experiment Station, Pendleton, OR

Variety	Market class	Plant height (in)	Yield (lb/a)	Test weight (lb/bu)
Baronesse	2RF	38	5423	54.8
Colter	6RF	39	4888	53.1
Crest	2RM	37	4693	55.6
Crystal	2RM	39	5190	55.3
Maranna	6RF	31	5279	53.8
Russell	2RM	38	4452	54.9
Steptoe	6RF	39	4894	52.0
Sunstar	6RF	40	4730	53.4
Trial average		38	4944	54.1
PLSD (5%)		3	461	1.2
CV (%)		5	17	1
P-VALUE		0.00	0.01	0.00

Neither lodging nor shattering was observed.

Table 26. 1994 drill strip winter wheat variety tests at fourteen sites across Oregon and southeast Washington

Variety	Ruddenklau Amity	Barnes Salem	Guthrie Prinevi	Bernards McMinn	Klages Joseph	Hales Pendl	Hill Pendl	Miller Dufur	John-son Dalles	Rietmann Condon	Nichols Dayton	Weimer Arltng	M&M Ranch Wasco	Bird Grs Vly	Average over 11 sites
							Yield - bu/a								
Dur.Pride						80	62				47				
Gene	160	142	113	118	120	72	75	82	65	48	59	58	30		88
MacVicar	154	157	141	133	119	86	78	49	45	58	57	48	20	33	88
Madsen	149	105	126	123	114	77	70	70	50	55	58	53	51	31	86
Malcolm	147														
Rod	141	138	153	133	125	89	82	69	91	57	45	65	28	37	95
Rohde	131	117	131	115	116	82	70	65	55	51	54	31	46	36	82
Stephens	149		121	121	109	83	78	79	61	57	50	50			87
Crew/Hyak								71							
Average	147	132	131	124	117	81	76	69	61	54	54	51	35	34	88
													PLSD (10%)		7
							Test weight - lb/bu								
D. Pride						61.6	62.5				57.5				
Gene	57.4	57.9	56.6	60.1	56.2	58.6	60.5	58.9	60.5	58.8	55.0	60.5	58.0		58.5
MacVicar	58.2	60.7	58.8	61.6	55.4	62.0	62.5	60.0	60.7	60.2	56.0	61.8	57.1	61.7	59.8
Madsen	61.1	60.0	58.3	61.6	57.9	60.6	61.2	59.4	60.7	59.3	58.0	60.2	58.8	57.8	59.8
Malcolm	58.9														
Rod	58.0	60.1	59.2	60.8	57.1	61.9	60.9	58.8	59.2	58.1	56.0	59.5	56.6	58.5	59.0
Rohde	61.4	61.7	61.1	62.5	59.5	61.9	62.8	60.4	61.5	58.6	60.0	61.2	60.7	60.2	61.0
Stephens	59.1	59.2	58.6	60.7	57.7	60.3	61.8	59.5	61.2	59.6	55.0	61.3	56.5		59.5
Crew/Hyak								57.7							
Average	59.2	59.9	58.8	61.2	57.3	61.0	61.7	59.2	60.6	59.1	56.8	60.7	58.0	59.6	59.6
													PLSD (10%)		0.7
							Protein percent								
D. Pride						--	11.2								
Gene	--	9.5	11.9	10.0	11.2	--	10.2	7.3	10.7	7.8	--	7.3	10.4	8.2	8.0
MacVicar	--	9.7	10.4	9.3	9.2	--	9.7	7.7	8.8	7.8	--	6.8	11.5	7.5	7.6
Madsen	--	9.8	11.3	10.1	10.4	--	10.5	8.4	10.2	7.2	--	6.5	10.5	8.1	7.9
Malcolm	--														
Rod	--	9.1	10.1	9.1	9.4	--	9.0	7.3	8.6	6.9	--	6.2	9.3	7.2	7.1
Rohde	--	10.0	11.0	9.2	9.8	--	9.9	7.7	8.3	6.2	--	6.3	9.7	7.2	7.3
Stephens	--	8.4	11.2	9.3	10.3	--	9.7	8.7	10.3	7.1	--	7.3	9.6	8.1	7.7
Crew/Hyak								7.3							
Average		9.4	11.0	9.5	10.1		10.0	7.8	9.5	7.2		6.7	10.2	7.7	7.6

Due to field or harvest problems, some yield data were lost.

We thank Anderson Seeds of Ione and Pendleton Grain Growers for supplying seed for these trials.

LONG-TERM TRENDS IN CEREAL YIELDS AT PENDLETON

Paul E. Rasmussen and Richard W. Smiley

INTRODUCTION

The yield of cereal grains, as well as that of many other crops, has risen over the years in response to variety improvement, better weed and disease control, greater water conservation techniques, and improved fertility management. The Pendleton Agricultural Research Center maintains several long-term experiments from which it is possible to extract trends in crop yield over time. The Center is located in the 16-18 inch precipitation zone which is the transition zone between annual cropping and wheat/fallow rotations. We often encourage annual cropping over a wheat/fallow rotation because it is much more effective in maintaining soil organic matter and other soil quality relations in areas traditionally prone to high soil erosion rates. Winter wheat yield is normally higher after fallow than after annual cropping. But the difference is not wide and has been closing in recent years. Is this the result of more efficient varieties better adapted to using water more efficiently? Or is it due to better growing conditions because of periodic fluctuation in the climate? We present and interpret some of the changes that have occurred over the past 60 years.

ROTATIONAL EFFECTS ON WINTER WHEAT YIELD

The nine-year moving average (average of 9 previous years) for winter wheat yield following fallow, spring peas, and winter wheat is presented in Figure 1. While the general trend has been steadily upward, there was a sharp jump in the mid

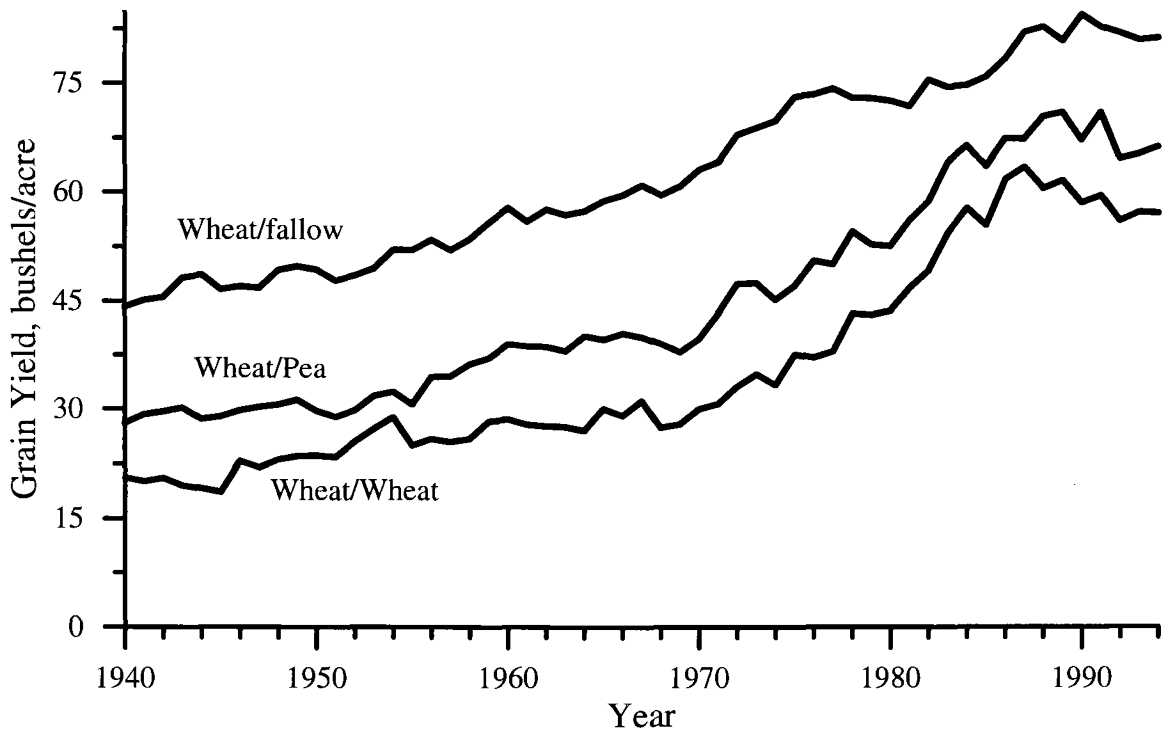

Figure 1. Nine year moving average of wheat grain yields following fallow, spring peas, and winter wheat at the Pendleton Agric. Res. Ctr., 1940-1994.

1960s after the introduction of semi-dwarf wheat. The upward trend since 1967 is more difficult to interpret, since it coincides with a very favorable winter weather pattern (Figure 2). The drop in yield the past 8-9 years appears highly related to a sharp drop in winter precipitation. The cropping trend is especially true for wheat grown annually, but also occurs for wheat following fallow. Variations in precipitation levels must be closely investigated when analyzing long-term yield trends, because drought stress occurs most years.

Wheat yield for annual cropping rose the same amount (24 bushels/acre) for the 1967-94 period as did yield for wheat in a wheat/fallow rotation. This strongly suggests that semi-dwarf wheats have better water-use efficiency (WUE) than the older medium-tall varieties. Most of the WUE is presumably attained by less winter dormancy, which permits earlier more vegetative growth in the spring before the onset of hot dry conditions. While differences in winter wheat yield between fallowing and annual cropping continue to decrease, there is greater fluctuation in winter wheat yield in annual cropping because of greater sensitivity to drought stress when it occurs. Thus, while it may be more profitable to annual crop, the risk of crop failure is higher.

Within annual cropping, there is about a 10 bushel/acre gain in winter wheat yield following spring peas compared to following winter wheat. Some of the difference can result from less depletion of soil water by peas than wheat the preceding year, but the rotational effect also contributes strongly. Rotation to a legume decreases the intensity of many soil-borne wheat diseases. No special disease management practices have been applied to these experiments.

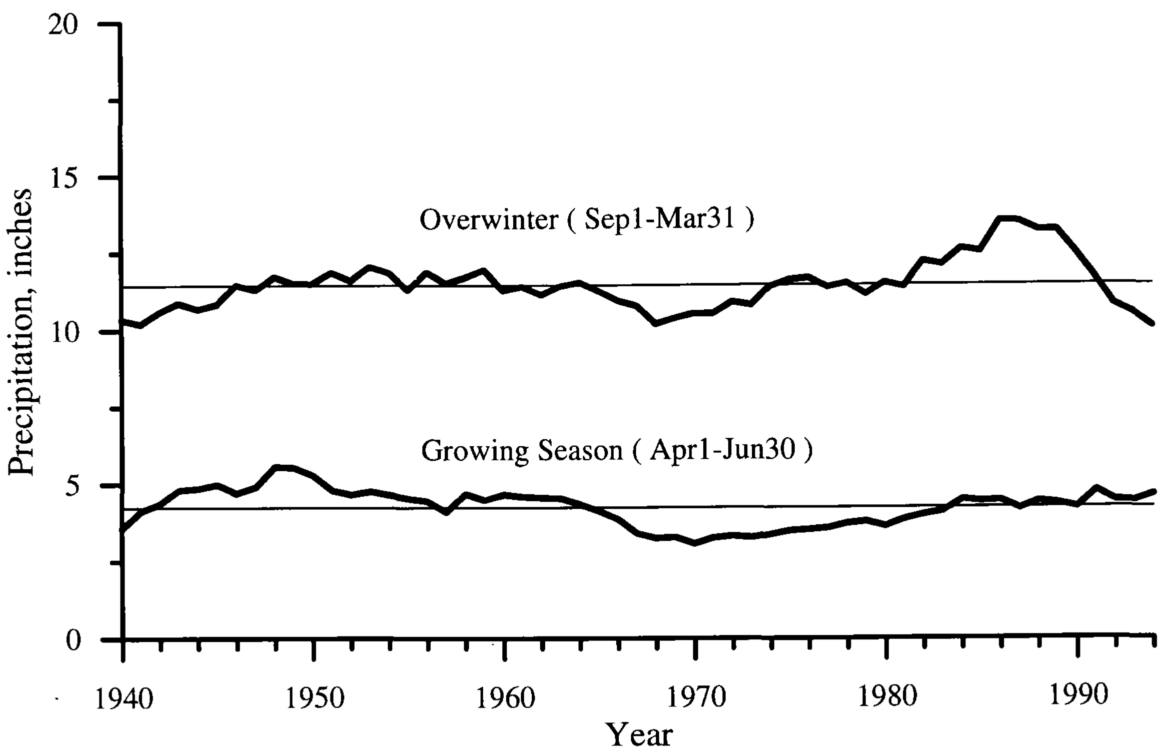

Figure 2. Nine year moving average for overwinter and growing season precipitation at the Pendleton Agric. Res. Ctr., 1940-1994.

PRECIPITATION EFFECTS ON WHEAT YIELD

Winter wheat following spring peas is slightly more sensitive to the amount of overwinter precipitation than is wheat following fallow (Figure 3). Winter wheat following peas also responds much more to growing-season rainfall than does wheat following fallow (Figure 4). This could be due to both a larger effect on total precipitation, or to greater late-season drought stress produced by lower total water available and slightly later seeding dates. The sensitivity of wheat yield to precipitation is usually much greater for semi-dwarf wheat grown after 1967 than for the taller varieties grown earlier. Growing-season precipitation has a much greater effect on yield than does winter precipitation. In the wheat/pea rotation, each additional inch of winter precipitation is worth about 2.4 bushels/acre, and each additional inch of growing-season rainfall is worth 9.7 bushels/acre.

In Figures 3 and 4, there is a fairly wide fluctuation in yield, even under specified conditions. A number of other factors affect wheat yield, such as soil temperature, efficiency of water storage, intensity of disease and weed infestation, stand establishment and tillering, and high air temperatures at flowering. Often, many of the variables are related, (e.g. precipitation and temperature) so that the effect of any single variable is difficult to interpret. We can presently define some of the variables that affect wheat yield, but our precision is fairly low. Maintaining and analyzing long-term experiments give us a start towards better prediction of yield under a variety of cropping systems.

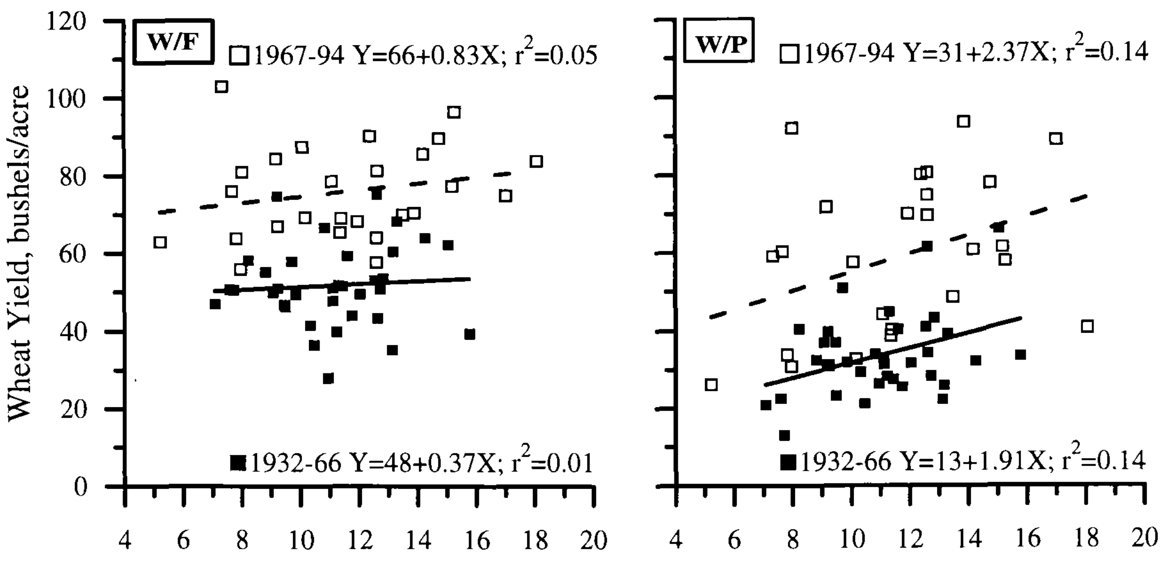

Figure 3. Sensitivity of wheat yield to the level of overwinter precipitation when grown following fallow or spring peas. 1932-1966 (medium tall wheat) and 1967-1994 (semi-dwarf wheat). Pendleton Agric. Res. Ctr.
W/F = wheat/fallow W/P = wheat/pea crop rotation.

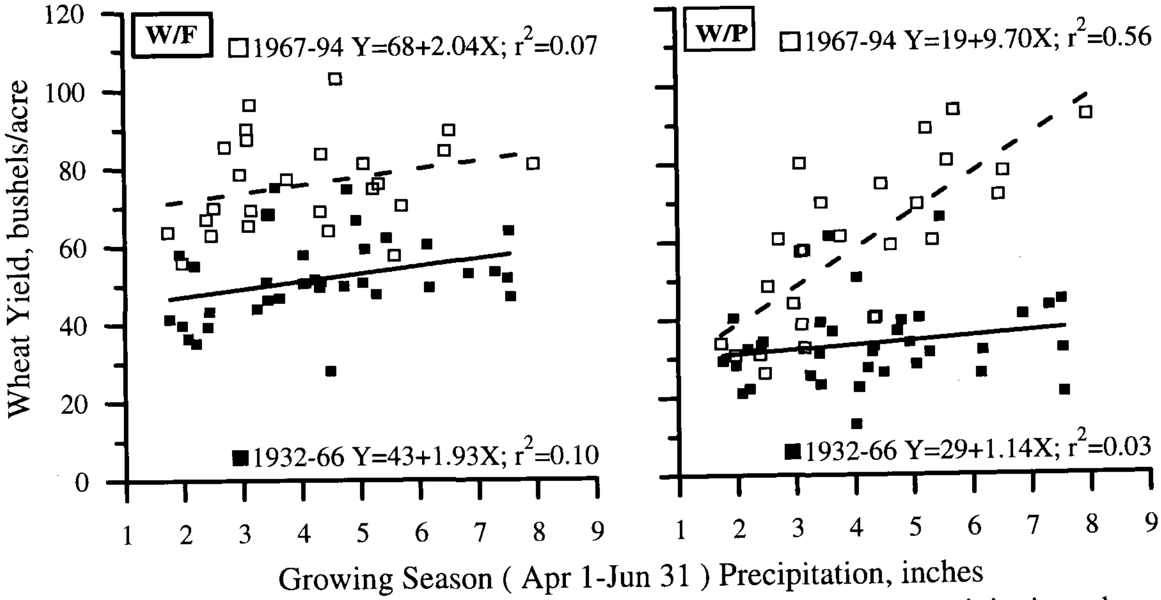

Figure 4. Sensitivity of winter wheat yield to level of growing-season precipitation when grown following fallow or spring peas. 1932-1966 (medium tall wheat) and 1967-1994 (semi-dwarf wheat). Pendleton Agric. Res. Ctr.
W/F = wheat/fallow W/P = wheat/pea crop rotation.

EFFECT OF CROP RESIDUE ON DOWNY BROME EMERGENCE

R. Holowecky, B. Klepper
and D. Wilkins

INTRODUCTION

The 1985 Food Security Act mandates that tillage and residue management systems should be implemented on highly erodible land (HEL) to slow soil erosion to acceptable levels. Many growers have elected to leave a minimum of 30 percent residue on the surface of their fields to meet these requirements. Growers in the Pilot Rock area noticed a marked increase in the incidence of downy brome (*Bromus tectorum* L.) in their winter wheat fields when they left sufficient residue on the soil surface to comply with conservation requirements. Similar increases in downy brome have been observed in other fields under tillage systems designed to retain more crop residues on the soil surface (Veseth et al., 1994).

An experiment was conducted in 1993 to study effects of surface residue, weather, and soil conditions on downy brome emergence. The plots were set on newly-seeded winter wheat fields in the Pilot Rock area. Treatments included four levels of crop residue: none (background level, about 10 percent) and additions of residue to give 20, 30, and 40 percent cover.

In these experiments, the numbers of downy brome plants that emerged were the same in all four residue treatments. However, the residue had a tendency to move from where it had been placed. It tended to fall from the top of the ridges where the data collection points were located, into the depression of the row formed by deep furrow drills. This movement of residue made the measured lack of correlation between residue cover and downy brome emergence questionable.

To investigate the possible correlation, another experiment was designed to answer the question of whether the presence of residues encourages downy brome establishment. The experiment was put on flat soil where the residue would have little chance of shifting.

MATERIALS AND METHODS

The site consisted of four replicate plots at the Pendleton Research Center on a Walla Walla silt loam (coarse-silty, mixed, mesic Typic Haploxerolls) soil. On October 20, 1994, downy brome was seeded across the site using a Gandy spreader at a rate of 50 seeds per square foot and lightly hand raked into the top half-inch of soil. Fumigated winter wheat residue was then spread over the four major plots, so that each replication had a range of residue across it with zero percent cover at one end extending to one hundred percent cover at the other end. Plastic large mesh netting held the residue in place.

Data were collected on December 20, 1994, when emergence was nearly complete. Percentage residue cover was measured five times within each replication using the line transect method (Laflen et al., 1981). Counts of emerged downy brome plants were made in the same five places within each replication where the residue cover data had been taken. A rectangular quadrat 53 square inches in area was used to count the emerged plants. If necessary, the netting was removed and residue pushed away from the count site to facilitate plant counts.

RESULTS AND DISCUSSION

The number of emerged downy brome plants per square foot was plotted against percent residue cover (Figure 1). There was no linear relationship between the amount of residue cover and the number of emerged downy brome plants; there were about 45 plants per square foot regardless of the level of residue.

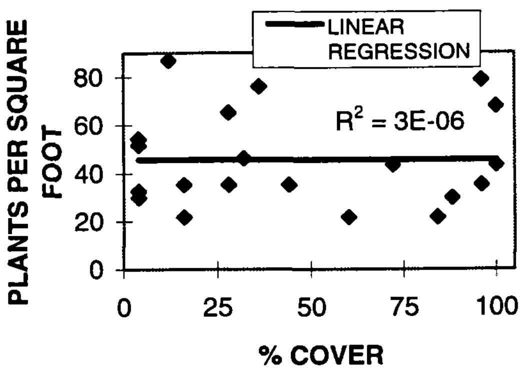

Figure 1. Influence of crop residue cover on downy brome seedling establishment, Pendleton, OR

Generally, emergence of downy brome is vigorous at temperatures between 32 deg F and 70 deg F if soil moisture is adequate (Veseth et al, 1994). In this experiment, soil moisture and temperature were both favorable and adequate growing degree days had been accumulated for emergence of downy brome (Table 1). A previous study (Hulbert, 1955) indicated that downy brome seeds sheltered from light emerge at faster rates than those exposed to light. Instead of seeing a marked increase in emerged plants in the areas with heavy residue cover where nearly all light is blocked and where moisture should also be favorable, the heavily covered areas exhibited no signs of increased plant emergence. This study showed no statistically significant differences in emergence of downy brome among the various residue treatments.

Table 1. Temperature, precipitation and cumulative degree days for experimental site at Pendleton, OR

DATE	PRECIP (IN)	AV. TEMP (F)	AV. TEMP (C)	TOTAL DEGREE DAYS
OCT 20-OCT 26	0.15	46.6	8.1	56
OCT 27-NOV 2	2.22	46.4	8.0	112
NOV 3- NOV 9	1.07	37.9	3.3	135
NOV 10-NOV 16	0.48	42.1	5.6	175
NOV 17-NOV 23	0.11	34.9	1.6	186
NOV 24-NOV 30	0.72	39.5	4.2	216
DEC 1-DEC 7	0.30	29.8	-1.2	233
DEC 8-DEC 14	0.24	30.9	-0.6	238
DEC 15-DEC 20	0.59	37.9	3.3	280

From these data we have concluded that the observations in the original experiment were valid: the mere presence of high levels of residue does not enhance downy brome emergence. It is probable that the increases in downy brome infestation observed by growers are related to the fact that fields with higher levels of residues also had higher levels of downy brome seed near the surface where they could emerge readily. These higher levels of seed occur because chiseling leaves statistically significantly more seed near the surface than does moldboard plowing (Staricka, 1990).

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GLYPHOSATE TIMING EFFECTS ON DOWNY BROME (*Bromus tectorum* L.) SEED PRODUCTION IN SUMMER FALLOW

Daniel A. Ball and Darrin L. Walenta

INTRODUCTION

Control of downy brome (*Bromus tectorum* L.) in winter wheat presents a major constraint to the adoption of conservation tillage systems in the Pacific Northwest. Moldboard plowing, which deeply buries weed seed, has long been the conventional practice for managing downy brome. However, this practice is being limited by government mandates to implement conservation tillage programs which minimize soil erosion. Selective chemical control of downy brome in the winter wheat crop provides only partial suppression and is prohibitively expensive, particularly in drier, lower yielding cropland. For these reasons, it is necessary to obtain effective control through multiple year crop rotations, which include spring crops if feasible for a particular location.

Precipitation patterns vary greatly throughout the inland Pacific northwest and can make spring cropping a risky and unprofitable option for some growers utilizing currently available farming practices. Government mandates, economics, climate, and lack of control options all come together to complicate efforts to manage downy brome in the winter wheat/summer fallow crop production areas of Oregon, Washington, and Idaho.

Because it is difficult to manage downy brome in the growing wheat crop, it is particularly important to prevent downy brome growth and seed production during the summer fallow period. Effective control of downy brome during the fallow period helps deplete seed in the soil which reduces downy brome populations in the subsequent winter wheat crop. Delaying fallow tillage operations or herbicide applications in the spring increases the risk for production of viable downy brome seed during the fallow period.

A more precise understanding of reproductive development of downy brome, particularly in regards to when viable seed production occurs, could improve downy brome management through improved timeliness of downy brome control operations in fallow. Specifically, if the "cut-off" date for prevention of downy brome seed production was known, managers of large acreages could more effectively schedule field operations in fallow to prevent downy brome seed production. In addition, there is considerable uncertainty regarding the effectiveness of glyphosate (Roundup®) for preventing downy brome seed production if applied during later stages of downy brome floral development. Knowing the effective period for glyphosate application to prevent downy brome seed production based on growing degree days (GDD), a measure of heat units, could help facilitate control decisions.

Vegetative and reproductive developmental stages of winter wheat, and other grasses including downy brome have been related to GDD based on air temperature (Ball et al. 1993, Dotray et al. 1993, Klepper et al 1982, Klepper et al. 1994). Research indicates that the development rate for downy brome is more rapid than wheat, but the overall developmental relationships to GDD are very similar to wheat (Ball et al. 1993). Therefore, models for winter wheat growth could likely be modified to estimate dates of downy brome seed production. This predictive ability could provide wheat growers a tool to better time fallow operations for effective prevention of downy brome seed production between winter wheat crops.

This study was initiated to determine if downy brome seed production can be predicted by using cumulative GDD to determine when seeds become viable in the seed head development stage, and also to determine when herbicide applications need to be applied to prevent downy brome seed production.

METHODS AND MATERIALS

An experiment was established at the Columbia Basin Agricultural Research Station near Pendleton to determine the cumulative GDD required to obtain downy brome seed production, and to determine when downy brome needs treatment with glyphosate or paraquat in order to prevent production of viable seeds. The plot area which had previously negligible levels of downy brome was irrigated on October 3, 1993 and a fine seed bed prepared by rototilling before and after irrigation. A small plot drill with double disc drill openers was used to seed 5 rows of downy brome with 12-inch spacing on October 10 to a depth of about 0.5 inch into moisture. Individual plots were 6 ft x 12 ft with 4 replications. After seeding, two 1.6 ft emergence sites per replication were marked in the second and forth rows of 8 randomly selected plots. Observations of downy brome seedling emergence were made daily until emergence started, then counts of seedlings made every other day. The first emergence counts were made on October 24, 1993. After no further emergence occurred, the time of 50 percent emergence was calculated.

Climatalogical data collected at the site was used to calculate GDD by using the equation:

$$(\text{daily max. temp.} - \text{daily min. temp.}) \div 2$$

where daily maximum and minimum termperatures are in degrees Centigrade. The time required to obtain initial development of downy brome seed was related to GDD from 50 percent emergence and from January 1, a hypothetical starting date after vernalization of downy brome.

Downy brome plots were treated with glyphosate or paraquat at one of five timings starting at initiation of seed head emergence and continuing until early maturity (Table 1). Glyphosate rates of 8 or 16 fl. oz. of Roundup® per acre or paraquat at 1.5 pt of Gramoxone Extra® per acre were applied at each application timing. An untreated control was included to evaluate potential downy brome seed production. After maturity of downy brome seed heads, but before seed shatter, 30 panicles were collected per plot. Seed was separated from accessory material by gently rubbing intact seed heads on a textured rubber mat and collecting debris and seed. Collected, uncleaned seed from each plot was dry stored for several months then placed in wood flats containing a standard greenhouse soil mix, placed in a heated greenhouse, and watered to germinate downy brome seed. Germinated downy brome seedlings were counted from each flat at seven and fourteen days after planting and counts averaged for each treatment.

RESULTS AND DISCUSSION

By assuming that vernalization in the field is complete by January 1, it may be possible to use cumulative GDD from January 1 to time seed production. If this is a valid assumption, calculating GDD from January 1 would improve the ability to predict downy brome floral development since it is difficult to know when emergence actually occurs in commercial fields.

Downy brome seed heads began to emerge in plots on April 26, 1994, which was 801 GDD after January 1, or 1232 GDD from time of planting (Table 1). Application of glyphosate or paraquat at this time prevented production of germinable downy brome seed (Table 2). Delayed application of glyphosate at the lower application rate allowed partial recovery of treated downy brome plants resulting in some seed production, but at a much greatly reduced level compared to untreated control plants. Delayed application of the higher glyphosate rate until nearly 100 percent seed head emergence prevented viable seed production at 965 GDD accumulated from January 1 (May 10), and the delayed application of paraquat prevented viable seed production as late as 1047 GDD accumulated from January 1 (May 23). The more rapid burn-down of downy brome from paraquat application compared to glyphosate likely contributed to the prevention or reduction of downy brome seed production at the very latest application timings.

Table 1. Growing degree day accumulation at time of herbicide application, Pendleton, 1994.

Application Date	Growth Stage	GDD	50% GDD	Jan1 GDD
April 26	2% heading	1232	1101	801
May 3	20% heading	1312	1181	881
May 10	100% heading	1396	1265	965
May 23	full heading	1479	1347	1047
June 7	early maturity	1586	1455	1155
Seed Collection	maturity	1794	1663	1363

GDD - Growing degree days accumulated from planting, based on air temperature.

50% GDD - Growing degree days accumulated from time of 50% total downy brome emergence.

Jan1 GDD - Growing degree days accumulated from January 1, 1994.

Table 2. Herbicide timing effects on downy brome seed production, Pendleton, 1994.

Treatment	Rate	Timing	7 DAP	14 DAP
	fl. oz. /A		--seedlings/30 heads-	
glyphosate	8	2% heading	0	0
glyphosate	8	20% heading	66	87
glyphosate	8	100% heading	3	10
glyphosate	8	full heading	31	77
glyphosate	8	early maturity	829	1184
glyphosate	16	2% heading	0	0
glyphosate	16	20% heading	0	0
glyphosate	16	100% heading	0	0
glyphosate	16	full heading	5	22
glyphosate	16	early maturity	421	656
paraquat	24	2% heading	0	1
paraquat	24	20% heading	3	5
paraquat	24	100% heading	0	0
paraquat	24	full heading	0	0
paraquat	24	early maturity	55	178
control	-	-	2180	2180
LSD (0.05)			234	265

seedlings/30 heads - Number of seedlings emerged after planting seed collected from 30 heads per treatment.

% heading - Percent of plants with seed heads both partially and completely emerged.

Full heading - All seed heads completely emerged from boot.

DAP - days after planting.

The above results indicate that late application of non-selective herbicides such as glyphosate or paraquat may be effective at preventing or greatly reducing downy brome seed production for some time after seed head emergence. This is not to say that it is desirable to wait until downy brome heading to treat with these herbicides. Late treatment increases the risk of seed production, requires higher herbicide application rates, and allows downy brome and other weeds to utilize soil moisture. However, these results suggest that effective control of downy brome seed production can be obtained soon after downy brome head emergence if conditions do not permit more timely herbicide applications.

This study will be repeated during the 1995 growing season to determine if viable seed production occurs at a GDD time similar to that observed in 1994. From the data

This study will be repeated during the 1995 growing season to determine if viable seed production occurs at a GDD time similar to that observed in 1994. From the data collected in the current study, it appears that viable seed production began sometime after an accumulation of 1047 to 1155 GDD from January 1, based on downy brome response to glyphosate and paraquat treatment. Further experimentation will be conducted to more fully identify the time (in heat units) required for downy brome to produce viable seed. This information will be used to improve weed control recommendations for downy brome in winter wheat/summer fallow crop rotations.

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DETERMINING SEED-ZONE SOIL WATER CONTENT

Dale Wilkins, Don Wysocki and Robert Adelman

INTRODUCTION

The Food Security Acts of 1985 and 1990 Farm Bills require producers with highly erodible crop land (HEL) to have farm conservation plans for minimizing soil erosion in order to be eligible to participate in USDA programs. These farm plans include erosion control structures, green crop cover, surface residue, surface roughness, infiltration rate, and water storage practices. The use of residue from previous crops for erosion protection has contributed to production problems in some areas of the Columbia Plateau, where summer-fallow is rotated with winter wheat. These areas are usually associated with cool moist conditions in the fall. Downy brome control (Veseth et al., 1994) and Cephalosporium stripe (Veseth et al., 1993) are more difficult to control in tillage systems that leave residue on or near the soil surface. Because of these risks associated with surface residue, some farmers in Agronomic Zones 4 and 5 (Douglas et al., 1990) of the Columbia Plateau use green crop cover and surface roughness in addition to crop residue, satisfying erosion protection requirements of their conservation plans.

Early seeding to provide crop cover for erosion protection during late fall and winter period in the Columbia Plateau is not without risk. Seed-zone soil water for wheat germination and emergence may not be adequate in dry years (Klepper et al., 1988). If water is present, some wheat diseases are favored by early seeding (Smiley and Patterson, 1994). A deep-fine soil mulch (3 to 4 inches) provides seed-zone water conservation (Papendick et al., 1973) but these fine deep mulches are highly susceptible to erosion. Chemical fallow provides protection from erosion but does not maintain seed-zone soil water as compared to conventional summer-fallowed tillage. Summer-fallowed fields, even with fine soil mulch, continue to lose water from the seed-zone soil at high rates in the early fall (Pikul et al., 1985).

Management of summer-fallowed fields in the Columbia Plateau to minimize soil erosion and simultaneously maximize soil water content in this seed zone at the optimum planting date for maximum production is a series of compromises. Management is especially critical during dry years. An average last seeding date to obtain green cover requirements by December 1 is set by average air temperature. Before that date, inadequate stand is a problem that requires even earlier seeding to meet green cover requirements.

This work describes a technique used to determine if sufficient seed-zone soil water existed in summer-fallowed fields for winter wheat seedling emergence.

MATERIALS AND METHODS

Eight summer-fallowed fields that had green cover requirements for conservation plans were sampled in the dry fall of 1994 to evaluate seed-zone soil water content. Average annual precipitation in these fields ranged from 12.5 to 17 inches. Soil series in these fields were McKay, Morrow, Condon and Pilot Rock silt loams. Table 1 shows the field characteristics.

Table 1. Sample site characteristics. Umatilla County, Oregon

Site	Soil Series	Field Size	Slope Aspect†	Annual Precipitation	Sample Locations	Soil Depth
		acres		inches	number	inches
1	Pilot Rock	301	N, S, NE	15.5	8	24 - 48
2	Condon	236	W, NW, SW, NE	15.5	9	--
3	Condon	218	N, S, SE	15.5	9	16 - 36
4	Pilot Rock	384	N, E, S, SE	15.5	10	11 - 34
5	McKay	147	N, E	17.0	10	--
6	McKay	204	N, NW, NE, SW	17.0	10	--
7	Morrow	263	E, N, NE, SE	13.0	10	16 - 28
8	Morrow	444	N, NE, E, W, SW	12.5	10	30 - 40

† N = north, S = south, E = East, W = west, NE = northeast, NW = northwest, SE = southeast and SW = southwest.

A computer model PLANTEMP, (Rickman, et al., 1990) was used to calculate the average last seeding dates to have 20, 30, and 50 percent green cover at each site. Eighty percent emergence, 10,000 seeds per pound, daily average maximum and minimum air temperatures and daily average precipitation for each site (average air temperatures and precipitation were generated with "WEATHER WIZARD", Zuzel and Karow, 1988) were used in PLANTEMP to determine the average last seeding dates.

Soil samples were taken on September 12 at sites 1, 2, 3, and 4 and on September 14 at sites 5, 6, 7, and 8. Eight to ten field sample locations were chosen from areas with aspects and slopes that represented over five percent of the field. This procedure was chosen to provide a representative field average and field variability of soil water content in the surface mulch (0 to 3 inches) and seed-zone (3 to 6 inches). The number of sample locations from each area was proportional to the percentage of land in the field with that slope and aspect; for example, if 60 percent of the field sloped north with a 12 percent slope, 6 of the ten sample locations in that field were from that area. Five soil samples from two depths (0 to 3 and 3 to 6 inches) were composited for each field location. Samples were taken with a cylindrical core sampler 0.75 inches in diameter and 12 inches long and placed in soil sample bags. These samples were taken to the laboratory and weighed to the nearest 0.00002 lb (0.01 gram). Soil samples were oven dried at 140°F for at least 24 hours. Soil water content was calculated as percentage of oven dry weight.

RESULTS AND DISCUSSION

Table 2 shows the average last seeding date for each site. Seeding should be completed by September 10 and 20, respectively for sites seven and eight and sites one through six to get 20 percent green cover by December 1.

Table 2. Predicted seeding date to achieve 20, 30 and 50 percent crop cover by December 1.

		Percentage Crop Cover On December 1		
Site	Row Spacing	20	30	50
	inches	predicted date to seed†		
1, 2, 3, 4	12	Sept. 20	Sept. 10	Aug. 25
5, 6	10	Sept. 20	Sept. 15	Sept. 7
7, 8	14	Sept. 10	Sept. 1	Aug. 20

† PLANTEMP (Rickman et al., 1990) computer model was used with the following assumptions: Seeding rate = 80 lb/ac, kernels per pound = 10000, germination percentage = 80 percent, and sites one, two, three, four, seven and eight were considered dry sites (less than 15 inches of annual precipitation).

Table 3 summarizes the results of the soil water contents measured for the eight sites. With these soil water conditions is it reasonable to expect good stand establishments in these fields? Is there sufficient soil water to delay seeding so that disease incidence and severity are minimized (Veseth et al., 1993)?

Table 3. Soil water content for the top six inches in summer-fallowed fields in mid September 1994. Umatilla County, Oregon

		Depth 0 to 3 inches				3 to 6 inches			
Site	Soil	Mean	Min.	Max.	Std. Dev.†	Mean	Min.	Max.	Std. Dev.
		% dry basis††							
1	Pilot Rock	5.8	4.5	6.2	1.1	13.0	10.2	18.5	2.4
2	Condon	4.5	3.4	5.2	0.7	12.0	9.3	14.5	1.8
3	Condon	6.3	4.6	8.0	1.2	14.1	10.9	16.3	1.7
4	Pilot Rock	6.6	5.3	8.9	1.1	13.8	11.7	15.8	1.6
5	McKay	9.0	6.6	11.1	1.4	22.0	17.4	25.0	2.4
6	McKay	7.3	4.9	10.7	2.0	16.3	11.9	19.3	2.3
7	Morrow	5.5	3.5	7.6	1.7	13.5	8.3	18.2	2.4
8	Morrow	7.0	4.6	9.9	1.6	11.2	7.1	15.6	2.6

† Std. Dev. = Standard deviation.
†† Oven dried 24 hours at 140°F.

Seed-zone soil water content should exceed nine percent (oven dry basis dried 24 hours at 240°F) for germination and emergence of winter wheat in a Ritzville silt loam soil (Lindstrom et al., 1976 and Wilkins et al., 1983). Morrow and Condon soils are very similar to Ritzville in water holding characteristics. Therefore, the 9 percent level should be applicable for Morrow and Condon soils. Pilot Rock and especially McKay soils have greater water holding capacity and require slightly higher percentage water (1/2 to 1 percent) for germination and emergence of wheat because the water is not as readily available.

Ideally, wheat seeds should be placed in soil with adequate water and not deeper than 2 inches. Seedlings forced to emerge from depths greater than 2 inches may be stressed and emergence may be reduced and delayed. Hoe type drills are ideal for seeding through deep-dry soil mulch because they can move dry soil away from the row. As much as 2 inches of soil can be moved from the row but in this process some dry soil is mixed into the seed-zone. A disadvantage with hoe and deep furrow drills is non-uniform seed depth placement. Disadvantages of disc drills are they tend to move more dry surface soil down into the seed-zone than hoe type drills, and they can not seed as deep as hoe drills (Wilkins et al., 1983).

It requires about one week with a mean daily temperature of 60°F to accumulate enough growing degree days for wheat to emerge (Klepper et al., 1988). During this week of emergence, as much as 2 percent seed-zone soil water will be lost through evaporation (Wilkins et al., 1983). Assuming a hoe drill is set to remove 2 inches of dry mulch and place the seed 2.5 inches deep (1.5 inches into moist soil) and accounting for soil drying and dry soil mixing during seeding, the minimum soil water content in the 3 to 6 inch zone should be 12 percent for silt loam soils.

The values in Table 3 were determined by drying at 140°F, but the 12 percent value was based on research when soil drying was at 220°F. Eight samples from four of the sites were dried an additional 24 hours at 220°F. An additional 0.9 percent water was removed. The lower limit of seed-zone soil water would be 11.1 percent (12.0 - 0.9 percent) for Morrow and Condon and slightly more for Pilot Rock and McKay soils (0.5 to 1 percent). This leaves no margin of error, such as hot dry winds during emergence or extra fine, dry soil sifting into the seed furrow. If the minimum soil water content in Table 3 is below 11.1 percent the portion of the field represented by that sample location would not have sufficient soil water for wheat emergence. The wheat may or may not emerge following fall rains.

The two McKay soils (sites five and six) have adequate soil water (Table 3). Site 5 could be seeded with a double disc drill provided disc penetration was sufficient to place seed 2.5 inches deep. Site 6 could be seeded with a hoe type drill by setting the drill to place seed about 4 inches below the original surface. Site 4 could be seeded deeply with a hoe type drill and expect good stand establishment. This site had the lowest standard deviation in water content in the 3 to 6 inch depth, indicating that conditions were uniform throughout the field at the 3 to 6 inch depth. Seeding would need to be done immediately or additional drying during September would reduce the soil water content below that necessary for emergence. Soil water evaporation rate remains high during the fall in summer-fallowed fields even though air temperatures are decreasing (Pikul et al., 1985).

Site 1 with Pilot Rock soil and site three with Condon soil have areas with seed zone water content below the threshold for wheat emergence. Site 1 was highly variable in soil water content in the 3 to 6 inch layer (Table 3 shows a standard deviation of 2.4). Site 3 had a mean soil water content of 14.1 percent in the 3 to 6 inch layer but there were areas in the field where soil water was below 11.1 percent. Either seedling establishment would be delayed and reduced because of deep seeding or areas within the fields would be void of seedlings because of a dry seedbed.

The fields with Morrow soil and site 2 with Condon soil could not be successfully sown because there is not sufficient soil water in the seed-zone throughout these fields to get uniform stand establishment. These fields could be "dusted in" but germination and emergence would not begin until rain wet the seedbed. Twenty percent green cover would not be achieved if rain was after September 20 (Table 2).

CONCLUSIONS

A technique for measuring soil water content in the seed-zone to determine if wheat establishment would be successful was demonstrated. Compositing five samples for each of two depths (0 to 3 and 3 to 6 inches), from 8 to 10 representative locations within a field gave a reliable measure of seed-zone soil water content and variability. This method could be used to determine the risk of obtaining poor stand establishment from delayed seeding.

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DROUGHT TOLERANCE STUDY ON WINTER WHEAT

Julio Cerono and Warren Kronstad

Post-anthesis drought and heat stress is frequent in wheat fields in eastern Oregon. Under normal conditions, grain filling is supported by relocation of stored carbohydrates (soluble sugars) and by current photosynthesis. Final kernel weight is an important component of yield, and it depends on the duration and rate of the grain filling phase. The rate of grain filling is dependent upon a continuous supply of carbohydrates to the developing kernel (Evans et al., 1975).

It is well known that the stems of wheat, and other cereals, contain a considerable amount of soluble sugars at anthesis, but at maturity, these substances have virtually disappeared (Stoy, 1965). During grain filling, stems can lose 30 percent or more of their maximum dry weight. It was observed that stem reserves in barley contributed up to 70 percent of kernel weight (Gallagher et al., 1975). Under drought stress, photosynthesis is inhibited and stored reserves become very important in the determination of kernel weight and final yield, since subsequent kernel growth is largely supported by the remobilization of the stored reserves (Austin et al., 1980).

Traditionally, selection of post-anthesis drought tolerant genotypes has required testing of segregating populations under unpredictable stress environments. Blum et al. (1983a), devised a methodology for rapidly and inexpensively selecting stress tolerant genotypes. They reasoned that a chemical desiccation after anthesis would measure the ability of a genotype to support kernel growth in the absence of photosynthesis. They finally concluded that kernel growth was more supported by stored reserves in treated plants than in untreated plants. In a second experiment (Blum et al., 1983b) they concluded that kernel weight injury under chemical desiccation was positively correlated with drought stress injury across cultivars.

This study was initiated under the hypothesis that concentrations of soluble sugars in wheat stems at anthesis play an important role in the ability of the cultivar to tolerate drought stress during grain filling. An experiment was designed to detect and associate changes in soluble sugar concentrations with drought stress tolerance in a set of winter wheat cultivars.

A total of 11 cultivars differing in drought tolerance are being studied in a split plot experimental design located at the Sherman County Branch Experiment Station in Moro. The treatments assigned to main plots are irrigation and no irrigation after anthesis. Cultivars are subplots. From anthesis up to maturity, soluble sugars, leaf water potential, soil water potential, and grain filling parameters will be monitored. Results from this experiment will be used in conjunction with another experiment involving desiccation tolerance, which is located at Hyslop Crop Science Field Research Laboratory in Corvallis.

It is expected that useful information will be obtained on the role that soluble sugars play in drought tolerance. Information will also be obtained on the ability of desiccation tolerance to predict post-anthesis drought tolerant wheat cultivars.

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WINTER CANOLA STAND ESTABLISHMENT USING THE ZIMMERMAN DEEP FURROW DRILL

Don Wysocki, Bill Schillinger, Sandy Ott and Kathy Ward

INTRODUCTION

The optimum sowing time for winter canola (*Brassica napus)* in eastern Oregon is mid-August to mid-September (Wysocki et al., 1992). The probability of a soaking rain is low during this time, so canola is usually planted on summer fallow. Hot, dry weather conditions or tilling too deep in summer fallow can cause the seed zone to be too hot and dry for seedling establishment. Ideally, canola seed should be placed as shallow as possible to get seed into moist soil with a minimum of soil cover. Shallow planting is difficult in summer fallow seedbeds because suitable moisture may be as deep as 3-6 inches.

Deep furrow, split packer wheel drills such as the John Deere HZ are usually used to seed winter canola on fallow. Winter canola seed should be placed 3/4 to 1 inch into moisture with a maximum of 2 inches of cover (Wysocki et al.., 1992). This strategy is generally successful unless seedbed moisture is marginal, weather conditions turn hot, or rains cause soil crusting before emergence. Under marginal moisture or hot conditions, germination and emergence can be poor. The soil dries too quickly for the seed to imbibe, or soil temperatures are so extreme that seedlings are "burned" or "pinched off" before emergence. Rainfall exceeding 0.3 inches after sowing can result in soil crusting that prevents emergence and necessitates reseeding. If seedbed water is marginal, planting deeper to reach better moisture conditions is an option. However, seeding deeper results in greater soil cover.

Deep furrow, split packer drills have usually been the preferred seeding implement because they move dry soil from the furrow and allow the seed to be placed into moist soil with a minimum of cover. Seed can be placed 1 inch into moist soil with a maximum of 2 inches of cover, even when adequate soil water is 4 inches deep, if these drills are adjusted and operated carefully. However, if soil conditions are too dry or tractor speed too fast it is difficult to hold a furrow. Thus, even with careful management and the best drill, stand establishment may not be possible. Unsuccessful seedings increase the risk of dryland canola production.

Recently, a new deep furrow drill has been developed by Bob and Don Zimmerman of Almira, Washington (Gaffney 1993). The Zimmerman drill (ZM) was designed to sow in dry, summer fallow seedbeds and has features that seem useful for overcoming some of the stand establishment problems in winter canola. The drill creates a deeper furrow than conventional split packer drills and moves more dry soil from the row. Row opener design is such that seed placement should be more consistent than with conventional drills.

METHODS

This study compared canola stand establishment using a John Deere HZ and the Zimmerman drill. Six drill treatments, three for each drill, were compared (Table 1). The John Deere drill was a single 8-foot drill box with 7 openers on 14-inch center. The drill was equipped with a Kincaid cone seeder. Seed was weighed in packets and dispensed to the cone to achieve a sowing rate of 9 lb/acre. Twelve-inch diameter, 15 pound, hard rubber press wheels with cast iron centers were added

Table 1. Experimental planting treatments comparing a John Deere HZ drill and the Zimmerman deep furrow drill, September 1994, Pendleton, Oregon.

Drill	Treatment	Description
John Deere HZ	HZ 1	Seed placed 1-inch into moist soil
	HZ 2	Seed placed 1-inch into moist soil, additional press wheel over row
	HZ 3	Seed placed 2-inches into moist soil
Zimmerman Drill	ZM 1	Seed placed 1-inch deep, front shank at moisture line
	ZM 2	Seed placed 1-inch deep, front shank 2-inches below moisture line
	ZM 3	Seed placed 0.5-inches deep, front shank 2-inches below moisture line.

to the drill. These press wheels, when lowered, packed over the center of the row.

The Zimmerman Drill had a 10-foot drill box with 8 openers on 15-inch center. The drill has three staggered gangs of shanks for placing fertilizer and opening the row. The shanks are followed by solid packer wheels with a smooth coulter in the center. The coulter is 2 inches larger in radius than the packer wheels. Packer wheels and coulter firm the seed row. The seed opener is behind the packer wheel/coulter. A press wheel follows the opener to pack over the row. The leading shanks can be adjusted for depth to move dry soil out of the row and to bring up moist soil from below. Each seed cup was adjusted to have 7/64 inch of flute exposed. This permitted each row to have a uniform seeding rate. At this setting, the drill seeded at 9 lb/acre.

Plots were sown on 7 September 1994 with Arabella winter canola in a randomized complete block with four replications. The soil was a Walla Walla silt loam with 1 percent slope. Plot length was 40 feet and plot width was 8 or 10 feet depending on drill width. Immediately after planting, seed zone water content was determined by collecting five, 0-3 inch soil cores located at random in the row of each plot. Cores were divided into 1-inch increments and bulked for each plot.

Soil temperature measurements were taken in the upper inch of the row on 13, 15, 20, and 23 September and 18 October 1994. Temperature was determined between 2 and 3 pm, by inserting a digital probe thermometer at 45° until the tip reached 1 inch in soil depth. Temperature was recorded after a 30 second equilibration period.

Emergence was determined on subplots consisting of three consecutive rows 40-inches in length. The same rows were consistently used in each plot to avoid any difference due to openers. Emergence counts were taken daily from 17 September through 30 September; every 4 days from 30 September to 1 November and on 30 November.

Depth of seeding was determined on 13 October using an incremental depth sampler. Samples were divided into 0.4- inch increments and sieved through a 0.02-inch sieve to collect seed. Seed depth was identified as the first increment in which seed was found.

Table 2. 1-inch soil temperature, seed zone water content, seed depth and estimated water content at seed depth, September 1994, Pendleton Oregon.

Drill Treatment	1-inch soil temperature F	Seedzone water content %			Seed depth (inches)	Estimated water content at seed depth
		0-1 inch	1-2 inch	2-3 inch		
HZ 1	98.2	3.5	9.8	15.2	2.7	15.2
HZ 2	94.3	4.1	11.1	15.7	2.1	15.1
HZ 3	98.7	3.9	8.3	13.2	3.1	14.0
ZM 1	90.6	6.8	13.6	15.9	1.6	13.9
ZM 2	89.2	7.3	12.4	15.5	1.5	12.4
ZM 3	89.1	6.6	13.2	15.9	1.1	10.4

RESULTS AND DISCUSSION

Significant differences in seed zone water content, soil temperature, seed placement, and seedling emergence were observed between the drill treatments in this study. Seed zone water content is given in Table 2. Seed zone water content was highest in the Zimmerman drill treatments. The Zimmerman drill moved more dry soil out of the row and created a deeper furrow. The seed was placed deeper into the soil with respect to the original soil surface and into wetter soil. This process created a wetter seed zone in the seed row of the Zimmerman drill treatments. The highest seed zone water content in an HZ treatment was where additional packer wheels pressed over the rows (HZ 2). Packing over the row compressed the dry surface layer and lowered the surface by about half an inch. The difference in water content was due mostly to deeper sampling with respect to the original surface. Treatment HZ 3 was lowest in seed zone water. In this treatment openers were set to run deeper, and apparently more dry soil was mixed into the seed row. Water content in all treatments approached approximately 15 percent below 3 inches. This is below the depth of the moisture line set by rodweeding.

Soil temperatures at 1-inch depth are shown in Table 2. These data are the average of the five observations taken on the dates previously listed. Differences in soil temperature among drill treatments are closely related to seed zone water content. The highest 1-inch soil temperature was observed in the HZ drill treatments. Soil in these treatments was drier and less packed at the surface. Loose, dry soil has lower heat capacity and its temperature will rise higher for each unit of heat input. Treatments that were drier or that were less packed became hotter. Comparing treatments HZ 1 to HZ 2, packing over the row reduced 1-inch soil temperature by about 4° F. Zimmerman drill treatments had soil temperatures that were 8-9° F cooler than HZ treatments. This difference is due to a wetter environment in the seed row.

Depth of sowing is shown in Table 2. The target placement in treatments HZ 1 and HZ 2 was to put seed 1 inch into moist soil. The actual seed depth is 1 inch plus the thickness of soil that flows back into the seed

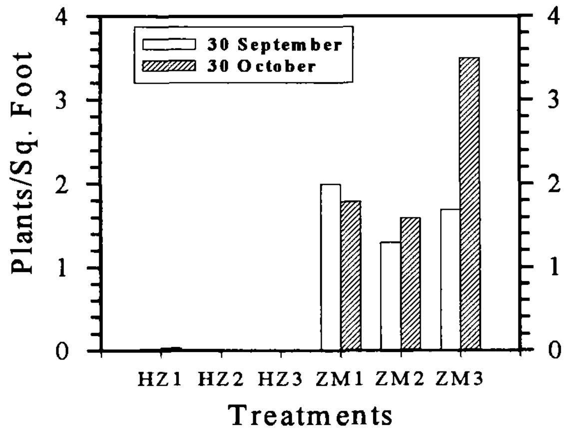

Figure 1. Canola stand on two dates in 1994 in Pendleton, Oregon.

furrow. This means that in treatment HZ 1 about 1.7 inches of dry soil was flowing back into the furrow. Dry soil cover was compressed to about 1.1 inches by using a press wheel over the row in HZ 2. There was about 1.1 inches of dry soil over moist soil in HZ 3. The difference in depth of dry soil cover between HZ 1 and HZ 3 is probably caused by mixing of moist soil in the furrow. Openers that were run 1 inch deeper in treatment HZ 3 than HZ 1 or HZ 3 brought up more moist soil from below. This changed the consistency of the soil so that less soil flowed back into the furrow over the seed.

The Zimmerman drill was adjusted for seed placement with respect to the bottom of the furrow. Seed openers and seeding depth adjusters were calibrated by placing the drill on a flat, concrete surface. The coulters within the press wheel were in contact with the concrete. This was assumed to be the bottom of the furrow. Openers were adjusted to the flat surface and then adjusted in 0.5-inch increments using a slab of metal of the correct thickness as a gauge. Depth adjusters were marked for 0-, 0.5-, 1.0-, 1.5-, and 2.0-depths. An adjuster depth setting of 1 inch meant that openers were 1 inch below the bottom of the coulter. The difference between opener depth setting and actual seed depth is attributed to soil flowing back into the row. The difference in depth setting between ZM 2 and ZM 3 was 0.4 inches (Table 1), and the corresponding difference in measured seed depth was also 0.5 inches (Table 2). This indicates that opener depth adjusters were correctly calibrated.

Seedling emergence counts on two dates are shown in Figure 1. John Deere HZ treatments had few or no plants emerge. Zimmermann drill treatments had better, but marginal, canola emergence. Weather conditions after planting were extremely hot and dry (Figure 2). Plant emergence began on 17 September. Maximum air temperatures exceeded 80° F until 30 September. Seed in all treatments did hydrate and germinate. However, we observed that seedlings did not emerge or died when cotyledons were "burned off" by excessive heat at the soil surface. Seed-zone water was measured once immediately after planting. It is not known if or how quickly the seed zone dried during the emergence period. Evaporation was high over this period (Figure 2). Many germinated seeds never emerged. We speculate that these seedlings did not surface because of the combined effects of hot, dry weather, high soil temperatures, and loss of moisture in the seed zone after planting. Because conditions were more favorable in Zimmerman drill treatments (Table 2), stand performance was better. These treatments achieved stands that were marginally acceptable.

Differences in stand density were observed between 30 September and 30 October in the Zimmerman drill treatments (Figure 1). Plants were lost over this period in treatment ZM 1. This decline resulted from predation by insects and birds. Increases in

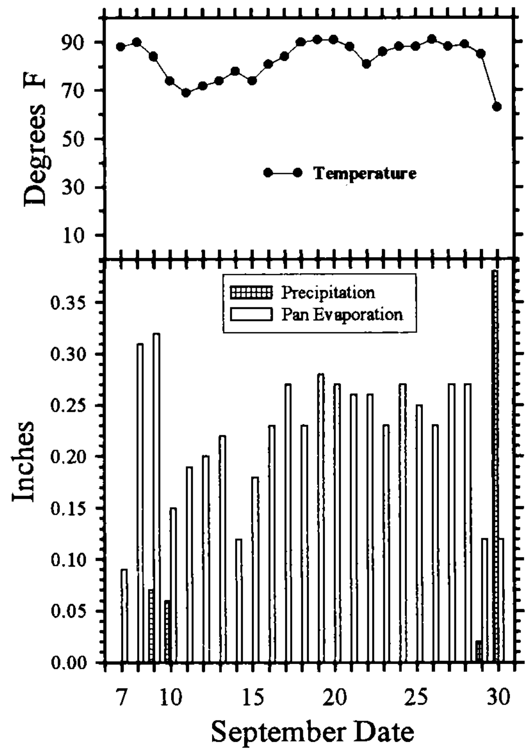

Figure 2. Maximum daily air temperature, rainfall, and pan evaporation for September, 1994, Pendleton, Oregon.

stand density were observed in treatments ZM 2 and ZM 3. This change resulted from 0.38 inches of rain on 30 September (Figure 2). The plant population nearly doubled in Treatment HZ 3. Seed was placed shallow and soil water content at seed depth was slightly over 10 percent (Table 2). This apparently was insufficient for some seed to hydrate. After rain on 30 September seed did hydrate. At that point, germination started and a flush of new seedlings were able to emerge.

CONCLUSION

We compared winter canola plantings using a John Deere HZ drill and the newly designed Zimmerman drill. Plots sown with the John Deere HZ drill had lower seed-zone water content, higher mid-day soil temperatures, and more dry soil over the row. Canola emergence was almost zero on HZ drill treatments, while plots, planted with the Zimmermann drill had stands that were slightly better, but marginal. Canola seed germinated in all plots but was unable to emerge. At the sowing rate used in this study, about 20 seeds per square foot were planted. In the best treatment (ZM 3), less than 25 percent of the seed was able to establish. Extremely hot and dry conditions during the emergence period caused seeding death before and after emergence.

The increase in stand from 30 September to 30 October in the ZM 3 treatment suggests that a shallow "dusting in" might be feasible. However, rainfall would need to be sufficient to germinate the seed and provide water to enable the roots to reach moist soil below.

We conclude from this study that the Zimmerman drill is capable of creating more favorable seed zone conditions for winter canola. This drill moves more dry soil from the furrow and consequently moist soil is closer to the surface. This is an advantage when seeding canola because the seed does not have to be planted as deep. In the exceptionally dry, hot September of 1994, the Zimmerman drill produced marginal canola stands, while the HZ drill produced none at all.

In a related study under very marginal seeding conditions on coarse silty soils at Lind, WA, winter wheat seedling emergence was best with the ZM drill compared to conventional drills (Schillinger and Donaldson, 1994). However the ZM drill pulverized surface clods and buried practically all surface residue. This suggests that the ZM drill, in its present form, may create an unacceptable wind erosion hazard in low rainfall areas and prevent growers from meeting residue requirements for participation in farm programs

ACKNOWLEDGEMENT

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DAMAGE TO WINTER WHEAT FROM DRYLAND ROOT ROT

Richard Smiley and Lisa-Marie Patterson

INTRODUCTION

Winter wheat root, crown, and foot (culm) rots caused by *Fusarium culmorum*, *F. graminearum*, *F. avenaceum*, *Bipolaris sorokiniana*, and others, are known as dryland root rot, Fusarium root rot, common root rot, or crown rot. Dryland root rot is the name used in this paper. Dryland root rot appears to cause at least some damage to crops during most years. Damage is highly variable within as well as among fields. Effects of crop management systems on the incidence and severity of dryland root rot are not well defined.

There are no estimates of economic damage caused by dryland root rot in the Pacific Northwest. Damage estimates provide several important types of information. Effects on grain yield and test weight provide information on farm profitability. Effects on grain protein content provide an insight into the milling and baking quality of the flour. Effects on straw yield are important to Conservation Compliance Provisions of the 1985 Food Security Act (Farm Bill). Damage estimates are needed to determine whether research on disease control is justified.

Objectives of this study were to determine effects of dryland root rot on grain yield, straw yield, test weight, kernel weight, and protein of winter wheat.

METHODS

Thirteen fields of mature winter wheat were selected for sampling during 1994. Seven fields were in Gilliam and Sherman Counties of Oregon, and six were in Benton and Walla Walla Counties of Washington. Varieties of winter wheat in each field were not determined until after sampling had been completed. This was done to avoid biasing results through inadvertant selection of fields with varieties or classes of wheat considered highly susceptible to dryland root rot.

All plants in a 10-foot row section were collected (dug up) from two randomly selected areas in each of 13 fields (26 samples). Numbers of plants with and without symptoms of dryland root rot were recorded. Tillers were then separated and leaf sheaths removed to expose culms. Tillers in each sample were separated into root rot classes representing the extent of culm browning attributed to dryland root rot. Root rot severity classes were D_0 (none), D_1 (browning up to the first node), D_2 (second node), D_3 (third node), and D_4 (4th node or above). Measurements of plant characteristics within each root rot classification included numbers of tillers, tillers without heads, percentage of headed tillers, straw weight, tiller height, grain weight, grain protein (calculated by multiplying percent N in grain by 5.7), and kernel weight.

Estimates of crop damage caused by dryland root rot were based on regression analyses of disease severity characteristics on individual tillers. Characteristics for calculating yield loss included five disease severity classes (described above), number of headed tillers (T) in each severity class, and grain weight/tiller for tillers in each severity class (G_{Dx}), where the "x" in "D_x" represents disease severity class numbers 0, 1, 2, 3, or 4. The measured yield (MY) for each bundle was calculated by adding grain weights obtained from heads in each severity class. Potential yield (PY) was calculated by

Table 1. Provisional dryland root rot ratings for winter wheat varieties; averaged data for incidence of whiteheads[†] in five wheat breeding nurseries in northeast Oregon from 1991 to 1994.

Category	White-heads/ft	Variety
Tolerant	<3	Basin, Dusty, Gene, Hyak, Madsen, Rohde, Rulo, Yamhill
Mod. Tolerant	2-5	Cashup, Eltan, Hill 81, Kmor, Lewjain, Rely, Tres
Highly Variable or Susceptible	2-22	Andrews, Batum, Buchanan, Daws, Durheim's Pride, Hoff, MacVicar, Malcolm, NuGaines, Rod, Stephens, Ute, Wanser, W301

† Whitehead counts were averaged for breeding nurseries at Arlington (1991), Lexington (1991), Moro (1993 & 1994), and Pendleton (1994).

adding numbers of headed tillers in each severity class and multiplying the sum by the grain weight/tiller, as obtained from healthy tillers in class D_0. The percentage yield loss (%YL) was then calculated by subtracting MY from PY, multiplying by 100, and dividing by PY. Equations for these calculations were as follows:

$$MY = G_{D0}+G_{D1}+G_{D2}+G_{D3}+G_{D4}$$

$$PY = (T_{D0}+T_{D1}+T_{D2}+T_{D3}+T_{D4})\ G_{D0}$$

$$\%\ YL = [(PY-MY)\ 100]\ /\ PY$$

For example, if the MY was equivalent to 42 bu/acre and the PY was estimated at 45 bu/acre, the percent yield loss from dryland root rot would be 6.7 percent.

RESULTS AND DISCUSSION

Six winter wheat varieties were represented in the 13-field sample from four counties. Varieties and county locations were; Gene (1 field in Benton), Lewjain (1 in Benton), Madsen (2 in Sherman; 1 in Walla Walla), Malcolm (1 in Gilliam), Stephens (3 in Gilliam, 1 in Sherman, 1 in Walla Walla), and Weston (2 in Benton).

Percentages of plants with dryland root rot ranged from 24 to 98 percent, with a mean of 76 percent. Gene had fewest infected plants (24 percent), Lewjain was intermediate (76 percent), and Malcolm had the most (98 percent). Samples of Madsen had 37-98 percent infected plants and Stephens had 62-96 percent, illustrating large differences that may occur within varieties. Similar ranges occurred for percentages of tillers affected for each variety; 6 percent for Gene, 12-79 percent for Madsen, 36 percent for Lewjain, 39-81 percent for Stephens, 67 percent for Weston, and 90 percent for Malcolm. These results are comparable to provisional disease susceptibility groupings from rankings in wheat breeding nurseries in Oregon (Table 1). Gene and Madsen are considered tolerant, Lewjain intermediate, and Stephens and Malcolm susceptible. Weston was not evaluated in the breeding nurseries.

Dryland root rot reduced all plant and yield characteristics examined (Table 2).

Table 2. Relationship between dryland root rot severity, plant characteristics, yield and yield components for winter wheat plants sampled from 13 randomly selected fields in Oregon and Washington during 1994.

Plant characteristic	Disease severity rating†					
	D_0	D_1	D_2	D_3	D_4	lsd (0.05)
Tillers in class (%)	47	25	17	6	5	-
Kernels/head	21	20	20	16*	6*	3
Grain protein (%)‡	12.6	12.5	13.0	13.3	14.2	ns
Kernel weight (mg)	43	42	41	36*	33*	3
Grain weight/head (mg)	899	806	794	673*	399*	119
Tillers with heads (%)	96	82*	85*	80*	84*	8
Straw weight/tiller (g)	1.7	1.6	1.7	1.6	0.9*	0.3
Tiller height (cm)	73	72	71	68*	64*	2
Reduction in grain yield from disease (%)	0	10	12*	28*	30*	10

† Root rot severity classes were: D_0 (none), D_1 (browning up to the first node), D_2 (second node), D_3 (third node), and D_4 (4th node or above).

‡ Two samples of Weston winter wheat were excluded from this analysis because the objective of producing high-protein grain (>13%) for this variety differed from the objective of producting low protein (<10%) in the soft white winter wheat varieties included in this analysis.

* Designates values, within a row, that differ significantly (p<0.05) from the D_0 value.

Increasing disease severity ratings were associated with decreasing numbers of kernels/head, kernel weight, grain weight/head, percentage tillers with heads, straw weight/tiller, and head height.

Grain protein content ranged from 8.2 to 16.7 percent in the 13 fields. Six fields had protein contents of 12 percent or lower, and four exceeded 14 percent. Protein content was not associated with variety or county. Stephens was produced in fields with the highest and lowest protein content, and samples of Weston (a hard red, bread wheat) had protein contents with the second- and fourth-highest rankings. There was a tendency for protein in soft white varieties to increase with severity of disease (Table 2), but this relationship was not statistically significant for the 11 fields analyzed. Excessively high protein contents in these samples apparently masked a more pronounced effect of root rot on protein than was anticipated by the authors.

The five fields with lowest protein, except the field of Gene that was not affected by dryland root rot, were evaluated as a sub-group to determine grain yield and quality responses to dryland root rot in situations where soil fertility was apparently not high enough to promote excessive grain protein contents for soft white winter wheat. This sub-group included the varieties Stephens (3 samples), Malcolm (1), and Lewjain (1) collected from Sherman (1 field), Gilliam (3), and Benton (1) Counties. Compared to the 13-field analysis (Table 2),

Table 3. Relationship between dryland root rot severity, plant characteristics, yield and yield components for soft white winter wheat plants from a 5-field, lower-protein (<12%), sub-group of 13 randomly selected fields† in Oregon and Washington during 1994.

Plant characteristic	Disease severity rating ‡					
	D_0	D_1	D_2	D_3	D_4	lsd (0.05)
Tillers in class (%)	38	26	23	6	7	-
Kernels/head	20	18	19	17	9*	5
Grain protein (%)	10.8	10.5	11.0	11.6*	12.9*	0.7
Kernel weight (mg)	45	44	43	37*	24*	7
Grain weight/head (mg)	871	784	795	605*	288*	194
Tillers with heads (%)	98	88*	89*	88*	93	8
Straw weight/tiller (g)	1.8	1.7	1.7	1.7	1.2*	0.4
Tiller height (cm)	72	72	71	55*	40*	15
Reduction in grain yield from disease (%)	0	14	14*	30*	39*	19

† Gene winter wheat had low protein (9.9%) but was excluded from this analysis because the variety was not affected by dryland root rot.

‡ Root rot severity classes were: D_0 (none), D_1 (browning up to the first node), D_2 (second node), D_3 (third node), and D_4 (4th node or above).

* Designates values, within a row, that differ significantly ($p<0.05$) from the D_0 value.

Table 4. Estimates of percentage yield loss (%YL) from dryland root rot in 13 randomly selected winter wheat fields in four Oregon and Washington counties during 1994, based on percentages of tillers with culm browning symptoms to the fourth node or higher (D_4).

Type and number of fields evaluated	Yield loss equation	*p*	r^2	df
Randomly selected (13)	%YL = 3.5 + 1.1 (%D_4)	<0.001	0.66	25
Stephens only (5)	%YL = 0.9 + 1.1 (%D_4)	<0.001	0.82	9
Low-protein only (5)	%YL = 4.1 + 1.1 (%D_4)	<0.001	0.89	9

Table 5. Relationships between dryland root rot and yield loss in two sub-groups (four with "light" and four with "heavy" disease damage[†]) of 13 randomly selected Oregon and Washington winter wheat fields during 1994.

Disease severity group	Plants with root rot (%)	Headed tillers per foot of row	Headed tillers (%) in disease severity class:					Yield loss (%)	Grain protein (%)
			D_0	D_1	D_2	D_3	D_4		
Light	63	47	67	29	19	3	1	2.5	13.1
Heavy	87	41	25	15	14	12	15	17.7	13.5
lsd (0.05)	ns	ns	15	6	ns	6	7	9.9	ns

† Lightly affected fields include two each of Stephens and Madsen, and heavily affected fields included three of Stephens and one of Madsen. Root rot severity classes were: D_0 (none), D_1 (browning up to the first node), D_2 (second node), D_3 (third node), and D_4 (4th node or above).

the 5-field lower-protein sub-group (Table 3) exhibited more pronounced effects of root rot on grain protein, kernel weight, grain weight/head, tiller height, and yield loss. Protein content was significantly increased with disease severity.

When all tillers were considered, dryland root rot in the 13 fields reduced yields by 0 to 35 percent (average of 9 percent). Grain yield was correlated with the percentage of tillers in disease severity class D_4. Yield declined by 1 percent for each 1 percent of tillers in D_4 (Table 4). Similar relationships were found for calculations based on the five fields planted to Stephens, and the five lower-protein fields.

Yield loss relationships were also evaluated by comparing two groups of four fields selected for either high or low root rot severity, from among the 13 fields sampled. Yield losses for plants in four "lightly" and four "heavily" affected fields averaged 3 percent and 18 percent, respectively (Table 5). Numbers of plants with root rot and numbers of headed tillers/foot of row were similar in the light and heavily affected fields. Compared to heavily affected fields, lightly affected fields had a higher proportion of tillers in disease severity classes D_0 and D_1, and a lower proportion of tillers in classes D_3 and D_4. Protein did not differ significantly among groups of fields when evaluated on the basis of entire bundles (Table 5) or sub-samples for disease severity classes D_0 (healthy) through D_3 (moderately severe). Grain from D_4 tillers had higher protein in the heavily affected than lightly affected fields (protein contents were 15.7 and 12.5 percent, respectively; lsd=2.0).

These data indicate that yield losses from dryland root rot are important in semi-arid regions of eastern Oregon and Washington, where 185 million bushels of winter wheat were produced on 3.2 million acres in 1992, for a farm gate value exceeding $700 million. Average yield in these counties during 1992 was 42 bushel/acre, and the average market price for grain was $3.85/bushel. A 9 percent yield loss for the 13-field sample represents a direct economic loss of $15.40/acre. The 18 percent loss in four heavily affected fields represented a negative impact of $30.80/acre. The 13 fields were selected at random, before symptoms of dryland root rot were evident. If the varieties and climates of these fields and counties represent 20 percent of the non-irrigated acreage in eastern Oregon and Washington, estimates of direct economic damage from dryland root rot in the region would be 3.6 million bushels, or $14 million. Further economic loss would occur if test weight decreased, or protein increased, to the extent of reducing the market grade for grain produced.

Dryland root rot occurs with variable intensity across most fields, causing difficulty in assigning a "field average" without intensive sampling protocols in the field followed by labor-intensive assessments performed tiller by tiller. Research reported here is being repeated and expanded during 1995 to determine if yield loss assessments can be based reliably on percentages of whiteheads rather than number of tillers in D_4. Whiteheads can be enumerated much more easily than disease classifications on culms.

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PATHOGENS ASSOCIATED WITH DRYLAND ROOT ROT IN EASTERN OREGON AND WASHINGTON

Richard Smiley and Lisa-Marie Patterson

INTRODUCTION

Root, crown, and foot (culm) rots in dryland areas are difficult to diagnose and often go unnoticed until whiteheads (prematurely ripening heads that yield shriveled or no grain) appear shortly before the crop matures. Several names are used interchangeably to designate the disease or pathogen. Disease names include Fusarium foot rot, dryland foot rot, Fusarium crown and root rot, crown rot, and common root rot. The name officially recognized by the American Phytopathological Society is common root rot. For reasons of clarity in the Pacific Northwest, the disease is named dryland root rot in this paper.

Confusion over the names of the disease is understandable in view of the complexity of dryland root rot. Several pathogenic fungi are capable of causing nearly identical symptoms and damage to winter and spring wheat and barley, many rotational crops, and grasses. The pathogens include but are not limited to *Fusarium culmorum*, *F. graminearum*, *F. avenaceum*, *Bipolaris sorokiniana* (also known as *Cochliobolus sativus*; and previously known as *Helminthosporium sativum*), and *Microdochium nivale* (previously known as *F. nivale*). These organisms typically occur as mixed populations in cereal production regions throughout the world, with proportions of each varying in response to climatic, cropping, and edaphic characteristics.

The dryland root rot fungi are considered "unspecialized" pathogens because they are capable of attacking any plant tissue they contact, providing conditions in the micro-environment at the tissue surface are favorable for infection. Infection typically occurs under the soil surface for non-irrigated cereals in semiarid climates, but may also occur in the foliar canopy in irrigated crops or in areas of higher rainfall. Several of these fungi cause head scab if conditions favor their spread to the head during cool, wet weather. *F. graminearum* is particularly well adapted for spreading to the head. Two forms (Group 1 and Group 2) of this pathogen are recognized. Group 1 is considered truly soilborne and has no known perfect stage. Group 2 forms fruiting structures (perithecia) capable of ejecting spores into the air. The perfect stage of *F. graminearum* Group 2 is named *Gibberella zeae*, the pathogen mostly associated with head scab of wheat and crown rot of corn.

The dryland root rot pathogens cause similar symptoms on underground plant parts, and similar damage to components of yield, yet they possess certain differences that influence their survival and pathogenicity. These differences cause the population of each specific pathogen, or its prevalence in a mixture, to vary among regions. The pathogens also have subtle differences for plant structures (crown roots, subcrown internode, crown, foliage, etc.) they infect preferentially. The biology of several dryland root rot pathogens has been studied in depth in Washington. Considerable attention has also been given to development of control practices for this disease. Much of the work was performed where *F. culmorum* was by far the dominant pathogen. Little of the disease control research in the Pacific Northwest has been done where *F. graminearum* is the principal pathogen, and none has been performed where *Fusarium* species were known to be intermixed with *B. sorokiniana*. During the course of plant pathological investigations throughout northcentral and northeast Oregon we have noted instances where either *F. graminearum* or *B. sorokiniana* appeared to be the primary pathogens causing necrosis of plant crown tissue. No concerted investigation of the geographic distribution of these pathogens or of disease etiology had been conducted in Oregon. It is possible that difficulties in controlling dryland root rot in Oregon could be related to differences in pathogen species and their response to control practices, as compared to earlier investigations in Washington.

F. culmorum and *B. sorokiniana* survive as spores either in plant residue or soil. *F. graminearum* and *F. avenaceum* survive mostly or entirely as mycelial fragments in plant residue. The pathogens can be seed-borne, providing immediate access to seedlings emerging from untreated seed. *F. culmorum* colonizes roots at points of injury, especially where crown roots penetrate crown tissue as they emerge. The principal sites for infection by *F. graminearum* and *F. avenaceum* depend on the vertical distribution of crop residue in the plow layer. Infections by *F. graminearum* occur mostly in crowns when residue is at the surface and through the subcrown internode, or at the seed when residue is incorporated or burned. *F. avenaceum* infects the coleoptile, sub-crown internode, crown roots and seminal roots during periods of abundant moisture. *B. sorokiniana* can infect all tissues below or above the soil surface. These pathogens all cause chronic infections of the plant. Measurable effects on yield seldom become apparent unless the plant is subjected to water stress and/or warm temperatures late in the growing season. However damage can also be substantial during very wet periods and in irrigated wheat.

Information on chemical control and genetic resistance for reducing damage from dryland root rot are not currently available in disease control guidelines for the Pacific Northwest. New fungicides are showing intermediate levels of promise for reducing disease severity and increasing yield (Smiley and others, unpublished results of seed treatment studies). Unfortunately, each species of pathogen involved in the dryland root rot complex appears to have a different sensitivity to each fungicide. Local and international research shows new promise for techniques to select varieties with improved levels of adult-plant tolerance to dryland root rot, however, the varieties are likely to respond differently to some pathogens.

Additional progress in minimizing damage from dryland root rot will require a more complete knowledge of the composition of the pathogen population in each geographic region. The objective of this study was to determine the identities of dryland root rot pathogens in northcentral and northeast Oregon. Initial findings made it imperative that the survey be expanded into other parts of Oregon and into Washington, so that results could be linked to and expanded upon the knowledge developed during studies in Washington two and three decades earlier.

METHODS

Winter wheat plants and soil were initially collected from 72 fields in eight Oregon counties during the spring of 1993. Counties included Wasco, Sherman, Gilliam, Morrow, Umatilla, Union, Wallowa, and Baker. Numbers of fields sampled were approximately proportional to acres of winter wheat harvested in each county during 1992, with an arbitrarily assigned minimum of two samples/county. Samples consisted of 15 or more plants collected while moving in a circle (30-50 foot diameter) located 100 to 200 feet inside each field. Symptoms of dryland root rot were never apparent in the foliage at the time plants were dug from the soil. Plants were collected at random with respect to field selection, field history, sampling loci within fields, and selection of individual plants. Approximately one pound of soil between drill rows was collected from the same subsampling sites where plants were collected. Plants were washed to remove soil and examine them for presence of all common diseases of roots and foliage (data not presented).

Crown tissue was dissected from 15 plants/field. Half of each crown segment was cultured in the laboratory on two media semi-selective for isolating either *Fusarium* or *Bipolaris*. Fungi that grew out of the tissue segments were transfered to a third culture medium for identification and, in the case of *F. graminearum*, an opportunity to identify the group type. Selected isolates were then placed into semi-permanent cultures for more exhaustive studies. Results of fungi isolated from crowns of winter wheat are reported in this paper.

Preliminary evaluation of results during 1993 revealed surprises that made it important to tie the present survey together with information collected in Washington during the 1960's and 1970's. The survey was immediately expanded during 1993 to encompass a total of 146 fields in two additional Oregon and seven Washington counties. Counties included Malheur and Jefferson in Oregon, and Benton, Walla Walla, Columbia, Adams, Lincoln, Whitman, and Asotin in Washington. After sampling was completed, Extension agents assisted in collecting information on field histories and the varieties planted.

The survey was continued in 1994 and expanded to include Klickitat and Franklin counties in Washington. Samples were collected from the in-crop field nearest that sampled during 1993, except for several sites that were eliminated to minimize samplings from adjacent fields; 142 fields were sampled, 83 in 10 Oregon counties and 59 in nine Washington counties.

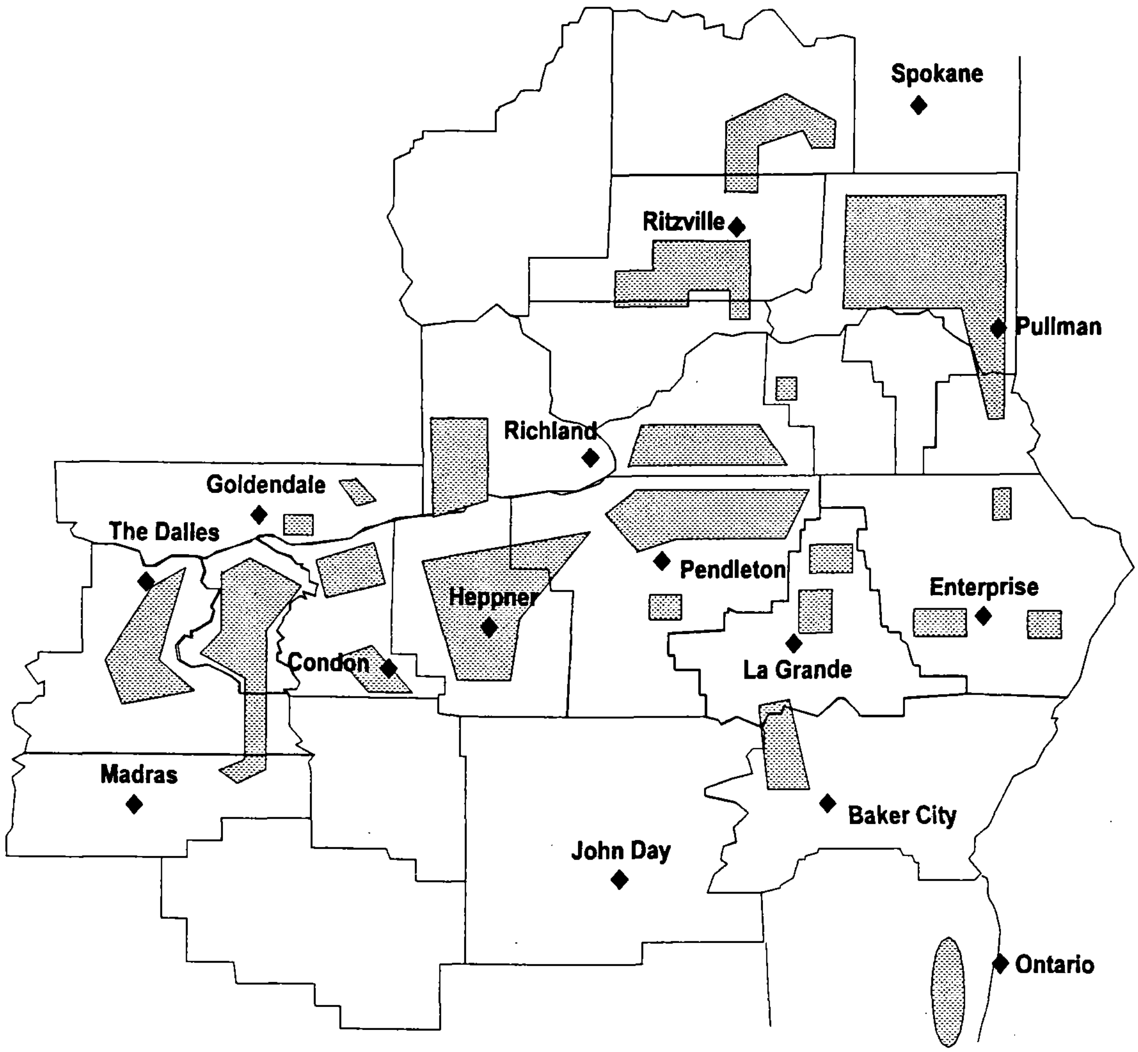
Soil samples are currently being evaluated for the presence of pathogens such as *F. culmorum*, which may survive as spores in soil. Results of this work may be used to expand information achieved with isolations made from plant tissue. Taxonomic and pathogenicity studies are also being conducted in the laboratory and greenhouse, using about 230 fungi isolated from plant tissue.

RESULTS AND DISCUSSION

Samples were collected from 178 fields in 10 Oregon counties and 110 fields in nine Washington counties. Regions included in the survey are illustrated in Figure 1. Numbers of wheat crowns excised from plants and plated onto culture media in the laboratory included 3,445 from Oregon and 1,945 from Washington. Approximately half of the 5,390 crowns from 288 fields were examined during each of the two years of this survey.

The 1991-1992 growing season had normal precipitation except for abnormally wet periods during April and July (refer to the last page of this publication). Excellent soil moisture in the summer fallow prompted many growers to plant winter wheat earlier than normal in the autumn of 1992, leading

Figure 1. Sampling regions for surveys of dryland root rot pathogens in 288 fields located in 10 Oregon and nine Washington counties during 1993 and 1994.



to numerous instances of severe dryland root rot. Infections in some fields became intense as early as November 1992. The winter and spring of the 1992-1993 season were very wet, leading to 20 percent higher than normal precipitation for the crop year. The summer, autumn, and winter of the 1993-1994 season were very dry. Plantings were often delayed until rains began during November. Plants showed signs of drought stress as early as April 1994.

Summaries of percentages of fields yielding isolates of the dryland root rot fungi in each state are presented in Table 1. *F. graminearum* was isolated more frequently than *F. culmorum* during each year in each state. The third-most prevalent pathogen was *F. avenaceum* during 1993 (wet year), and *M. nivale* during 1994 (dry year). The least prevalent pathogen was *B. sorokiniana* during 1993 (wet year), and *F. avenaceum* during 1994 (dry year). Further evidence for seasonal fluctuation among pathogens

Table 1. Numbers of fields sampled and percentages of fields yielding isolates of dryland root rot pathogens during surveys conducted in eastern Oregon and Washington during 1993 and 1994.

Pathogen species	1993			1994		
	OR	WA	OR+WA	OR	WA	OR+WA
	- percentages of fields with isolates -					
Fusarium graminearum	43	59	49	31	23	28
Fusarium culmorum	24	38	29	16	13	15
Fusarium avenaceum	13	5	18	1	3	2
Bipolaris sorokiniana	2	6	3	5	22	12
Microdochium nivale	6	10	8	19	27	23
Number of fields sampled	95	51	146	83	59	142

associated with wheat crowns is apparent in Tables 2 and 3. These data, literature from other regions and countries, and previous work in Washington, indicate that seasonal variability in pathogen prevalence was due to the different weather patterns during the two years of this survey.

One or more of the five pathogens associated with dryland root rot were present in each Oregon county during one or both years (Table 2). The most dominant pathogens region-wide in Oregon were *F. graminearum* and *F. culmorum*, but *M. nivale* was prominent in two counties where elevations typically exceed 3,000 feet and average soil temperatures tend to be cooler than in other areas. *B. sorokiniana* was present in six of the 10 counties, but did not appear to be a dominant member of the root rot complex.

The pathogen complex was also diverse in Washington (Table 3). Either *F. graminearum* or *F. culmorum*, or both, were present in each area. The lack of isolation of these pathogens in Columbia County was considered an artifact; it is clear that dryland root rot also occurs in that county. Lack of isolation of any of these pathogens does not infer that they are not present in the field. It was of interest that *B. sorokiniana* and *M. nivale* each appeared dominant in three Washington counties during 1994.

Dryland root rot pathogens evolved with relatively little specificity for the types of tissue or the species of plants they are able to infect, or to survive upon. The frequent identification of each pathogen throughout eastern Oregon and Washington, and the seasonal variability perceived to occur for their dominance in association with wheat crowns, indicates that all may be important in some areas during some years. The complexity of this situation indicates that chemical, cultural, and genetic disease management strategies must be developed to improve overall plant health rather than specifically targeting to one or two pathogen species. This is a challenging task but previous and current information illustrates that it is achievable. For instance, a growing body of evidence suggests that certain combinations of fungicides, selection of varieties, timing, placement and rate of nitrogen application, type of rotation, and management of surface residue provides more season-to-season stability for minimizing damage from dryland root rot than is true for other choices among these crop and soil management variables.

Table 2. Identities and relative prevalence† of dryland root rot pathogens‡ isolated from Oregon winter wheat fields sampled during surveys conducted during 1993 and 1994.

County	1993						1994					
	Fields/ county	Fg	Fc	Fa	Bs	Mn	Fields/ county	Fg	Fc	Fa	Bs	Mn
Baker	2					X	1					
Gilliam	13	X	X	x	x		9	X	x			x
Jefferson	2					X	2					
Malheur	5	X	X			x	5					
Morrow	9	x	x	x			7	X	X		x	X
Sherman	19	X	X	x			16	X	x	x	x	x
Union	4			x	x	x	4					x
Umatilla	29	X	x	X	x	x	23	x	x		x	X
Wallowa	2		X				6					
Wasco	10	x					10	X			x	

† An 'X' indicates the pathogen was dominant among isolates and an 'x' indicates the pathogen was isolated from at least one field in the county.

‡ Fg = *Fusarium graminearum*; Fc = *F. culmorum*; Fa = *F. avenaceum*; Bs = *Bipolaris sorokiniana*; Mn = *Microdochium nivale*.

Table 3. Identities and relative prevalence† of dryland root rot pathogens‡ isolated from Washington winter wheat fields sampled during surveys conducted during 1993 and 1994.

County	1993						1994					
	Fields/ county	Fg	Fc	Fa	Bs	Mn	Fields/ county	Fg	Fc	Fa	Bs	Mn
Adams	5	x	X		x		8	X	x		X	X
Asotin	3	X					4	x				
Benton	11	X		x		x	9	x			x	x
Columbia	2						2					
Franklin	0						1	X				
Klickitat	0						5		x			x
Lincoln	7	x	X		x	x	7		X		X	x
Walla Walla	13	X	x	x	x		10	X	x	x	x	X
Whitman	10	X	x	x		x	13				X	X

† An 'X' indicates the pathogen was dominant among isolates and an 'x' indicates the pathogen was isolated from at least one field in the county.

‡ Fg = *Fusarium graminearum*; Fc = *F. culmorum*; Fa = *F. avenaceum*; Bs = *Bipolaris sorokiniana*; Mn = *Microdochium nivale*.

Authors of this paper are conducting studies to improve these strategies for reducing damage from dryland root rot in the Pacific Northwest.

Non-pathogenic as well as pathogenic fungi were isolated during this study. Fungi isolated from 2,550 wheat crowns during 1993 included 831 *Fusarium* isolates representing 19 species. Species isolated from more than 50 crowns included *F. oxysporum* (260 isolates), ***F. graminearum*** (254; all except one of which was Group 1), ***F. culmorum*** (74), and *F. reticulatum* (67). Other fungi capable of causing dryland root rot were isolated less frequently, including 32 of ***F. avenaceum***, 16 of ***M. nivale***, 8 of ***B. sorokiniana***. Also enumerated but not reported here were isolates of the following species of *Fusarium*: *acuminatum, compactum, decemcellulare, dimerum, episphaeria, equiseti, lateritium, moniliforme, sambucinum, semitectum, solani, sporotrichioides, tricinctum,* and *trichothecoides*. Fungi that were not enumerated included species of *Alternaria, Aspergillus, Cephalosporium, Chaetomium, Cladosporium, Mucor, Penicillium, Pythium, Rhizoctonia, Stemphyllium,* and *Verticillium*.

Fungi isolated from 2,840 wheat crowns during 1994 included 487 *Fusarium* isolates representing 19 species. Species isolated from 50 crowns or more included ***F. graminearum*** (108 isolates; all were Group 1), *F. reticulatum* (101), *F. oxysporum* (93), and *F. solani* (50). Other fungi capable of causing dryland root rot were isolated less frequently, including 37 of ***M. nivale***, 30 of ***B. sorokiniana***, 22 of ***F. culmorum***, and 3 of ***F. avenaceum***. Also enumerated but not reported here were isolates of the following species of *Fusarium*: *acuminatum, dimerum, equiseti, graminum, lateritium, merismoides, moniliforme, proliferatum, sambucinum, scirpi, sporotrichioides, sulphureum,* and *tricinctum*. Fungi that were not enumerated included species of *Alternaria, Cephalosporium, Cladosporium, Fumago, Heterosporium, Pythium, Rhizoctonia, Stemphyllium,* and *Verticillium*.

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SEED TREATMENTS AND GENETIC RESISTANCE FOR CONTROLLING SMUT DISEASES IN WINTER WHEAT

Richard Smiley and Lisa-Marie Patterson

INTRODUCTION

Smuts were the most destructive diseases of winter wheat in the Pacific Northwest (PNW) until 1956 (Shafer, 1987). Until that time the major emphasis of wheat breeding programs was developing smut-resistant varieties (Hoffmann, 1982). Unfortunately, the pathogens quickly evolved to overcome the resistance of each newly released variety. Fungicide seed treatments (formaldehyde, copper carbonate, and organic mercuries) that were effective in other regions or countries failed to control common bunt (*Tilletia caries*), dwarf bunt (*T. controversa*) and flag smut (*Urocystis agropyri*) because, in the semiarid PNW, spores of the pathogens persisted in soil as well as on seed. Loose smut (*Ustilago tritici*) was not amenable to control by chemical seed treatment because the pathogen was protected within infected seeds.

Soilborne inoculum of the smut pathogens was not controlled by chemical seed treatments until the advent of the polychlorophenols, particularly hexachlorobenzene (HCB) and pentachloronitrobenzene (PCNB), in the mid-1950's. Seed treatment technology for smut control was advanced markedly when TBZ (thiabendazole) and Vitavax (carboxin) were registered in the 1960's. These were the first systemically translocated fungicides and they greatly improved the control of most smut diseases, including loose smut. Neither fungicide is completely effective against soilborne inoculum of the common bunt pathogen at recommended application rates (Gaudet et al., 1989). However, during the past two decades approximately 95 percent of winter wheat seed planted in the PNW has been treated with Vitavax. Combination of seed treatment and resistant host variety, each of which provide incomplete control, have been utilized as an effective integrated control strategy that virtually eliminated economic damage from all except dwarf bunt.

Near freedom from common bunt and an emerging crisis with stripe rust caused breeders to reduce emphasis on common bunt. Numbers of pathologists and geneticists specializing in smuts of wheat in the PNW have declined from nine to zero during the past three decades. Some of the new winter wheat varieties in the PNW are susceptible to all smut pathogens. The hazard of placing excess emphasis on fungicides was clearly defined in Europe by the development of races of the common bunt pathogen resistant to HCB (Kuiper, 1965). Outbreaks of the disease occurred shortly after the fungicide defense was breached. The barley loose smut pathogen also developed tolerance to carboxin in several European countries during the 1980's (Brent, 1988; Leroux and Berthier, 1988). Experiences in several regions of the world indicate that when reliance is shifted too heavily toward chemical treatments, and away from development of resistant varieties, many fungicides ultimately fail, requiring a renewed emphasis on breeding resistant varieties and on development of new fungicides. Combining chemical control with genetic resistance usually prevents the failure of either component of the dual-control system.

Winter wheat varieties lacking genetic resistance to these diseases are once again being released in the PNW. That presents a challenge for disease management specialists because smut pathogens are still present in soil at threatening levels (Hoffmann, 1982; Hoffmann and Waldher, 1981). One or more smut diseases are observed on a small percentage of winter wheat plants every year, apparently because the critical amount of fungicide does not adhere uniformly to all seeds during treatment. In Oklahoma, during a period of drier-than-normal summers, common bunt reappeared suddenly even though it had been nearly non-existant for 40 years and Vitavax was being used (Williams, 1990). PCNB seed treatment and a series of wetter summers (normal) brought the outbreak under control. There does not appear to be any evidence that the pathogen had become tolerant of Vitavax in Oklahoma.

Although tolerance to Vitavax also does not appear to have occurred among smut pathogens in the PNW, fungicides unrelated to Vitavax and a return to the dual-control strategy are clearly needed to assure the stability of the wheat industry. In 1990 and 1991, for instance, a Umatilla County producer who grew a flag smut-susceptible variety without seed treatment for two successive years in a winter wheat-summer fallow rotation experienced 50 and 19 percent yield reductions due to flag smut during the second crop on each field of the rotation (Karow et al., 1994; Smiley and Uddin, 1992). A seed treatment is also needed to supplement the incomplete host resistance available for controlling dwarf bunt, the disease that prevents export of PNW wheat to the People's Republic of China.

Several new triazole-derivative fungicides have been registered during the past decade. They are systemically translocated in plants, have broad spectrum of fungitoxicity, and varying degrees of plant growth regulating activity. Baytan (triadimenol) was the first triazole fungicide to be used as a translocated seed treatment (Buchenauer and Grossman, 1977; Frohberger, 1978). Plant growth regulatory (phytotoxic?) effects of Baytan include delayed emergence, reduced surface area of coleoptiles, growth retardation, reduced root length and tillering aberrations (Buchenauer and Rohner, 1981; Fletcher and Hofstra, 1985; Forster et al., 1980; Gao et al., 1988; Monfort et al, 1995; Smiley et al., 1990). Baytan provides excellent protection against smuts when used at recommended rates and with shallow planting depth. It is not recommended for use with deep-furrow drills.

Dividend (difenoconazole), registered in 1994, is a triazole fungicide that recently gained attention because of its ability to control dwarf bunt (Sitton et al., 1994) and other smuts. The influence of Dividend on seedling emergence, grain yield, and farm profitability have not been reported. Of particular interest was whether Dividend, as with many other new fungicides, will be limited to a niche market to control dwarf bunt, or whether it has characteristics enabling it to become the primary seed treatment for general use throughout the PNW?

The objectives of this study were to review the status of fungicide seed treatments currently available for controlling smuts, review smut disease reactions for currently recommended winter wheat varieties, and investigate comparative effects of Dividend and Vitavax on winter wheat seedling emergence and development, grain yield, test weight, and profitability.

METHODS

Status of Fungicide Seed Treatments for Smut Diseases

The 1994 and 1995 "Pacific Northwest Plant Disease Control Handbooks" were used to determine current recommendations for seed treatments on winter wheat. Reports in the technical literature were also examined.

Status of Varietal Resistance to Smuts

Levels of resistance or susceptibility to smut diseases of winter wheat varieties were determined from the publications "Winter Cereal Varieties for 1994" (from Oregon State University) and "1994 Certified Seed Buying Guide" (from the Washington State Crop Improvement Association). When rating discrepancies were reported for a single variety the most susceptible of the ratings was used for assessments in this paper. Many races of each pathogen exist in the PNW and regional differences occur for susceptibility of a given variety.

Grain Yield and Test Weight

Comparisons of Dividend 3FS (0.25-1.0 fl oz/cwt) and either Vitavax 200F (3-4 fl oz/cwt) or RTU Vitavax Thiram (4-5 fl oz/cwt), or neither, were made in 24 experiments performed over five years (1990-1994 crops) at 12 eastern Oregon and Washington sites using seven winter wheat varieties. These experiments resulted in as many as 44 comparisons of yields among treatments for individual varieties, locations and years.

Most (16 of 24) tests were conducted in commercial fields. One experiment (at Echo) was located in an annually cropped irrigated field and others were in non-irrigated winter wheat-summer fallow rotations in 11- to 20-inch rainfall zones. All sites except Prosser, WA (Horse Heaven Hills area) were in Oregon. Soils, planting dates and depths, mean annual precipitation, and soil temperature at planting depth for each location are presented in Table 1.

Seed was planted with a Hege plot drill, at six seeds/foot of row (75-80 pounds/acre, depending on seed size). All tillage, fertilizer and weed management procedures were in accordance with commercial practices. Experiments were randomized complete block designs with five replications per treatment. Plots measured 5 x 20 feet and contained 5 rows spaced at 12-inch intervals. Plots were harvested with a Hege plot combine and grain samples were cleaned before determining grain yield, test weight, and kernel weight.

Data was analyzed by conducting an analysis of variance on the maximum number of tests in which each variable (fungicide treatment and/or rate) of interest occurred. That data were also evaluated by grouping tests that included a single variety, and by grouping tests according to yield brackets (10-bushel intervals) for grain produced from untreated seed.

Profitability

Summarized yield data from experiments described above was used to determine profitability of seed treatments. Other values used in the calculations were planting rate (80 lb seed/acre), income from grain produced ($3.50/bushel), grain test weight (60 pound/bushel), and costs for Dividend

Table 1. Characteristics of 12 locations where seed treatments were evaluated for effects on seedling emergence and grain yield from 1990 to 1994.

Location and number of tests	Soil series and texture[†]	Annual precipitation (in.)	Planting dates	Planting depth	
				inches	temp. (°F)
Arlington - 4	Walla Walla	11	Sep 9-18	3-4	72-74
Dufur - 2	Wamic	14	Sep 9	2.5	61
Echo - 1	Shano	10	Oct 29	1.5	70
Elgin - 4	Palouse	20	Sep 12	1.5	67
Flora - 6	Cowsly	20	Sep 12-22	1.5	52-61
Haines - 1	Hutchison	14	Sep 12	1.5-3	65
Helix - 3	Walla Walla	15	Sep 13	3.5	78
Heppner - 6	Valby	14	Sep 10-18	3	73
Moro - 5	Walla Walla	12	Sep 9-18	2-4	68-75
Pendleton - 9	Walla Walla	16	Sep 11-20	3	73-75
Prosser - 2	Ritzville	11	Sep 2	5	74
Reith - 1	Walla Walla	15	Sep 18	5	75

† All soils were silt loams except for Wamic loam at Dufur.

($565.00/gallon), and RTU Vitavax Thiram ($32.50/gallon).

Seedling Emergence and Development

Seedling emergence was estimated at six sites during the 1993-1994 winter wheat season and at two sites during 1994-1995. Three sites each were selected to represent areas where standard planting depths during September are either shallow or deep (Table 1). Deep plantings (>3 inch) were in areas where rainfall is traditionally marginal and summer fallow consists of a deep mulch of dust plus residue. All seed preparation and planting procedures were as described for yield trials. Seedling emergence was monitored at 2- to 7-day intervals depending on the depth of planting and rate of seedling emergence. A qualitative emergence scale (0-3) was used in view of the large number of plots, distance between plots, and frequency of observation. Ratings were as follows: 0 = <10% seedlings emerged, 1 = 10-50%, 2 = 50-85%, and 3 = >85%. Plant height and tillers or heads per foot of row were evaluated at maturity. During 1994-1995, emergence was monitored only at two very dry sites where soil moisture at planting depth (5-7 percent) was inadequate for optimal seedling emergence.

RESULTS AND DISCUSSION

Status of Fungicide Seed Treatments for Controlling Smut Diseases

Seedborne inoculum of most smut pathogens is killed by Captan, Vitavax (carboxin), Dividend (difenoconazole), Mancozeb, PCNB (pentachloronitrobenzene), TBZ (thiabendazole), Thiram, and Baytan (triadimenol). In contrast, very few fungicides are completely effective for controlling soilborne inoculum. The list of recommended products ("1994 Pacific Northwest Plant Disease Control Handbook") for preventing disease from soilborne inoculum in the Pacific Northwest includes only Baytan, Dividend, PCNB, and TBZ. Loose smut is controlled only by the systemic fungicides Baytan, Dividend, TBZ, and Vitavax. Baytan is not recommended for deep-furrow planting systems because it tends to reduce the rate of internode elongation, which can adversely affect seedling emergence. At least one smut pathogen has developed tolerance to Baytan, TBZ, or Vitavax elsewhere in the world. There is a clearly defined need for at least two primary seed treatment fungicides to minimize the potential for an outbreak of a smut disease should tolerance to one fungicide be developed in the PNW.

Status of Variety Resistance to Smuts

For the purposes of this report there is no distinction made between susceptible or moderately susceptible varieties; all are considered susceptible in our summary. A variety is also considered susceptible if reported as such in either Oregon or Washington. Most (80-90 percent) soft white common, club, and hard red winter wheat varieties recommended for production in Oregon and Washington are susceptible to dwarf bunt and flag smut (Tables 2 and 3). Information is not available for loose smut. Many (32 percent) varieties are also susceptible to common bunt and differences in ratings occur among varieties released by public or private breeders in the two states. No varieties released by private breeders are apparently susceptible to common bunt. Six of eight varieties of soft white common wheat from Oregon are reported susceptible to common bunt (Table 2) and one of ten released from Washington (WSU and USDA-ARS) is susceptible (Table 3). Only one of seven hard red wheat varieties is susceptible and it was released by Oregon. Three of nine club wheat varieties are susceptible and all were released from Washington.

Grain Yield and Test Weight

Productivity of winter wheat varied from 20 to 100 bushel/acre (Table 4), reflecting a diversity of conditions under which fungicides were compared. Experimental locations were selected to examine seed treatments in areas where at least nine diseases or disease complexes were present. Diseases and other conditions affecting yield, such as drought or Hessian fly, were reported annually for each variety and fungicide treatment from 1991 to 1994 (*Fungicide and Nematicide Tests* volumes 47-50 [1992-1995]; American Phytopathological Society, St. Paul, MN), and are summarized in Table 4. Nearly half the comparisons in these studies involved situations where yield and response to fungicides was prevented by drought, disease-resistant varieties, or diseases against which the fungicides were not expected to be active. These tests provided a conservative measure of benefits likely to be experienced from use of seed treatments in commercial practice.

Table 2. Smut disease reactions for winter wheat varieties developed by public institutions in Oregon or private companies in the Pacific Northwest.

Release Year	Wheat Class and Variety	Common Bunt	Dwarf Bunt	Flag Smut
	Oregon Soft White Common			
1969	Yamhill	S	S	MS
1977	Stephens	R (S)	S	MS
1981	Hill	R (S)	S	MS
1987	Malcolm	R	S	MS
1987	Oveson	MR	S	MS
1991	Gene	S	S	MS
1992	MacVicar	S	S	-
1992	W301	MS	MS	MR
	Oregon Club			
1965	Moro	R	MR	MR
1976	Faro	MR	S	S
1992	Rohde	MR	S	(VS)
	Oregon Hard Red			
1991	Hoff	S	S	S
	Private-release Soft White Common			
1985	Basin	R	MR (S)	R (MS)
1985	Cashup	R	S	R (MS)
1991	Durheim's Pride	-	(S)	(MS)
1994	Banner	-	(S)	-
	Private-release Club			
1978	Jacmar	MR	MR	MR

† Disease reaction data are from the following publications: "Winter Cereal Varieties for 1994" (from Oregon State University) and "1994 Certified Seed Buying Guide" (from the Washington State Crop Improvement Association); VS = very susceptible, S = susceptible, MS = moderately susceptible, MR = moderately resistant, R = resistant. When discrepancies occur, or a rating was not provided in the Oregon guide, ratings from Washington were placed in parenthesis.

Table 3. Smut disease reactions for Washington public-release winter wheat varieties.

Release Year	Wheat Class and Variety	Common Bunt	Dwarf Bunt	Flag Smut
	Soft White Common			
1961	NuGaines	R	S	-
1973	Sprague	R (S)	S	MS
1976	Daws (USDA)	R	S	MS
1982	Lewjain (USDA)	R	MR	MS
1984	John	MR	S	MS
1985	Dusty	R	S	MS
1988	Madsen (USDA)	R	S	MS
1990	Eltan (USDA)	R	R (MR)	(MS)
1990	Kmor (USDA)	R	S (MR)	(MS)
1992	Rod (USDA)	R	S	(MS)
	Club			
1979	Tyee (USDA)	MR	S	VS
1982	Crew (USDA)	R	S	S
1984	Tres (USDA)	MS	S	VS
1988	Hyak (USDA)	MS	S	S
1990	Rely (USDA)	MS	S	VS
	Hard Red			
1965	Wanser	R	S	VR
1979	Hatton	MR	S	R
1979	Weston (USDA)	R	R	R
1985	Batum (USDA)	R	S	MS (R)
1987	Andrews	R	MR	R
1989	Buchanan	MR	S	R

† Disease reaction data are from the following publications: "Winter Cereal Varieties for 1994" (from Oregon State University) and "1994 Certified Seed Buying Guide" (from the Washington State Crop Improvement Association); VS = very susceptible, S = susceptible, MS = moderately susceptible, MR = moderately resistant, R = resistant. When discrepancies occur, or a rating was not provided in the Oregon guide, ratings from Washington were placed in parenthesis.

Table 4. Yield (bu/ac) and principal yield constraint for seven winter wheat varieties grown from seed treated with Dividend, Vitavax 200 (or RTU Vitavax Thiram), or untreated, in 24 experiments over five years at 12 Oregon and Washington locations.

Crop Year	Location	Main yield con-straint	Wheat variety	Seed Treatment (fl oz/cwt) Dividend 0.25-0.33	Dividend 0.5	Dividend 1.0	Vitavax 4-5(RTU) 3-4(200)	None
1990	Elgin	RR	Hill	69.2	68.1	73.3		69.3
			Lewjain	73.2	57.2	53.7		65.3
1990	Moro	CR	Stephens	35.5	36.0	35.5	-----	32.2
1990	Pendleton	N	Hill	61.8	63.8	61.3	-----	58.0
			Lewjain	67.4	70.4	63.3	-----	66.4
1991	Elgin	RR	Hill	76.9	74.6	69.8	77.2	66.1
			Lewjain	75.2	72.6	73.7	79.4	71.6
1991	Flora	DB,	Hill	81.2	87.6	84.9	73.7	69.8
		SM	Lewjain	76.3	79.4	88.8	75.3	71.6
1991	Haines	RR	Hill	63.2	66.1	73.0	59.9	71.5
1991	Echo	TA	Stephens	60.8	65.5	59.2	-----	62.5
1991	Reith	FS	Tres	32.7	38.2	33.9	29.0	21.3
1992	Arlington	CR	Stephens	-----	53.7	-----	52.8	50.1
1992	Flora	DB,	Hill	68.7	69.2	69.0	70.8	73.1
		SM	Lewjain	68.7	77.3	73.2	66.9	69.9
1992	Heppner	CS,	Lewjain	-----	21.9	-----	17.1	20.8
		D	Madsen	-----	21.9	-----	21.5	22.6
			Stephens	-----	24.6	-----	20.8	21.5
1992	Moro	CR	Stephens	-----	69.5	-----	62.4	62.7
1992	Pendleton	FR	Lewjain	-----	62.4	-----	57.6	60.8
			Madsen	-----	82.7	-----	80.4	82.1
			Stephens	-----	74.7	-----	62.4	64.4
1993	Arlington	CR	Stephens	-----	49.5	62.6	48.9	47.4
1993	Flora	DB,	Hill	69.5	70.2	68.2	73.3	63.6
		SR	Lewjain	66.4	72.6	67.8	74.8	57.3

Table 4. (continued)

1993	Dufur	CS, SM,HF	Hill Lewjain	22.0 25.3	19.7 19.7	19.8 23.2	14.1 18.2	19.4 18.6
1993	Moro	CR	Stephens	-----	44.2	46.8	44.2	44.8
1993	Pendleton	FR	Madsen Stephens	59.5 69.9	70.9 70.5	66.2 71.7	61.3 68.7	68.6 64.0
1994	Arlington	CR	Rohde Stephens	----- -----	59.2 59.0	61.8 61.8	61.2 57.3	61.0 58.5
1994	Helix	CS	Madsen Rohde Stephens	----- ----- -----	55.4 47.8 46.8	54.6 49.8 47.2	51.1 46.5 49.8	51.6 46.0 51.9
1994	Heppner	CS	Madsen Rohde Stephens	----- ----- -----	34.5 25.0 29.1	30.8 26.7 35.5	31.8 24.4 31.4	30.1 23.9 30.2
1994	Moro	CR	Rohde Stephens	----- -----	45.9 45.7	44.5 45.9	46.5 43.7	48.4 45.6
1994	Prosser	CR	Rohde Weston	----- -----	55.9 46.8	62.4 53.3	57.6 43.7	48.8 46.4
1994	Pendleton	FR	Madsen Stephens	----- -----	93.9 95.8	96.7 96.9	87.7 93.4	99.9 101.8

† Yield was constrained primarily by Fusarium root rot (CR), a root disease complex (RR), take-all root rot (TA), strawbreaker foot rot (FR), snow mold (SM), flag smut (FS), dwarf bunt (DB), Cephalosporium stripe (CS), stem rust (SR), Hessian fly (HF), drought (D), or undetectable constraints (N). Disease assessments for 1991-1994 were published in *Fungicide and Nematicide Tests* volumes 47-50 (1992-1995).

Comparison of yields from fungicide-treated and untreated seed indicated (Table 5) that yield of winter wheat was improved more often by Dividend than by Vitavax. Compared to Vitavax, the Dividend treatment (0.5 fl oz/cwt) improved production of wheat by 5 percent (2.7 bu/acre) in 39 comparisons that represented 5 years of testing with 7 varieties at 11 locations. The yield improvement from Dividend was 13 percent (3.0 bu/acre) for areas yielding less than 40 bu/acre and 5 percent(2.7 bu/acre) for areas yielding more than 40 bu/acre (Table 6).

Wheat treated with Dividend at 1 fl oz/cwt yielded slightly more grain than for the 0.5 fl oz/cwt rate, however the response was skewed with respect to the range of productivity expected in the test area. Increasing the Dividend application rate from 0.5 to 1.0 fl oz/cwt increased yield by 4 percent (1.4 bu/acre) in areas yielding less than 50 bu/acre (based on 14 comparisons). In contrast, there was a corresponding

Table 5. Comparison of winter wheat yields in low and high producing areas, as influenced by seed treated with Dividend, Vitavax 200 or RTU Vitavax Thiram, or untreated (combined data from Table 4).

Treatment and rate (fl oz/cwt)	Yield potential where tests were performed		
	< 40 bu/acre	> 40 bu/acre	all areas
Untreated control	23.3	63.2	53.4
Dividend (0.5)	26.1	65.8	56.2
Vitavax (3.0-5.0)	23.1	62.1	53.5
lsd (P=0.05)	2.8	2.4	1.8
Years tested	5	4	5
Locations tested	4	7	11
Varieties tested	6	6	7

Table 6. Relative influence of Dividend or Vitavax (Vitavax 200 or RTU Vitavax Thiram) seed treatments on winter wheat yield and profitability, compared to untreated seed (combined data from Table 4.

Treatment and rate (fl oz/cwt)	Data pairs tested	P > F	Increase in yield		Net profit or <loss>†
			bu/acre	%	$/acre
Dividend (0.25-0.33)	20	0.03	3.2	5.5	$10.32
Dividend (0.5)	44	0.004	2.6	4.8	$ 7.33
Dividend (1.0)	36	0.007	3.1	5.6	$ 7.32
Vitavax (3.0-5.0)	38	0.9	0.1	0.2	<$ 0.92>

† Compared to untreated seed and based on the following criteria: planting rate of 80 lb seed/acre, income of $3.50/bu of grain produced, test weight of 60 lb/bu, and treatment costs of $565.00/gal for Dividend and $32.50/gal for RTU Vitavax Thiram. Calculations were based on Dividend applied at 0.25, 0.5, and 1.0 fl oz/cwt, and RTU Vitavax Thiram applied at 5.0 fl oz/cwt.

Table 7. Emergence[†] of winter wheat seedlings from 3-inch planting depth at two locations during 1993 (seed-zone moisture content was 17.7% at Pendleton and 11.7% at Helix).

Treatment	Days after planting at Pendleton					Days after planting at Helix			
(fl oz/cwt)	8	10	12	14	18	10	12	14	18
Control	1.9	2.8	3.0	3.0	3.0	2.5	2.7	2.9	3.0
Dividend (0.5)	1.6	2.8	3.0	2.9	3.0	2.2	2.7	2.9	3.0
Dividend (1)	1.5	2.2*	3.0	3.0	3.0	2.3	2.9	3.0	3.0
RTU Vitavax Thiram (5)	0.9*	1.5*	2.4*	2.7*	2.9	1.5*	2.5	2.8	2.9
lsd (P=0.05)	0.4	0.4	0.2	0.2	0.2	0.4	0.3	0.3	0.2

† Emergence was rated visually as follows; 0 = none, 1 = <10% of seedlings emerged, 2 = 50-85%, 3 = >85%. Combined data for the varieties Madsen and Stephens at Pendleton and Madsen, Rohde and Stephens at Helix. Data within each column differ (P<0.05) from emergence of untreated seed when marked by an asterisk (*).

Table 8. Emergence[†] of winter wheat seedlings from 4- to 5-inch planting depths at Arlington and Prosser during 1993 (seed-zone moisture content was 7.7% at Arlington and 9.1% at Prosser).

	Days after planting at					
	Arlington		Prosser			
Treatment (fl oz/cwt)	15	22	14	21	28	34
Control	2.4	2.9	1.5	2.1	2.1	2.0
Dividend (0.5)	2.8*	3.0	2.2*	2.6*	2.5*	2.6*
Dividend (1)	2.5	2.8	2.2*	2.5	2.1	2.5*
RTU Vitavax Thiram (5)	1.3*	2.5	0.9*	1.5	1.8	1.7
lsd (P=0.05)	0.4	0.4	0.5	0.5	0.4	0.4

† Emergence was rated visually as follows; 0 = none, 1 = <10% of seedlings emerged, 2 = 50-85%, 3 = >85%. Combined data for the varieties Rohde and Stephens at Arlington and Rohde and Weston at Prosser. Data within each column differ (P<0.05) from emergence of untreated seed when marked by an asterisk (*).

decrease of 2 percent (1.3 bu/acre) as the Dividend application rate was increased from 0.5 to 1 fl oz/cwt in areas that produce more than 50 bu/acre (22 comparisons).

Winter wheat varieties appeared to differ in yield response to seed treatments (analysis not shown). All varieties had higher mean yields when treated with Dividend compared to untreated seed or Vitavax-treated seed. Compared to Vitavax, Dividend improved yield of Rohde, Stephens, Lewjain, Hill, and Madsen by 0.6, 2.3, 2.4, 4.2, and 4.2 bu/acre, respectively. Compared to untreated seed of these varieties, Dividend increased yield by 2.2, 1.7, 5.1, 5.2, and 0.6 bu/acre, respectively. The numbers of comparisons for each variety were small (5-12), suggesting that these relationships should be considered preliminary until further tests are completed. Fungicide seed treatments did not affect bushel test weights or kernel weights in these experiments (data not presented).

Profitability

At current prices for each fungicide and for wheat produced, the yield data indicated that fungicides applied to provide equivalent levels of protection from smut had very different influences on profitability (Table 6). A net profit was shown for application of Dividend and a net loss for application of Vitavax. It must be stressed that critically important smut-controlling properties of these fungicides were not included in these calculations. Vitavax will continue to serve a highly profitable requirement where it is used preferentially over Dividend. All seed planted in the inland Pacific Northwest must continue to be treated with a smut-controlling fungicide, and the presence of two or more effective fungicides with different active ingredients will provide prolonged assurance for protection in the event that a pathogen develops resistance to one of the fungicides.

Dividend applied at 1 fl oz/cwt yielded slightly more grain than for the 0.5 fl oz/cwt rate but did not increase profitability (Table 6). A closer inspection revealed that the 1.0 fl oz rate increased profitability by $3.13/acre over the 0.5 fl oz rate in areas of lower production, but reduced profitability by $2.78/acre in higher production regions.

Profitability was highest for Dividend applied at 0.25-0.33 fl oz/cwt, however, it is not clear that this low rate is sufficient for complete protection from smuts. More experience with these low rates is required before they can be recommended or registered for commercial practice. Region-wide, the 0.5 fl oz/cwt rate of Dividend appears near optimal for controlling smuts and improving profitability.

Seedling Emergence and Development

Differences in emergence rate among fungicide treatments were noted but not quantified during the course of yield trials during 1992. Seedlings emerged from deeply planted seed more rapidly for Dividend than Vitavax treatments. Seedling emergence from Dividend-treated seed was equal to or better than for Vitavax-treated seed in all six experiments conducted during 1993-1994 (Tables 7-9). Dividend was particularly advantageous when seed was planted deeply into warm seedbeds (Tables 7 and 8). Plant height and numbers of tillers or heads per foot of row did not differ among treatments (data not presented).

Table 9. Emergence[†] of Weston winter wheat seedlings from 5-inch planting depth at Ione and Prosser during 1994 (seed-zone moisture content was 4.9% at Ione and 6.6% at Prosser, and most soft white wheat varieties did not emerge at Ione and were marginally acceptable at Prosser).

	Days after planting							
	Ione				Prosser			
Treatment (fl oz/cwt)	16	23	29	36	13	21	28	34
Control	0	0.4	0.8	0.7	0.8	1.8	2.4	2.8
Dividend (0.5)	0.2	1.0	1.4	1.4*	1.8*	2.2	2.6	2.8
Dividend (1)	0.8*	1.4	2.2*	2.2*	1.6*	2.2	2.6	2.8
RTU Vitavax Thiram (5)	0.8*	1.4	1.6	1.6*	1.6*	2.4	2.6	2.8
lsd (P=0.05)	0.7	ns	0.8	0.7	0.6	0.7	ns	ns

† Emergence was rated visually as follows; 0 = none, 1 = <10% of seedlings emerged, 2 = 50-85%, 3 = >85%. Data within each column differ (P<0.05) from emergence of untreated seed when marked by an asterisk (*).

SUMMARY

Most winter wheat varieties currently recommended in Oregon and Washington are susceptible to dwarf bunt and flag smut, and increasing numbers of varieties susceptible to common bunt are being released. Until more emphasis is placed on developing varieties with resistance to these smuts, fungicide seed treatments will be required to protect winter wheat from infection by the fungi causing these diseases.

Vitavax dominated the seed treatment market for 25 years before Dividend was registered in 1994. This research indicated that Dividend can improve disease management and farm profitability for winter wheat production in the PNW. Dividend (0.5 fl oz/cwt) increased yield 5 percent (2.7 bu/acre) over that from Vitavax-treated seed (5 fl oz/cwt), for an $8.24 increase in net profit per acre. Profitability of Dividend was increased by reducing the application rate to 0.25-0.33 fl oz/cwt, but the efficiency of such low rates for controlling smuts remains unclear. Profitability of Dividend was higher in regions where wheat production is less than 40 bu/acre compared to areas of higher productivity. Emergence of Dividend-treated wheat was as good or better than seed treated with RTU Vitavax Thiram.

This review and research indicated that, by switching from Vitavax to Dividend as the basic smut control fungicide, producers can increase winter wheat yield, profitability, control dwarf bunt, improve seedling emergence from deep seedbeds, and reduce by a factor of ten the amount of fungicide placed into the environment. Dividend achieved about 70 percent (>2.5 million acres) of the market share for a primary seed treatment on winter wheat in the PNW during its first market season (C. Zita, Ciba Crop Protection, personal communication).

Dividend was not tested on spring cereals. Our experience is that fungicide seed treatments are often more effective against diseases of spring than winter cereals (Smiley et al., 1991). Studies should be conducted to determine if yield enhancements from Dividend may be even more important on spring than winter cereals.

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'D3R' A RESIDUE MANAGEMENT AID

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INTRODUCTION

With the current concerns for residue cover on fallow and cropped fields there is a need to be able to predict, with some accuracy, the amount of residue cover on a field at a particular time. Since both type and timing of natural decomposition and tillage practices influence the amount of residue left on the surface, the question of concern may be "how do my tillage practices change residue cover?"

The computer program D3, Degree Day Decomposition, was developed to implement a residue decomposition model (Douglas and Rickman, 1992). The primary purpose of the model was to estimate wheat residue decomposition, both on and below the surface, utilizing the concept of degree days (DD) as developed by Klepper, et al., 1982. The model required knowledge of initial nitrogen content of the residue, the amount of residue left in the field after harvest, and the number of cumulative DD determined from air temperature.

The program D3 has been updated (now called D3R) to estimate the amount of residue left in a field by the previous crop and compute the amount of residue left on the surface or buried by different tillage implements, while continually determining the amount of decomposition occurring. Tables, developed by CTIC (1992), are utilized by D3R to determine the amount of residue left on the soil surface after a tillage operation.

USE OF THE PROGRAM D3R

Daily temperature is a required input of D3R. The program accepts electronic data in columnar form in either Fahrenheit or Celsius. Precipitation data, if available, are used to determine when the soil is moist enough for decomposition to begin. Either actual yearly climatic data or historical average data may be used. A date when decomposition is expected to begin can be entered if precipitation data is not available. Initially, information about crop residue and planned tillage practices must be entered. This includes nitrogen content of the residue, yield or amount of residue left in the field after harvest, and date and type of all planned tillages.

The program displays on the screen, and saves to a file, the continuing decline in surface cover and buried residue from both tillage and decomposition. These data may be examined graphically, either by scientific graphing software or a spreadsheet program. Either metric or English units may be used for entering the starting information and either may be chosen for the output.

DISCUSSION

Figure 1 shows the model's decomposition prediction compared to observed decomposition of a number of soft white winter wheat varieties, buried in an irrigated field, near Twin Falls, ID. Figure 2 shows the calculated residue decomposition, both on and below the soil surface, for dryland areas near Odessa, WA. Also note that in these two figures, decomposition can be plotted against either cumulative degree days or time in weeks or months. Figure 3 shows decomposition of corn residue left on the soil surface after three tillage

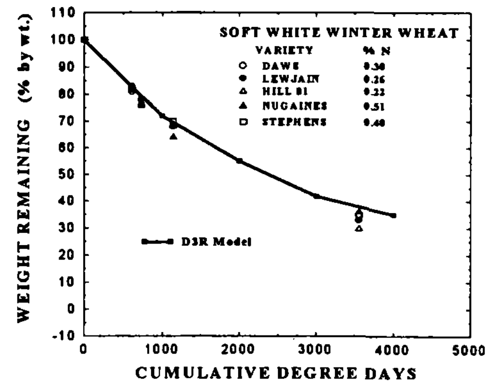

Figure 1. Decomposition of buried residues compared to the D3R model. DD calculated from 1983-84 air temperatures at Twin Falls, ID (Data from Smith and Peckenpaugh, 1992).

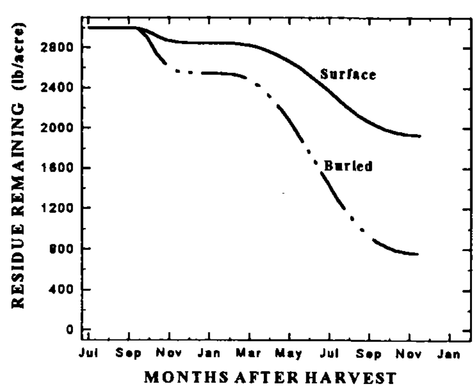

Figure 2. Decomposition of surface and buried residues near Odessa, WA. Data based on 30-yr. air temperatures.

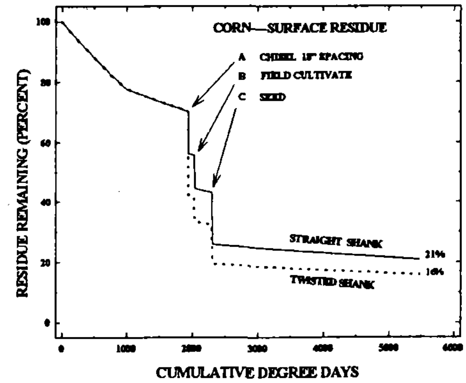

Figure 3. Effect of straight and twisted shank chisel points (Data from Broder and Wagner, 1988, Columbia, MO).

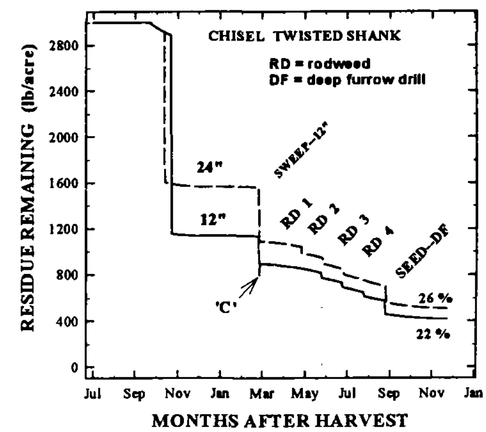

Figure 4. Effect of shank spacing on surface residue near Odessa WA. Data based on 30-yr. air temperatures.

operations near Columbia Missouri.

The effect of different shank spacing on a chisel plow is shown in Figure 4. More residue is left on the surface when chisel shanks are moved from 12 to 24 inches apart. Just one tillage early in the spring with the closer shank spacing decreased the amount of surface residue at time of seeding by 4 percent. This represents approximately 100 lbs of residue, which in some cases may be very important for obtaining adequate soil protection.

The effect of rod weeding and sweep tillage is shown in Figure 4. The slight dip at 'C' indicates a small amount of residue is returned to the surface when a rod weeder is used immediately after sweep tillage.

The D3R program will also keep track of both surface and buried residues during a number of tillages as shown in Figure 5. Buried residues start at 0 and surface residues at 3000 lbs/acre on August 1 in this example.

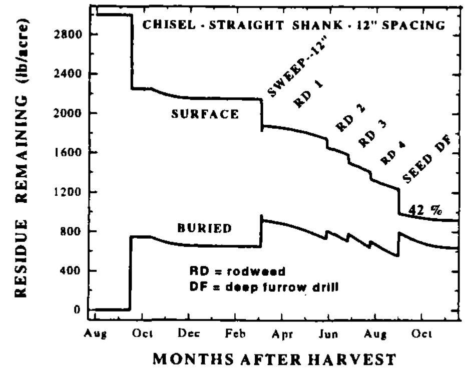

Figure 5. D3R estimation of residue left both on and below the soil surface with selected tillage operations plus decomposition. Data based on 30-yr air temperature at Odessa, WA.

Tillage with a straight shank chisel in mid-September results in approximately 800 lbs of residue being buried. The slight decrease in both surface and buried residues from mid-September until March is the result of over-winter decomposition. The remaining step changes are the result of selected tillage operations, such as a sweep and several rod-weeding operations, plus seeding. The gradual reductions in surface and buried residue from March through October is the result of decomposition.

CONCLUSIONS

The D3R program can compare a variety of tillage options for their effects on the amount of crop residue on the soil surface without actually performing the tillage. It is both an educational and planning tool. One can learn the consequences of decomposition and examine the incremental effects of tillage. The program is DOS based and can be run on any DOS (IBM compatible) computer.

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WORK IN PROGRESS: SOIL ROUGHNESS AND POROSITY MEASUREMENT WITH ACOUSTICS

R.W.Rickman

INTRODUCTION

Soil erosion by water can be held to an acceptable level in cropped fields with appropriate combinations of structures, cropping, and management practices. Infiltration of water into the soil, thereby preventing runoff and consequent erosion, is directly influenced by tillage operations that are part of management. Tillage determines both the amount of crop residues that remain on the soil surface and the roughness of the surface. Residues on the surface provide protection from rain, and both residues and roughness slow water movement. "Roughness" as used in RUSLE (Revised Universal Soil Loss Equation) actually refers to two features of the soil surface: its geometric shape (pits, ridges, and mounds as they contribute to the ponding of water) and the porosity of the surface (the size and number of interconnected pores as they contribute to infiltration of water into the soil).

Measurement of roughness with current practices such as rill meters, comparative photographs or laser profile meters, provide a measure of the geometry of the soil surface. The porosity of the surface is not characterized by any of these methods. Acoustical measuring techniques have the potential for characterizing both the geometric shape and the porosity of a soil surface. The objective of this paper is to report the current status of research with acoustical soil measurements conducted at the Columbia Plateau Conservation Research Center at Pendleton Oregon.

METHODS

All measurements are made in the frequency range detectable by the human ear (20 to 20,000 cycles per second). Two types of sound measurements, direct sound absorption within the soil and reflection from the soil surface, are being investigated. The measurements of sound absorption by the soil are made with a buried microphone and a high amplitude speaker-amplifier system (250 watt). Three different uniform soil materials; mason sand, 2mm silt aggregate, and silt less than 1mm, were used to test buried microphone measurements. According to the measurements, the relative conductivities to air of these uniform materials, were 0.68, 0.10, and 0.01 respectively with a variability of +/- 20 percent. This can be interpreted as the sand with a reading of .68 being 6.8 times more porous than the silt aggregate, which was 10 times more porous than the silt.

Buried microphone measurements in a fallow cultivated field (Walla Walla silt loam that had been plowed and cultivated to a surface roughness of about 1 inch) were extremely variable, ranging between 0.50 and 0.001, or from similar to the porosity of the sand to less permeable than the silt. The observations indicate the large differences in porosity that occur from place to place in a cultivated field.

The area sampled by a buried microphone depends on the porosity of the soil surface around the microphone. Where the soil is finely pulverized or crusted only a few square inches of soil control the measurement because the sound is totally damped out within an inch of the surface. Where large clods and residue support cracks and holes into the soil, sound may travel a foot or more along a crack to reach a microphone. Note that it is the cracks or holes in the soil that determine the values measured just as it is the cracks and holes that allow water to move into the soil.

Each total observation requires from 15 minutes to 1 hour to complete. For good sound absorption readings, the microphone must be buried with as little soil disturbance as possible. Any cracking of the soil surface during installation destroys the observation as it is the crack, not the original soil pores, that will conduct sound into the soil. Once a microphone has been buried, several readings are taken for each of 10 frequencies between 100 and 5,000 cycles per second. The magnitude of the signal at each frequency at different depths are analyzed to obtain relative conductivity values.

Measurements of sound reflected from the soil surface utilize different microphones and speakers than those used for measuring sound absorption. The speaker has only a 1 inch diameter throat so it will produce spherically shaped sound waves. Standard condenser microphones are used. The speaker and one microphone are mounted 2.00 m apart 0.50 m above a soil surface on a rigid light-weight frame. A second microphone is placed directly below the first, 0.10 m from the soil surface. Exact positioning is important since it is the difference between the signals of the two microphones that is important.

A single reflection measurement can not be used to represent a surface. Reflected sound is influenced by adjacent objects, ambient noise, wind, air temperature profiles, and both the porosity and geometric shape of the soil surface As many as 50 separate samples are collected and averaged to produce one stable average measurement of a surface. Fortunately, each measurement can be taken in less than one second and required computations performed in a few seconds. Microphone signals are recorded at the rate of 32,000 points per second. Only 8,000 data points are needed to provide the frequencies present at each microphone. Within five minutes an average reflection pattern for any surface can be obtained.

Graphical comparisons of average signals reveal clearly detectable qualitative differences between rough plowed, crusted fallow, and freshly tilled smooth fallow surfaces. Conversion of these qualitative differences to repeatable quantitative values that relate to water infiltration rates or soil loss rates to erosion remains to be done. Complex theoretical computations are necessary to separate the effects of roughness and porosity. Currently, measurements must be taken above a soil surface when it is dry and when it is very wet (essentially when it is porous and when it is nonporous) to separate the two factors. New theoretical descriptions of surface reflection of sound are being developed to more clearly incorporate the separate effects of reflection from an irregular surface and absorption by a porous surface. These descriptions will be evaluated and incorporated into measurements of surface reflection as soon as they are available.

SUMMARY

The use of acoustic measurements for characterizing the geometry and the porosity of soil surfaces is a developing technology. Qualitative differences between surfaces can be illustrated, but quantitative descriptions usable for routine field evaluation may be two years or more away. The complexity of sound reflection from and absorption of a rough, porous surface slows progress in achieving an accurate theoretical description of the process.

SOIL QUALITY AND SOIL ORGANIC MATTER

S. L. Albrecht and P. E. Rasmussen

SOIL QUALITY

Recent interest in sustainable agricultural has brought renewed attention to soil quality, a critically important aspect of any agricultural system. Soil quality is a complex concept incorporating physical, chemical, and biological processes. Its complicated nature makes it hard to define and difficult to measure. Soil organic matter (SOM) is essential to soil quality. Soils with high SOM content are generally considered high quality soils; those with low SOM are regarded as low quality soils. A variety of methods to assess the SOM have been developed; however, they are subject to high variability and can be easily misinterpreted. To understand the exact role of SOM in maintaining high soil quality, more information is needed on how SOM responds to tillage practices, crop rotations, residue, fertilization, and other management practices.

SOIL ORGANIC MATTER

Not all carbon-containing material in the soil is organic matter. Carbonate minerals contain inorganic carbon. Together, the carbonate minerals and SOM constitute the bulk of soil carbon. While carbonate minerals are usually present only in arid soils, organic carbon occurs in all soils.

The SOM content in surface soils can be as low as half a percent in desert soils, and over 5 percent in the surface layer of temperate grassland soils. The annual production of foliage and roots by plants in humid temperate regions is about 9 tons per acre. Semiarid regions typically produce only 2 to 4 tons per acre. In general, the amount of SOM decreases with soil depth (Bohn et al., 1979).

Soil organic matter is composed of living and dead fractions. The living component includes plant roots, soil animals such as worms, and microorganisms such as bacteria, algae, and fungi. The dead fraction includes the remains of plants and animals, organic material in all stages of decomposition, and humus--the end product of decomposition.

In most soils, humus is the largest fraction of SOM. Humus is brown or black in color and composed of a varied group of substances of unknown origin. Soil scientists have investigated humus composition for a long time, but its exact chemical structure is still unknown. It is a product of microbial metabolism, that is continually being reformed by soil microorganisms from organic material. Only a small portion of humus is soluble in water. Although very resistant to further decomposition, humus is an important food source for soil microorganisms.

The largest source of organic material entering the soil comes from plant residues. Within the residues, the various chemical components have different susceptibilities of decay (Table 1).

Table 1. Amount and Type of Material Contributed to the Soil by Plant Residues

Residue Fraction	Percent by weight	Average Life Span
Cellulose	15 - 60	1-3 Yr
Hemicellulose	10 - 30	3-60 Yr
Lignin	5 - 30	60-1000 Yr
Protein	2 - 15	10-40 Da
Soluble material†	10	10 Da

†Sugars, amino sugars, organic acids and amino acids. Yr = years, Da = days. Adapted from Jenkinson and Ayanaba, 1977, and Paul and Clark, 1989.

Soil microorganisms quickly utilize the soluble carbohydrates and proteins that are leached from the residues. These compounds are used for energy and production of new microbial tissue. Ammonia, sulfate, and carbon dioxide are liberated during the decomposition process. Soil microorganisms do not attack cellulose or hemicellulose as rapidly as the soluble materials. Lignin is even more difficult to decompose. Lignin is retained for the longest time and contributes greatly to the humus content of soils.

It is generally assumed that the SOM content in undisturbed soils slowly increases or remains relatively constant. The organic matter in untilled soils has built up over thousands of years. The long-term addition of organic residue to the soil has been greater than decay and any loss to erosion. Temperature, water content, and oxygen concentration all impact SOM by changing the balance between organic residue addition and loss of older SOM. Soil organic matter content tends to increase as average soil temperature decreases. Cool temperatures reduce the activity of the soil microorganisms and thus SOM decomposition. Soil organic matter tends to increase with increasing precipitation, primarily due to greater biomass production in the wetter environment. Likewise, the use of irrigation can increase SOM content. This increase can be negated, however, if a substantial amount of the harvested crop is removed from the field.

The main factor controlling the decay of SOM is access to oxygen in the presence of adequate water. Poorly drained soils (wetlands and bogs) in cool climates can accumulate SOM. The amount of vegetation produced exceeds the amount decayed because of cool temperatures and low oxygen concentrations. In well-drained soils, the potential decay rate is usually comparable to the natural production of vegetation. When a soil is cultivated or drained, the internal oxygen level rises. Efficient aerobic microorganisms multiply rapidly and decompose the accumulated SOM more rapidly.

LOSS OF SOIL ORGANIC MATTER

Soil organic matter is lost either by decomposition (biological oxidation) or erosion (Bohn et al., 1979). Cultivation of grassland soils commonly causes the loss of one-third to one-half of the native SOM in the first 40-60 years (Rasmussen and Collins, 1991). Agricultural practices that remove plant material, such as burning, grazing or harvesting part of the cultivated crop for human or animal feed, decrease SOM levels. Practices that increase plant growth, such as fertilization or irrigation, will increase SOM levels. Green manuring or the addition of manure will slow the rate of SOM loss. In long-term plots at the Columbia Basin Agricultural Experiment Station, annual addition of manure to a wheat-fallow rotation has maintained a SOM content roughly equal to that of annually cropped soil receiving moderate inorganic fertilizer application. Erosion is very incompatible with maintaining SOM, especially on sloping landscapes. Any management practice that retards erosion will decrease the loss of SOM. Retaining residue on the ground is beneficial in both reducing erosion and maintaining SOM content.

ESTIMATION OF SOIL ORGANIC MATTER

Soil organic matter is difficult to accurately measure. It is generally estimated indirectly by laboratory analysis of carbon liberated during wet or dry combustion and applying a conversion factor, ranging from 1.7 to 2.2 (Nelson and Sommers, 1982). Dry combustion is performed by heating the soil with a catalyst to about 1,850° F under oxygen or carbon dioxide free air. Wet combustion in generally carried out by refluxing a soil sample with a mixture of potassium dichromate and strong acid (normally sulfuric and phosphoric acids). The carbon dioxide liberated by either method is trapped in a suitable reagent and determined by weight or volume. The estimation of SOM by combustion is not highly accurate because the ratio of SOM to carbon dioxide liberated varies widely from soil to soil and within the soil profile.

Soil organic matter may be estimated by direct determination. In this technique, SOM must be removed from the rest of the soil. In the most common procedure, the soil is weighed before and after the SOM is destroyed by oxidation (Nelson and Sommers, 1982). It is assumed the loss in weight of the soil reflects only vaporized organic material. Any method used to oxidize SOM must remove it entirely, but cannot destroy or alter any inorganic fraction that changes its weight. The two most common methods of SOM analysis are oxidation with hydrogen peroxide (Walkley-Black procedure) and burning at about 1,750° F (Loss-on-Ignition procedure). Oxidation with hydrogen peroxide is usually incomplete and accuracy varies with soil type. The loss-on-ignition method gives quantitative oxidation, but at 950° F carbonate minerals are decomposed and some soil fractions will lose structural water. This results in weight losses considerably in excess of the actual SOM. Carbonates and waters of hydration can be removed by pretreatment with hydrochloric and hydrofluoric acid, to improve accuracy, but the procedure is elaborate and time-consuming. The oxidation of SOM by heating at a lower temperature, 665 to 825° F, will reduce carbonate decomposition and retain structural water, but may not completely destroy SOM. Some soils lose structural water at temperatures as low as 570° F.

These relatively harsh treatments measure soil carbon quantity--not organic matter quality. Nearly elemental and essentially inert forms of carbon that are not SOM, such as charcoal or ash, will be reported as SOM. It is improbable that these inert forms of carbon, including the charred material from residue burning, can support the activity of microorganisms or will ever be incorporated into SOM (Albrecht, et al., 1994).

SUMMARY

Soil organic matter is a significant part of soil quality. The humus fraction is especially important as it provides soil structure, pH-buffering and water and mineral-holding capacities. Agricultural practices that increase SOM will enhance soil quality. To maintain SOM, crop residue must be added to the soil. Current methodologies do not accurately measure SOM, and are of limited value. A greater understanding of how management practices affect SOM will contribute significantly to sustainable agriculture and increase soil health, yields, and profits.

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IS BURNING AN EFFECTIVE MANAGEMENT PRACTICE FOR THE PACIFIC NORTHWEST CEREAL REGION?

S.L. Albrecht, P.E. Rasmussen, K.W. Skirvin and R.H. Goller.

Many cereal producers on the Columbia Plateau burn stubble as a management practice. The reasons offered include disease, insect, and weed control, improved tillage efficiency, reduced immobilization of N fertilizer, and sociological precedents ("The neighbors do it."). However, stubble burning, if used regularly, contributes to erosion and the loss of organic matter. Stubble burning may also produce undesired side effects including increased air pollution, driving hazards, polluted water, and ill will among the urban populations near the burned field. Emerging environmental restrictions are making the practice of burning increasingly difficult.

Burning is a natural part of some ecosystems. Fires in tallgrass prairies occurred frequently, altered nutrient cycling, and temporarily increased primary productivity. Ojima et al., (1994) found that, in the short term, fire in the tallgrass prairie enhanced microbial activity, increased above and below ground plant production, and N use efficiency. Repeated annual burning resulted in a significant reduction in soil organic N, lower microbial biomass and N availability, and increased N immobilization. This response occurred within two years and persisted over the next 50 years of annual burning. Burning forest understory removes flammable biomass that contributes to harmful fires if allowed to accumulate. Uncontrolled fire can cause severe economic and ecosystem damage. Burning grass-seed producing fields can reduce disease incidence and improve crop yield and quality. The effects of fire in these environments is not the same as that in cereal crops in the dryland Pacific Northwest. Cereal production involves much more soil tillage, which alters burning effects and increases susceptibility to wind and water erosion. The closest dryland cereal production can come to either a forest or grass-seed system would be a burn no-till management system. Burning produces different effects in unlike environments, in part due to the intensity of the tillage that follows.

EFFECT ON PESTS

Burning can destroy insects, plant pathogens, and weed seed found in cereal residues and thus reduce their incidence. Unfortunately, the positive effects of burning for reducing pest populations, and thus increasing cereal grain yield, are not always consistent (Hardison, 1976). The high temperatures generated above the stubble during burning are not uniform throughout the canopy. Incomplete destruction of pathogens, insects, or weed seeds at the soil surface will allow their propagation following a fire, thereby producing inconsistent results (Rasmussen, et al. 1986). Rasmussen and Rohde (1988) found that stubble burning did not decrease Strawbreaker foot rot (*Pseudocercosporella herpotrichoides*) incidence or severity, although burning did reduce downy brome (*Bromus tectorum*) density when not effectively controlled by mechanical tillage. It is possible that burning can actually worsen pest problems. Fields blackened by a burn and planted with wheat reflect the long-wave light attractive to aphids (Cook and Veseth, 1991). Stubble burning is rarely necessary where crop rotations offer the same or better control of root diseases, insect pests, and possibly some weeds. Burning may be justified as an emergency treatment, but not as a long-term tool for cereal health management (Cook and Veseth, 1991)

EFFECT ON EROSION

Maintaining residue on the soil surface is effective for controlling soil erosion in the Pacific Northwest. Soils exposed by burning are very susceptible to both wind and water erosion. Nutrients are lost when soil erodes. Repeated burning can alter both physical and chemical properties of soil. The loss of organic matter, coupled with excessive tillage, increases soil compaction and reduces water infiltration and retention. Adverse effects on water infiltration and surface crusting are very difficult to reverse. The negative impact of burning on erosion is difficult to measure; it may not be evident for 10 to 15 years (Pimentel et al., 1995).

EFFECT ON NUTRIENT AVAILABILITY

Many mineral nutrients (e.g. calcium, magnesium, potassium, zinc, copper, and manganese) remain on the soil in the ash following stubble burning. However, the major elements required for plant growth, N and S, are appreciably vaporized during burning (Boerner, 1982). Table 1 shows the volatilization of several elements, based on the burn loss of 65 percent of the stubble biomass.

After carbon, N is the element most affected by fire; a temperature of only 200°C can induce volatilization (Raison, 1979). Data for many ecosystems affected by fire

Table 1. Volatilization of Elements By Burning.

Element	Initial	Lost	Percent Loss
	---lbs/acre---		
Carbon	3570	2320	65
Nitrogen	32.1	11.6	36
Sulfur	5.4	1.4	26
Phosphorus	5.4	0.3	6
Potassium	88.4	4.9	6

show that, in general, the total soil N content decreases after a fire (Dunn et al., 1979, Raison, 1979). In the Pacific Northwest dryland cereal regions, soils are generally deficient in N and S and their loss through stubble burning has the potential to decrease long-term nutrient availability and increase fertilizer requirements.

Only when residues have a high C to N ratio, will burning increase short-term N and S availability. Burning removes a significant portion of the wheat stubble, thereby reducing carbonaceous material in the soil that serves as the food supply for soil microorganisms. Reduced growth by microorganisms decreases their demand for N and consequently lessens microbial immobilization of N fertilizer in soil (Boerner, 1982).

EFFECT ON BIOLOGICAL ACTIVITY

Information about burning, as it affects soil organic matter, is scarce. Repeated burning can cause gradual loss of organic matter and decreased microbial activity (Biederbeck et al., 1980, Rasmussen et al., 1980). One possible reason for reduced microbial activity is the loss of soil microorganisms during fires. Microbial populations generally recover rapidly with new plant growth. The soil microorganisms are reestablished from underlying soil, wet and dry deposition, or from small islands of unburned residue.

Microbial activity in the soil can be lost or reduced by removal of the food supply. Fire may reduce the most labile organic fractions, leaving only the resistant ones. This decreases soil microbial activity and the amount of N generated by mineralization. As shown in Figure 1, about 80 percent of crop residue in an unburned system is oxidized by the soil microorganisms and lost as carbon dioxide through microbial respiration.

The remaining 20 percent is incorporated into soil organic matter. This material is generally either in microbial biomass, a by-product of microbial metabolism, or in a form that microorganisms cannot easily use.

When stubble is burned, about 60 percent of the crop residue is lost immediately as carbon dioxide or carbon dioxide, and some as carbon monoxide (Figure 2). The remaining 40 percent is eventually incorporated into the soil. If this burned stubble is oxidized by soil microorganisms in the same way as unburned material, then only eight percent (NOT 40 percent) will be converted into soil organic matter.

If soil microorganisms cannot use this material efficiently, the amount that eventually becomes soil organic matter will be even less than eight percent. Burn ash, including the charred C, may not be a possible energy source for microorganisms. Carbon exists in forms (e. g., diamonds) that cannot support microbial growth. If the soil microorganisms cannot derive energy from the burned stubble, regardless of whether it contains C, it cannot contribute to the biological activity of the soil or help form soil organic matter.

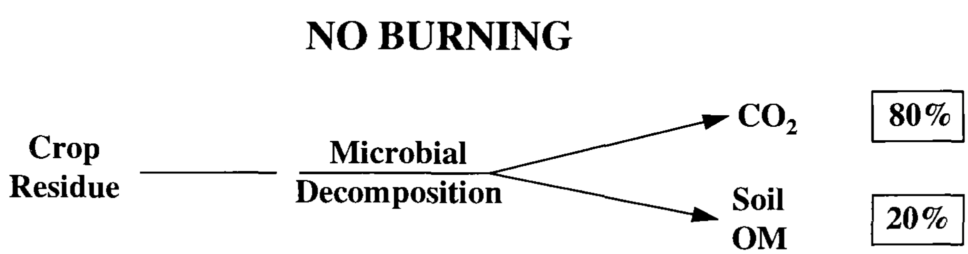

Figure 1. Pathway of C following microbal decomposition. Percentages in boxes represent amount of C partitioned into each end product. OM = organic matter.

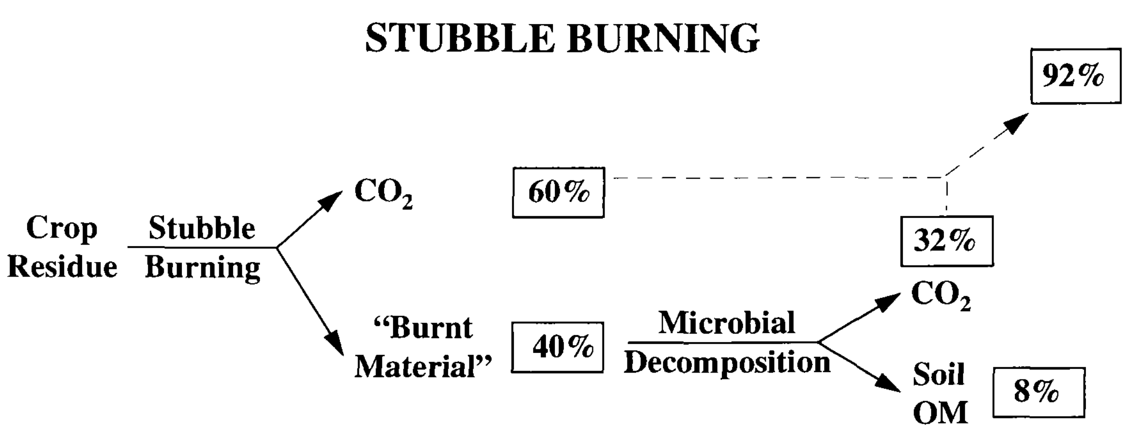

Figure 2. Pathway of C following a fire and microbial decomposition. Percentages in boxes represent amount of C partitioned into each end product. OM = organic matter.

Incubation Tests. Wheat residue or burned wheat stubble was added to an Adkins fine sandy loam soil (Mixed, mesic, Xerollic Camborthid), to determine if microorganisms would utilize the burned stubble as well as the unburned residue. Burned stubble and wheat straw were added to the soil at rates of 7,925 and 4,750 pounds per acre, respectively. Soil samples without residue additions were used as a control. Soils were watered to field capacity and incubated for up to 10 days at 75° F. Nitrate mineralization or immobilization was determined using an ALPKEM rapid flow analyzer and soil biological activity estimated by carbon dioxide respiration using a Beckman infrared gas analyzer. Total C and N were determined using a Fisons carbon-nitrogen analyzer.

The effect of residue addition on biological activity is shown in Table 2. The addition of wheat straw increased the respiration rate of soil microorganisms much more than did the addition of burned stubble. Following the addition of burned stubble, the sustained increase in biological activity was less than seven days, while that for wheat straw residue greatly exceeded 10 days.

Table 2. Change in Biological Activity with Residue Additions. 1994, Pendleton, OR.

Day	Wheat Straw	Burned Stubble
1	80†	29
4	61	9
7	47	0
10	28	0

† Percent increase over control.

The change in nitrate mineralization following the addition of wheat straw and burned stubble is presented in Table 3. After one day the wheat straw had immobilized 71 percent of the nitrate present in soil, while the burned stubble showed a 12 percent increase. After seven days, the addition of wheat straw had completely immobilized all the nitrate, but the burned stubble actually increased mineralization by 24 percent.

Table 3. Change in Nitrate Mineralization Following Residue Additions. 1994, Pendleton, OR

Day	Wheat Straw	Burned Stubble
1	-71†	12
4	-100	24
7	-100	24

† Percent increase or decrease in mineralization when compared to control.

Why did wheat straw quickly immobilize nitrate while burned stubble did not? The carbon added in the burned stubble failed to support microbial respiration. This C appeared to be chemically different from the C in wheat straw and was not available as an energy source for soil organisms. This C in burned material would be detected by all present soil testing laboratory analysis and be reported as "soil organic matter". But, as shown here, the burned stubble is much less biologically active in soil. This strongly suggests that the traditional methods for estimating soil organic matter are inadequate and results must be interpreted cautiously.

EFFECT ON YIELD

Burning has a mixed effect on cereal yield, depending on cropping sequence, disease history, and weed seed intensity. In an annual wheat no-till system, burning increased winter wheat yield about 13 percent and spring wheat three to four percent (Rasmussen, unpublished data). After fallow, winter wheat yields neither increased nor decreased following wheat stubble burning (Rasmussen and Rohde, 1988).

SUMMARY

Stubble burning remains controversial. Although burning is an easy way to quickly prepare grain fields for tillage, there is little evidence burning will consistently control plant diseases, weeds or insects. The loss of soil organic matter favors erosion and may alter nutrient cycling. Fertility is modified immediately after the fire and, more importantly, for the long term. This consequently affects the recovery of the soil and impacts agricultural sustainability. In semiarid regions where drought limits yield, the reduction of organic matter by burning, and subsequent loss of infiltration may eventually be detrimental to cereal yields. In conclusion, when the positive and negative aspects of burning as a management tool are weighed, short-term benefits may often be outweighed by long-standing harm to soil quality.

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PRECIPITATION SUMMARY - PENDLETON

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

Crop Yr	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
65 Year Average	**.72**	**1.31**	**1.98**	**2.06**	**1.91**	**1.50**	**1.70**	**1.51**	**1.47**	**1.25**	**.36**	**.50**	**16.26**
1974-75	.02	.35	1.56	1.76	3.73	1.68	.97	1.72	.68	.69	.05	1.38	14.59
1975-76	0	2.16	1.47	3.40	2.13	1.09	1.69	1.65	1.21	.58	.04	2.58	18.00
1976-77	.44	.53	.47	.59	.90	.57	1.72	.46	1.70	.31	.12	2.21	10.02
1977-78	1.54	.69	1.79	3.19	2.27	1.71	1.40	3.50	.81	1.27	.59	1.37	20.13
1978-79	1.61	0	1.68	2.28	1.31	1.54	1.74	1.82	1.15	.18	.12	2.08	15.51
1979-80	.17	2.56	2.31	1.05	2.85	1.55	2.12	1.20	2.45	1.42	.23	.18	18.09
1980-81	1.24	2.96	1.81	1.99	1.26	2.31	2.30	1.29	2.30	2.12	.40	.02	20.00
1981-82	1.51	1.62	2.41	3.27	2.61	1.86	1.99	1.54	.48	1.12	1.02	.50	19.93
1982-83	1.68	2.68	1.46	2.69	1.63	2.97	3.90	1.23	2.08	1.92	1.00	.68	23.92
1983-84	.82	.91	2.79	3.44	.99	2.56	3.23	2.37	2.11	2.05	.05	1.25	22.57
1984-85	.98	1.18	3.43	1.96	.69	1.49	1.33	.65	.89	1.42	.05	.98	15.05
1985-86	1.54	1.34	2.66	1.27	2.38	3.04	1.94	.83	1.79	.09	.61	.19	17.68
1986-87	1.87	.91	3.41	.95	2.08	1.31	1.85	.83	1.63	.62	.47	.06	15.99
1987-88	.04	0	1.44	1.61	2.60	.32	1.65	2.59	1.79	.94	0	0	12.98
1988-89	.40	.08	3.65	1.10	2.86	1.55	2.95	1.94	2.19	.33	.15	1.19	18.39
1989-90	.24	1.00	1.65	.49	1.43	.63	1.89	1.77	2.14	.70	.37	.76	13.07
1990-91	0	1.37	1.73	1.18	1.15	.86	1.71	1.01	4.73	2.22	.15	.24	16.35
1991-92	.03	.89	4.18	.97	.96	1.34	.85	1.29	.20	.90	1.74	.78	14.13
1992-93	.58	1.70	2.61	1.30	2.43	1.04	2.32	2.67	1.58	2.01	.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						
20 Year Average	**.74**	**1.16**	**2.15**	**1.82**	**1.93**	**1.55**	**1.90**	**1.58**	**1.74**	**1.08**	**.40**	**.96**	**17.01**

PRECIPITATION SUMMARY - MORO

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

Crop Yr	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
85 Year Average	**.59**	**.90**	**1.69**	**1.64**	**1.61**	**1.15**	**.98**	**.78**	**.81**	**.69**	**.22**	**.29**	**11.36**
1974-75	0	.37	1.02	1.39	2.01	1.47	1.25	.46	.53	.84	.40	1.26	11.00
1975-76	0	1.17	1.34	1.26	1.25	.93	.95	1.06	.14	.06	.79	1.17	10.12
1976-77	.04	.10	.43	.20	.18	.63	.50	.08	2.70	.28	.37	.90	6.41
1977-78	.88	.22	2.00	3.22	2.80	1.31	.74	1.42	.43	.44	.59	1.32	15.37
1978-79	.33	.01	.79	.69	1.59	1.54	.99	1.06	.28	.10	.07	1.05	8.50
1979-80	.53	2.59	2.23	.65	3.41	1.83	.94	.89	1.27	1.37	.16	.11	15.98
1980-81	.42	.79	1.73	2.95	1.52	1.22	.65	.41	1.06	1.15	.20	0	12.10
1981-82	.92	.82	1.99	4.73	1.10	.72	.55	1.45	.37	1.15	.21	.40	14.41
1982-83	1.42	1.96	1.08	1.89	1.40	2.43	2.74	.61	1.96	.39	.80	.60	17.28
1983-84	.52	.62	2.45	2.31	.17	1.07	2.34	1.32	.97	1.09	.17	0	13.03
1984-85	.53	.86	3.18	.41	.27	.97	.44	.14	.63	.92	.05	.14	8.54
1985-86	1.11	1.09	1.19	1.12	1.84	2.39	.98	.34	.35	.06	.54	.07	11.08
1986-87	1.52	.45	1.53	.78	1.68	1.10	1.54	.28	.99	.29	.78	.11	11.05
1987-88	.07	.01	.66	3.23	1.60	.21	1.25	2.21	.55	1.02	.04	0	10.85
1988-89	.56	.02	2.51	.22	1.33	.77	1.91	.84	.91	.08	.11	.50	9.76
1989-90	.07	.59	.96	.48	1.91	.17	.76	.79	1.36	.39	.15	1.43	9.06
1990-91	.29	1.27	.61	.74	.87	.60	1.43	.40	.77	1.27	.33	.16	8.74
1991-92	0	1.40	2.57	1.02	.47	1.64	.64	2.38	.04	.28	.81	.02	11.27
1992-93	.68	.85	1.50	1.68	1.42	1.47	1.68	1.22	1.42	.87	.39	.30	13.48
1993-94	.02	.09	.41	.68	1.40	.90	.55	.40	.62	.61	.11	.07	5.86
1994-95	.19	2.27	1.79	.90	3.67	1.18	1.14						
20 Year Average	**.50**	**.76**	**1.51**	**1.48**	**1.41**	**1.17**	**1.14**	**.89**	**.87**	**.63**	**.36**	**.48**	**11.19**

CUMULATIVE GROWING DEGREE DAYS

(BASE = 0°C)