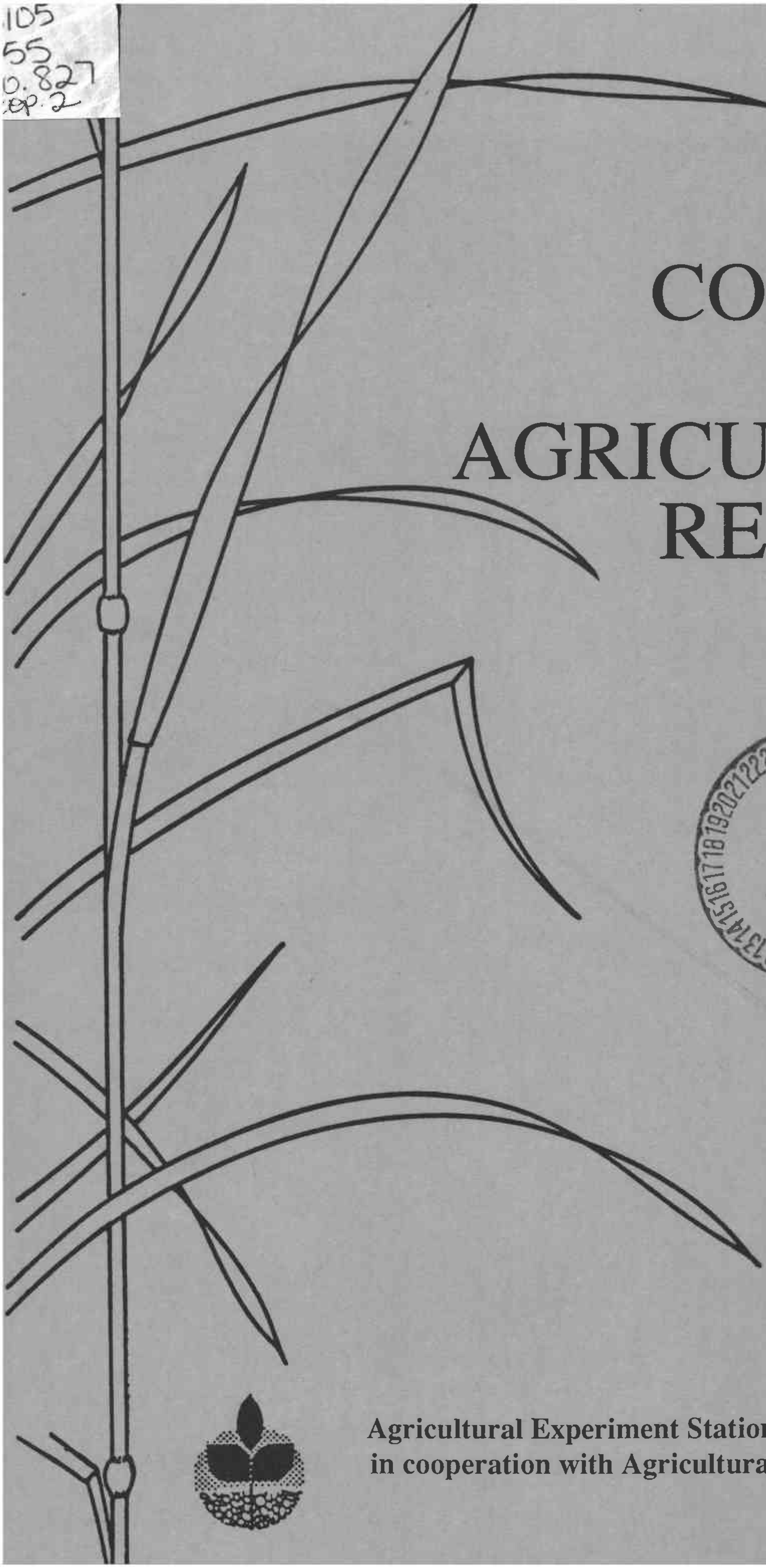


1988 COLUMBIA BASIN AGRICULTURAL RESEARCH

Special Report 827
Agricultural Experiment Station • Oregon State University
in cooperation with Agricultural Research Service • USDA

COLUMBIA BASIN AGRICULTURAL RESEARCH

SPECIAL REPORT 827 JUNE, 1988

Editorial Committee

Clyde Douglas, Jr., chairman

Ron Rickman

Hal Collins

Pam Zwer

Acknowledgement is made to Carol Brehaut and Pat Frank, for typing.

CONTENTS

INTRODUCTION

The staffs of the Columbia Basin Agricultural Research Center (CBARC-Oregon State University; Pendleton and Sherman Stations) and the Columbia Plateau Conservation Research Center (USDA-Agricultural Research Service; Pendleton) are proud to present results of their research. This bulletin contains a representative sample of the work in progress at these Centers. A collection of bulletins over a three-year period is required to become more fully acquainted with the productivity and applicability of research conducted on behalf of the producers of field crops in eastern Oregon and comparable agricultural regions. Changes in staffing, programming, and facilities at these Centers during the past year are summarized below.

Promotions and Awards

Betty Klepper was elected a Fellow of the American Association for the Advancement of Science and was appointed to the Editorial Board of Crop Science and to the Fellows Committee of the Soil Science Society of America. Richard Smiley began three-year appointments as Editor-in-Chief of APS Press, the book publishing division of the American Phytopathological Society, and Chairman of the APS Committee on Standardization of Common Names of Plant Diseases, the policy committee for nomenclatural standards for plant pathologists. Paul Rasmussen was appointed Associate Editor for Agronomy Journal. Clyde Douglas was appointed to the Soil and Geomorphology Committee of the Soil Science Society of America and to the Communications Committee of the Oregon Chapter of the Soil and Water Conservation Society. Awards for exceptional performance of duties have gone to Larry Baarstad, Carol Brehaut, and David Steele. Gloria Eidam was promoted to administrative assistant, Grace Freeman to administrative clerk, Joe Pikul to soil scientist, Julie McClendon to computer assistant, and Roger Goller, Gail Smead, and Jon Barrows were promoted to biological technicians. Last, the entire staff became the proud recipients of a first-place trophy in the commercial division for our very first entry into the Dress-Up Parade that precedes the Pendleton Roundup. Our float featured three styles of field-plot combines amidst a "field" of standing wheat, in an artistic decor with our Center's banner proudly drawing the attention of the appreciative crowd along the parade route through Pendleton.

Staff Changes

New staff members include Jon Barrows (Federal Junior Fellow), who works with Clyde Douglas on a residue management project, and Pat Frank (clerk-typist), who replaced Grace Freeman, who in turn replaced Sharron Wart, who resigned. Harold Collins began a two-year postdoctoral position in September, 1987, to initiate a new program in soil microbiology. Hal completed the Ph.D. degree at Washington State University. Muriel Lytton (clerical assistant) replaced Theresa Gaines, who resigned. Ralph Perry (machinist), and Julie Biddle, Theresa Miglioretto, and Kathleen Van Wagoner (research assistants) also resigned. Erling Jacobsen (biological aide) resigned in August, 1987, and returned to the position in May, 1988. Chuck Rohde and Vance Pumphrey retired after 35 and 30 years of service as plant breeder and agronomist, respectively, with OSU. Pamela Zwer joined the staff as plant breeder in February, 1988. She completed her Ph.D. degree at the University of California-Davis and conducted cereal rust research and surveys for The Plant Breeding Institute at Sydney University, Australia, before coming to Pendleton. Staff members who served in three- to six-month appointments included Heidi Bornstedt (technician), Steve Brehaut (welder), Colleen Doyle (technician), Dan Goldman (research assistant), Maralyn Horn (technician), Darrell Johnson (technician), Gerald Moore (craftsman), Harold Powell (engine repair), John Thoreson (technician) and Larry Triebelhorn (technician). The programs of the Centers were also served by 22 additional employees (three months or less) during 1987-1988.

New Projects

A major new research project on soil microbiology was initiated by Hal Collins. He is studying microbiological differences in the long-term management sites at the Pendleton Station. Joe Pikul started new research into the stability and structure of macropores left in soils by the passage of tillage implements. Pamela Zwer initiated a major new emphasis on the improvement and development of club wheat cultivars. Extensive replacement of experimental equipment and data management systems was accomplished to support Dr. Zwer's new plant breeding program. Don Wysocki provided leadership in the development of a multi-disciplinary, multi-agency cropping systems study team that will monitor and evaluate farm-scale management systems on two eastern Oregon farms. Richard Smiley coordinated the initiation of studies that greatly amplified the breadth and depth of research on cereal cyst nematode in the Pacific Northwest.

Facilities

The computer laboratory was refurnished to improve the air-conditioning and to provide dust-free storage for all computer-related materials. Two new laboratories for erosion mechanics and soil microbiology have been furnished and provided with laboratory services. A new welding center in the USDA shop was developed to provide a safer, more convenient work area. New shelving has been purchased for the storage building and the last four bays of the garage were completely reorganized for storage of field equipment. A washing facility for plant roots and green peas was constructed. The greenhouse was re-activated by renovating the benches, sealing glass panels and ridge vents, and by installing new gravel floors, winter and summer temperature control systems, electrical wiring and lights and controllers, and two root-temperature control chambers. A new water well was drilled at the Pendleton Station and grain holding tanks were installed. At the Sherman Station, erosion-control channels, dams, and some roadways were cleaned and improved, and structural improvements were made to preserve the garage. Allocations of maintenance funds for the repair of roofs, sidings, and foundations were made for residential units at both Stations.

Visitors

Distinguished visitors hosted by staff at the Center included Norman James (Director, Pacific West Area, USDA-ARS), John Byrne (President, OSU), Roy Arnold (Dean, College of Agri. Sciences, OSU), Thayne Dutson (Director, Oregon Agri. Exp't. Stn.), Ernie Smith (Director, Extension Service, OSU), Kelvin Koong and Van Volk (Associate Directors, OAES), Wilson Foote (Agri. Res. Foundation, Corvallis), James Stiegler (USDA-Extension Service, Washington, D.C.), Gerald Wall (USDA Crop Simulation Res. Unit, Starkville, MS), Bart Duff (Int'l. Rice Res. Inst., Manilla, Philippines), Josh DeKock (Director, Small Grain Centre, Bethlehem, South Africa), Fred Schneiter (U.S. Wheat Associates, Hong Kong), Albert Rovira (Chief, Div. of Soils, CSIRO, Adelaide, Australia), P. Gajri (Punjab Agri. Univ., India), Tom

Matsumota (Calif. Dept. Fish. & Agri., Sacramento), Bill Kellogg (Calif. State Polytechnic Univ., San Luis Obispo), Frank Casimaty (Hobart, Australia), John Cary (Battelle Laboratories, Richland, WA), Wayne Youngquist (Univ. of Nebraska), Jack Ward Thomas (U.S. Forest Service, La Grande) and Earl Rother (U.S. Forest Service, Pendleton). Department Heads who visited the Centers included Sheldon Ladd (OSU-Crop Science), Benno Warkentin (OSU-Soil Science), Andrew Hashimoto (OSU-Agri. Engineering), Norman Bishop (OSU-Botany and Plant Patholody) and Duane Miller (WSU-Agronomy and Soils).

Our visitors list also included numerous representatives of equipment and chemical companies, Soil Conservation Service, Soil and Water Conservation Districts, and faculty and staff from research and extension programs in Washington, Idaho, and Oregon. Cooperative research plots at the Center were operated by Floyd Bolton, Warren Kronstad, Patrick Hay, Chris Mundt, Russ Karow, Ron Welty, Jim Cook, Lloyd Elliott, and the Soil Conservation Service. Other visiting scientists included Duane Miller, Gaylan Campbell, Dave Bezdicek, Ann Kennedy, Jeff Smith, Alan Bussaca, John Kraft, and Alex Ogg from Washington, John Hammel and Bob McDole from Idaho, and Arnold Appleby, Peter Bottomley, and Richard Dick from Oregon. We hosted wheat trade teams from India, Pakistan, and China, and a team of scientists from Pakistani universities and federal service. The staff also conducted workshops for Extension Service and Soil Conservation Service personnel, and a four-week Saturday Academy course for high school youth, titled "Frontiers in Research."

Seminars

The seminar series at the Center was coordinated by Don Wysocki. Seminars included the following speakers and subjects: Albert Rovira (tillage effects on microorganisms and wheat yield in Australia), Tom Thompson (seeding grasses for soil conservation), Gerald Wall (temperature and carbon dioxide effects on wheat), Earl Rother (Umatilla National Forest Management Plan), Hal Collins (soil microbiology in agronomic systems), Bart Duff (global rice research), Jack Ward Thomas (Starkey Experimental Forest and Range), John Winter (Electron microscopy and energy dispersive analysis equipment at Whitman College; presented at the College), John Cary (hazardous organic chemical movement in soil), Jim Vomocil (salinity abatement in the Peoples Republic of China), Peter Bottomley (interactions of soil factors, soil rhizobia and legumes), and Dave Bezdicek (nitrogen fixation, cropping systems, and molecular biology at WSU).

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 link among growers, industry, scientists, and their parent institutions or agencies. The committee chairmen and OSU and USDA administrators encourage and welcome your concerns and suggestions for improvements needed in any aspect of the research centers or their staffs. The Pendleton Station Liaison Committee, led by Chairman Larry Coppock (Adams: 503-566-3776), met on June 16 and November 25, 1987. The Sherman Station Liaison Committee, led by Chairman

Tom McCoy (Moro: 503-442-5233), held meetings on April 19, June 17, and October 14 and 22, November 25, 1987, and January 27, 1988.

<u>Expressions of Appreciation</u>

The staff wishes to express appreciation to individuals, associations, and corporations who have given special assistance for the operation of experimental plots on or associated with the Center during 1987-1988. The Oregon Wheat Commission continues to provide the critical support upon which many of the Center's projects are founded. Thanks are also given to those who donated funds to replace plant breeding equipment at the Center (Oregon Wheat Commission, Harvest State Cooperatives, Continental Grain Co., Louis Dreyfus Corp., Columbia Grain International, Cargill Commodity and Pendleton Grain Growers), funds and/or chemicals (Agricultural Research Foundation, Mobay Chem. Co., Monsanto Chem. Co., Gustafson, Rhone Poulenc, Nor-Am Chem. Co., Merck & Co., PureGro, Ciba-GEIGY, du Pont, Chevron Chem. Co., R&A Plant/Soil, Sandoz Crop Protection Corp., ICI Americas, Inc., and Uniroyal Chem. Corp.), donated seed (Perfection Seed Co., Asgrow, and Pendleton Grain Growers) or loaned equipment or facilities (Frank Tubbs, D&K Foods, Umatilla County Extension Service, and Soil Conservation Service.

We also acknowledge those who donated labor, supplies, equipment, or funding for the Pendleton Field Day (Umatilla County Ag Lender's Assoc., Wheatland Insurance, Umatilla County Wheat Growers League, Pendleton Grain Growers, Frank Tubbs, and Larry Coppock) and the Moro Field Day (Sherman County School District, Sherman Farm Chemicals, Monsanto Chem. Co., Midco Grain Growers, PureGro, Sherman Coop Grain Growers, and Condon Grain Growers).

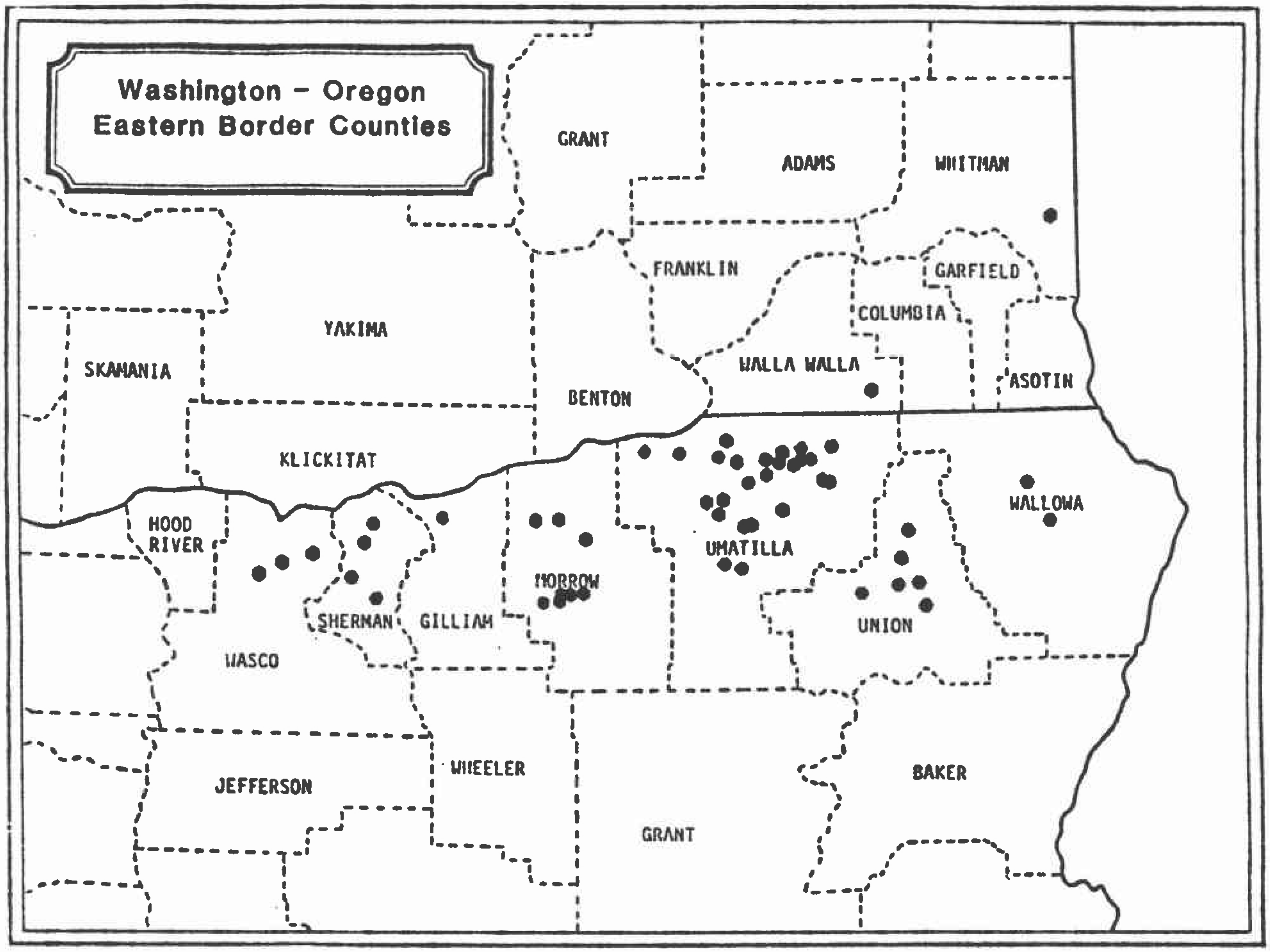
We thank the SCS District Conservationists in Oregon and Washington for their assistance. Additionally, we are very thankful for ever-present assistance from the Extension Service personnel in all counties of the region, and especially from Umatilla, Union, Sherman, Morrow, Gilliam, Wallowa, and Wasco counties and from Columbia and Walla Walla counties in Washington. We also wish to thank the many farmers who have allowed us to work on their property and who have often gone the extra mile by performing field operations, loaning equipment, donating chemicals, and adjusting their practices to accommodate our plots. The locations of these outlying sites, the names of our cooperators, 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 needs of our region. We welcome your suggestions on how we may continue to improve our attempts to reach this goal.

Richard Smiley
Superintendent
OSU-CBARC

Betty Klepper
Research Leader
USDA-ARS-CPCRC

OFF-STATION RESEARCH PLOT LOCATIONS



SHERMAN, OREGON
Bill Todd
Leroy Martin
Les Grey
Pat McNab

MORROW, OREGON
Keith Rea
Charles Anderson
Eric Andersonson
Frank Anderson
Ken Peck
Lyle Peck
Joe Rietmann
Tad Miller

UMATILLA, OREGON
Ken Thompson
Dwight Wolfe
Leon Reese
Sherman Reese
Bob Newtson
Larry Newtson
Jim Harris
Fred Rice
Stan Timmerman
Bob Johns
Maurice Johns
K. C. Loiland
Doug Harper
Clint Reeder
Frank Tubbs
Sheldon Kirk
Gunder Terjeson

WHITMAN, WASHINGTON
Jon M. Whitman

UMATILLA, OREGON
Dutch Clark
Glenn Broigotti
Don Woodward
Don Mills
Frank Mader
Glenn Thorne
Mike Thorne
Larry Coppock
Dick Goodwin
Carl Schuenning
Bob Schmidtgall

WASCO, OREGON
Van Harth
Fred Schrieber
Bud Hammel

WALLOWA, OREGON
Stu Coleman
George Marshall

GILLIAM, OREGON
Louis Rucker

UNION, OREGON
John Cuthbert
Kent Hug
Bernal Hug
Gil Weatherspoon
Bill Weatherspoon
Bob Broigotti
Kurt Von Blockland

WALLA WALLA, WASHINGTON
Donald Meiners
Pat Meiners

ANNIVERSARY CELEBRATIONS

Oregon Agricultural Experiment Station: 100 Years
Pendleton Experiment Station: 60 Years

The Oregon Agricultural Experiment Station has had one major goal since its beginning in 1888: To improve life in Oregon and in the rest of the world. The Experiment Station is a division of the College of Agricultural Sciences, in partnership with the Extension Service, International Agriculture, Academic Programs, and Agricultural Communications. Scientists from the Experiment Station have led or assisted in studies leading to solutions of numerous animal, crop, soil, water, air, and marketing problems during the past century. The Experiment Station now administers research and teaching programs that address nearly every facet of Oregon's diverse and complex systems in natural resources, horticulture, agriculture, and food technology and marketing. In addition to the main campus at Corvallis, the Experiment Station has Branch Stations at Aurora, Klamath Falls, Medford, Ontario, and Redmond/Madras, and Research Centers at Burns/Union, Hermiston, Hood River, and Pendleton/Moro. We trust that the Oregon Agricultural Experiment Station will enjoy continued success in meeting the needs of humanity and nature into the 21st Century.

"The Pendleton Field Station" was established in 1928, through cooperative agreement between the Oregon Agricultural Experiment Station, Umatilla County, and the United States Bureau of Plant Industry. The Umatilla County Court purchased the 160-acre tract of "good wheat land, representative of the area," and leased it to " . . .the Agricultural Experiment Station, for and during such time hereafter as the said premises shall be maintained and used as a branch Agricultural Experiment Station . . ." The Pendleton Station has always been closely aligned with the Sherman Station, established in 1909 at Moro "to investigate and demonstrate the conditions under which useful plants may be grown on dry, arid, or nonirrigated lands of the State of Oregon, and to determine the kinds of plants best adapted for growth on these lands." The Superintendent of the Sherman Experiment Station, Mr. George Mitchell, became the first Superintendent of The Pendleton Field Station, with an appointment made jointly by the Agricultural Experiment Station and the U.S. Bureau of Plant Industry. The Sherman and Pendleton Stations became administratively unified in 1973, when they became two branches of the Columbia Basin Agricultural Research Center. In 1970 the USDA-Agricultural Research Service constructed new buildings and increased the diversity and numbers of its personnel at the Pendleton Station, and named its new facility the Columbia Plateau Conservation Research Center. Scientists at the two Centers continue to specialize in research and extension important to production of field crops and maintenance of natural resources on one million acres in north-central and northeast Oregon. Wheat, barley, and legumes in this region generate 10 to 15 percent of Oregon's agricultural cash receipts, with a market value over $150 million annually. In 1987-1988 the Centers infused nearly two million dollars into the economy of the region, and were served by a staff of 69, including 14 scientists, 23 full-time staff, 10 employees of three to six months, and 22 employees of three months or less.

PUBLICATIONS - 1987

The following list consists of publications by personnel of the USDA-ARS, Columbia Plateau Conservation Research Center and Oregon State University, Columbia Basin Agricultural Research Center in 1987.

Allmaras, R. R., J. M. Kraft, and J. L. Pikul, Jr. 1987. Lime and gypsum effects on pea-root-pathogen inoculum and related factors in a wheat-peas rotation. Agronomy Journal 79:439-445.

Auld, D. L., G. A. Murray, and F. V. Pumphrey. 1987. Alternate crops in conservation tillage systems. pp. 137-158. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Belford, R. K., Betty Klepper, and R. W. Rickman. 1987. Studies of intact shoot-root systems of fields-grown winter wheat. II. Root and shoot developmental patterns as related to nitrogen fertilizer. Agronomy Journal 79:310-319.

Douglas, C. L., R. W. Rickman, J. F. Zuzel, and B. L. Klepper. 1987. Criteria for delineation of agronomic zones in the Pacific Northwest. p. 17. In Proceedings Soil Conservation Society of America. Billings, MT. August 1987.

Douglas, C. L., R. Rickman, J. Zuzel, and B. Klepper. 1987. Agronomic Zones for the Pacific Northwest. pp. 593-594. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Douglas, C. L. Jr., J. F. Zuzel, R. W. Rickman, and B. L. Klepper. 1987. Agronomic zones in the Pacific Northwest. pp. 48-51. In 1987 Columbia Basin Agricultural Research, Oregon Agricultural Experiment Station Special Report 797.

Douglas, Clyde L. Jr., Robert E. Ramig. Paul E. Rasmussen, and Dale E. Wilkins. 1987. Residue management: Small grains in the Pacific Northwest. pp. 22-24. Crops and Soils, Vol. 39, No. 9.

Douglas, C. L. Jr., P. E. Rasmussen, R. R. Allmaras and L. L. Baarstad. 1987. Residue distribution behind combines. pp. 557-559. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Elliott, L. F., H. F. Stroo, R. I. Papendick, C. L. Douglas, G. S. Campbell, and D. E. Stott. 1987. Decomposition of surface managed crop residues. pp. 81-91. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Goss, R. L. and R. W. Smiley. 1987. Diseases of turfgrasses in relation to management. New Zealand Turf Management Journal 1:17-20.

Grunes, D. L., R. W. Rickman, and B. Klepper. 1987. Plant roots in relation to soil fertility. pp. 245-255. In (T. C. Tucker, ed.) Future Developments in Soil Fertility and Plant Nutrition. Soil Science Society America, Madison, WI.

Hane, D. C., and F. V. Pumphrey. 1987. Conservation seedbed preparation for potatoes. pp. 561-563. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Hyde, G. M., D. E. Wilkins, K. Saxton, J. Hammel, G. Swanson, R. Hermanson, E. Dowding, J. Simpson, and C. Peterson. 1987. Reduced tillage seeding equipment development. pp. 41-56. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Istok, J. D., J. F. Zuzel, L. Boersma, D. K. McCool, and M. Molnau. 1987. Advances in our ability to predict rates of runoff and erosion using historical climatic data. pp. 205-224. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Kane, R. T., R. W. Smiley and M. E. Sorrels. 1987. Relative pathogenicity of selected Fusarium species and Microdochium bolleyi to winter wheat in New York. Plant Disease 71:177-181.

Klepper, B., R. W. Rickman, J. F. Zuzel, and S. E. Waldman. 1987. Use of growing degree days to project sample times for cereal crops. pp. 114-115. Agronomy Abstracts.

Klepper, B. and R. W. Rickman. 1987. Understanding wheat growth as a management tool. pp. 13-23. In (John L. Havlin, ed.) Proceedings Central Great Plains Profitable Wheat Management Workshop, Kansas State University, Manhattan, KS.

Klepper, B. L., R. W. Rickman, and P. M. Chevalier. 1987. Wheat plant growth in conservation tillage. pp. 93-107. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Koehler, F. E., V. L. Cochran, and P. E. Rasmussen. 1987. Fertilizer placement, nutrient flow, and crop response in conservation tillage. pp. 57-65. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Macnab, Alexander W. and Robert E. Ramig. 1987. Tillage and cropping system alternatives for low rainfall areas. pp. 395-407. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

McCool, D. K., J. F. Zuzel, J. D. Istok, G. E. Formanek, M. Molnau, and K. E. Saxton. 1987. Erosion processes and prediction for the Pacific Northwest. pp. 187-204. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Molnau, M., J. F. Zuzel, J. D. Istok, K. E. Saxton, and D. K. McCool. 1987. Hydrology and proceedings in the Pacific Northwest. pp. 159-186. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Morrison, L. A., F. V. Pumphrey, D. O. Chilcote, and M. F. Kolding. 1987. Plant growth regulator treatment of winter wheat and spring barley to prevent lodging and increase yield. pp. 20-26. In Oregon Agricultural Experiment Station Special Report 793.

Murray, G. A., D. L. Auld, and F. V. Pumphrey. 1987. Alternate crops for Pacific Northwest rotation and tillage systems. pp. 595-597. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Pikul, J. L. Jr. and L. Boersma. 1987. Simulation and field validation of heat and water flow during soil freezing and thawing. Agronomy Abstracts, p. 161.

Pikul, J. L. Jr. 1987. Simulation and field validation of heat and water flow during soil freezing and thawing. Ph.D Dissertation. Oregon State University, Corvallis, OR.

Pumphrey, F. V., D. E. Wilkins, D. C. Hane, and R. W. Smiley. 1987. Influence of tillage and nitrogen fertilizer on rhizoctonia root rot (bare patch) of winter wheat. Plant Disease 71:125-127.

Pumphrey, F. V. 1987. Nitrogen, phosphorus, and potassium fertilization of Kentucky bluegrass for seed production in northeast Oregon. pp. 13-14. Dept. of Crop Science Ext/CRS 68, Oregon State University, Corvallis.

Pumphrey, F. V. 1987. Winter cover crops for irrigated sandy soils in the Columbia Basin. pp. 565-569. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Pumphrey, F. V. 1987. Winter hardiness of grapes at Hermiston. pp. 27-29. Oregon Agricultural Experiment Station Special Report 793.

Pumphrey, F. V., M. F. Kolding, and Steven Broich. 1987. Intensively managed irrigated hard red winter wheat production. p. 22. In Oregon Agricultural Experiment Station Special Report 670.

Ramig, Robert E. and L. G. Ekin. 1987. Conservation tillage systems for annually cropped wheat in the Pacific Northwest. Journal of Soil and Water Conservation 42(1):53-55.

Ramig, Robert E. 1987. Tillage and residue management impacts on soil water storage. pp. 69-72. In Sixth Annual Inland Empire Conservation Farming Conference Proceedings, Feb. 2-3, Pullman, WA.

Ramig, R. E. 1987. Conservation tillage systems for green pea production in the Pacific Northwest. pp. 93-94. In (J. F. Power, ed.) The Role of Legumes in Conservation Tillage Systems. Proceedings of a National Conference, April 27-29. Published by the Soil Conservation Society of America.

Ramig. R. E., K. E. Saxton, T. W. Massee, G. S. Campbell, and D. C. Thill. 1987. Water conservation under reduced tillage systems. pp. 125-136. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Ramig, Robert E. and L. G. Ekin. 1987. Fallow systems for semiarid eastern Oregon and Washington. pp. 34-40. In 1987 Columbia Basin Agricultural Research, Oregon Agricultural Experiment Station Special Report 797.

Ramig, Robert E. 1987. Tillage and stubble management for fallow in a winter rainfall area. 1987 Agronomy Abstracts, p. 245.

Rasmussen, Paul E. and D. E. Wilkins. 1987. Winter wheat response to lime in a wheat-pea rotation. pp. 31-33. In 1987 Columbia Basin Agricultural Research, Oregon Agricultural Experiment Station Special Report 797.

Rasmussen, Paul E. 1987. Cereal response to phosphorus in northeast Oregon. pp. 6-7. In Western Phosphate Conference, 17-18 March. Oregon State Univ., Corvallis, OR.

Rasmussen, P. E. and D. J. Wysocki. 1987. Patchy yellowing of winter wheat in the spring - why? 1 p. In Proceedings, Dryland Agric. Fertilizer Conference, Walla Walla, WA.

Rasmussen, P. E. and C. R. Rohde. 1987. Long-term tillage and nitrogen effects on organic C and N in semiarid soil. p. 251. American Society Agronomy Abstracts.

Rickman, R. W., E. L. Klepper, and T. G. Lewis. 1987. CO_2 Wheat simulation design and coding. Progress Report to U.S. Dept. of Energy. Columbia Plateau Conservation Research Center, Pendleton, Oregon. 411 pp.

Rickman, R. W. and Betty Klepper. 1987. Estimating seeding rate increase to compensate for delayed planting. pp. 41-47. In 1987 Columbia Basin Agricultural Research, Oregon Agricultural Experiment Station Special Report 797.

Rickman, R. W. and Betty Klepper. 1987. Anticipating cereal development: An intensive management tool. pp. 47-55. Sixth Annual Inland Empire Conservation Tillage Conference, February 2, Washington State University.

Rickman, R. W. and E. L. Klepper. 1987. Predicting wheat development and living ground cover from air temperature after planting. p. 285. In Proceedings of the 2nd Annual National Wheat Research Symposium, National Association of Wheat Growers Foundation, Washington, D.C.

Rydrych, D. J. and L. C. Burrill. 1987. Herbicide management in CRP perennial grass seed establishment. pp. 63-64. In 1987 Columbia Basin Agricultural Research, Oregon Agricultural Experiment Station Special Report 797.

Rydrych, D. J. 1987. What's new in selective grass control in cereals. pp. 59-62. In 1987 Columbia Basin Agricultural Research, Oregon Agricultural Experiment Station Special Report 797.

Smiley, R. W. 1987. The etiologic dilema concerning patch diseases of bluegrass turfs. Plant Disease 71:774-781.

Smiley, R. W. 1987. Efficient use of fungicides on turfgrasses. Proceedings 40th Northwest Turfgrass Conference, Pasco, WA. p. 55-78.

Smiley, R. W. 1987. Fungicide effects on diseases and thatch. Proceedings 40th Northwest Turfgrass Conference, Pasco, WA. p. 158-164.

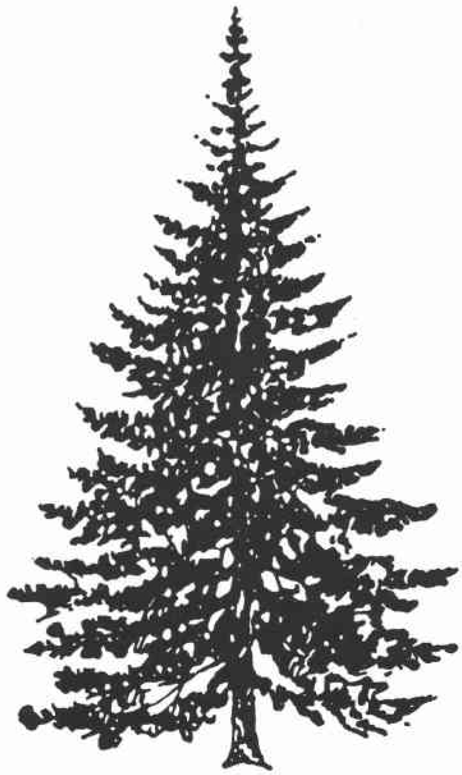
Wilkins, D. E., E. A. Dowding, G. M. Hyde, C. L. Peterson, and G. J. Swanson. 1987. Conservation tillage equipment for seeding. pp. 571-575. In (L. F. Elliott, ed.) STEEP-Conservation Concepts and Accomplishments.

Wilkins, D. E. and J. M. Kraft. 1987. Relation between seedling vigor and yield of peas. pp. 29-30. In 1987 Columbia Basin Agricultural Research, Oregon Agricultural Experiment Station Special Report 797.

Wilkins, D. E. 1987. Impacts of soil compaction on soil borne diseases. pp. 33-36. In Proceedings of Conservation Farming Conference, Pullman, WA.

Zuzel, J. F. and J. L. Pikul, Jr. 1987. Water infiltration into frozen soils. EOS 68:1268-1269. (Abstract).

Zuzel, J. F. and J. L. Pikul, Jr. 1987. Infiltration into a seasonally frozen agricultural soil. Journal of Soil and Water Conservation 42:447-449.



WHEAT VARIETAL DEVELOPMENT: PENDLETON 1987

S. Broich, M. Verhoeven, C. Love,
N. Scott, R. Knight, M. Moore, D. Kelley, and W. Kronstad[1]

Diversification has been a key word in conversation about Oregon agriculture in recent years. For wheat, diversification means development of varieties in market classes other than soft white winter wheat (SWW) or club wheat. Possibilities include varieties of hard red winter wheat (HRW), hard white winter wheat (HWW), spring wheats both soft white (SWS) and hard red (HRS), and spring and winter durum wheats for production in the Pacific Northwest. Diversification may also mean release of SWW varieties which mill into flour with particular physical and chemical properties needed to bake specific domestic products such as frozen pancake and waffles or gravy mixes.

Development of new wheat varieties is a continuous process. It takes 12 to 15 years from the time the initial cross is made to release of a new cultivar to growers. A successful breeding program must have material in all stages of the "pipeline," from genetically segregating plants to genetically stable lines, and these lines must be tested under a wide range of environmental conditions. Selections must be evaluated for yield and for resistance of tolerance to diseases and other environmental stresses as well milling and baking quality. In addition, diversification into new market classes of wheat or new end-product uses for a market classes traditionally grown in the Pacific Northwest requires that particular attention be paid to quality characteristics of selections in the variety development "pipeline."

The OSU cereals project carries out selection and conducts initial yield trials at three sites in Oregon: Hyslop Farm in the Willamette Valley, the Sherman Branch Experiment Station near Moro, and the Barnett-Rugg Ranch northeast of Pendleton. Quality testing is carried out in the OSU Wheat Quality Laboratory in Corvallis, and in co-operation with the Western Wheat Quality Laboratory in Pullman, Washington.

In this report, results are given for yield trials conducted in the Pendleton area during the 1986-87 crop year. Additional focus will be given to results of quality tests conducted in recent years and to initial plans being formulated to develop varieties resistant or tolerant to a new insect pest, the Russian aphid.

AGRICULTURAL PRACTICES

At the Pendleton site, breeding nurseries were planted on land following a crop of dry green peas. Soil tests were used to determine fertilizer requirements, and fall applications of anhydrous ammonia and Nitrosol were made at rates equivalent to 105 lb N and 22 lb S/A. A spring fertilizer application of 100 lbs N/A as liquid 32 solution was applied. Spring-applied herbicides included 2,4-D (1 pt/A) and Banvel (2 oz/A). The meteorological

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[1] Research associate, instructor, research assistant, senior instructor, senior research assistant, senior research assistant, biological aid, and professor, Crop Science Department, Oregon State University, Corvallis, Oregon 97331.

station at the Columbia Basin Agricultural Research Center, about five miles west of this site, reported a total precipitation of 15.99 in. for the 1986-87 crop year. This is somewhat higher than the long-term average of 13.01 in. for this area. While there were traces of leaf rust in some plots, in general, diseases were not a problem during this crop year at this site.

A total of 15.1 acres of experimental trials were planted this crop year on the Burnett-Rugg site. Just under one-half (7.7) of this acreage was planted to segregating populations which included 1300 F5 and 3600 F3 plots. F5 populations were planted at all three experimental sites, and evaluations made at Pendleton were important in the decision to advance 585 lines into preliminary yield trials during the 1987-88 crop year. An additional 925 F3 populations were advanced into an F4 nursery at Corvallis. The remaining 7.4 acres were planted to yield trials; results from these trials are discussed below by market class.

SOFT WHITE WINTER WHEAT (SWW)

SWW is the traditional main stay of wheat production in the Pacific Northwest. This year about 34% of the yield trial acreage was planted to soft white winter advanced lines along with appropriate checks. This included four separate yield trials containing 376 selections under evaluation. Results from the SWW elite yield trial are presented in Table 1. Mean yield of this trial was 103.8 bu/A, 2.7 bu/A higher than the long-term Pendleton average in our trials. The 1987 yields of 'Stephens,' 'Hill 81,' and 'Malcolm' were 106.0, 106.0, and 117.0 bu/A, respectively. A

Table 1. Mean yields for selected lines from the 1987 soft white winter wheat elite yield trial grown near Pendleton, Oregon

Selection	Number of years tested	Yield 1987	Yield Long term
		bu/A	bu/A
Stephens	14	114.0	94.1
Hill 81	14	106.0	94.9
Dusty	3	88.1	85.0
Malcolm	11	117.0	91.7
Tres	2	80.2	82.5
OR CW 8631	4	112.9	105.7
OR CW 8632	4	125.9	111.9
OR CW 8633	4	120.7	103.4
OR CW 8634	4	112.0	104.7
OR CW 8724	4	131.2	103.7
OR CW 8725	4	123.9	105.8
OR 8300211	3	125.0	110.6
OR 8300801	3	127.6	102.1
OR 8302665	3	124.8	100.4
OR 8302784	3	127.9	105.3
Ave		115.8	100.1

number of the newer selections have achieved equal or better yields both in the 1987 harvest and over a longer period of time. These data indicate that there are several very promising SWW selections in the advanced stages of yield testing.

Historically, 70% or more of the SWW produced in the Pacific Northwest was destined for the export market. While exports will probably continue at about this level, consideration of alternate end-product uses for SWW in the domestic market is now under investigation. A cooperative research program with the Pendleton Flour Mills is underway to evaluate selections for a somewhat higher water absorption capacity needed for flours used in domestic frozen pancake and waffle production. Another potential special end-product use, varieties with flour characteristics optimal for gravy mixes, is also being considered. It is possible that in the future SWW varieties selected for particular domestic end-product uses could be released for production in the Pendleton area.

HARD RED WINTER WHEAT (HRW)

Interest in the possibility of HRW production in Oregon remains positive. In the past several years, the Oregon Wheat Commission has invested growers assessment funds to lay the foundation for HRW varietal development. This year about 22% of the yield trial acreage was planted to HRW selections. There were four separate HRW yield trials containing a total of 292 breeding selections. Results of the HRW elite yield trial are presented in Table 2. Yields of 'Wanser,' 'Hatton,' 'Batum,' and 'Stephens' were 70.9, 63.3, 84.0, and 117.4 bu/A, respectively. In this trial 'Centura,' a Great Plains HRW cultivar, yielded 69.4 bu/A. A number of unreleased HRW selections with yield potentials equal to 'Stephens' SWW are listed in Table 2. At the fertilization rates applied (approximately 100 units N in the fall and spring), most selections achieved grain protein contents of 12.0% or better at fairly high yield levels.

Table 2. Mean yields for selected lines from the 1987 hard red winter wheat elite yield trial grown near Pendleton, Oregon

Selection	Number of years tested	Yield 1987	Yield Long term	Protein1/
		- - - - - bu/a	- - - - -	- % -
Stephens (SWW)	14	117.8	95.0	----
Wanser	10	70.9	52.1	12.1
Centura	4	69.4	62.6	13.2
Hatton	7	63.3	59.3	12.9
Batum	2	84.0	83.9	12.9
OR CR8313	9	118.1	92.9	12.1
OR CR8602	5	119.4	114.4	12.1
OR CR8603	5	118.7	107.6	12.1
OR8300282	4	124.9	113.5	12.3
OR8301455	4	117.6	97.7	10.9
OR8302306	3	118.1	110.8	10.2
Ave		100.4	89.5	12.1

1/ 12% moisture basis.

Grain samples from HRW selections have been submitted for complete milling and baking tests at the Western Wheat Quality Laboratory in Pullman, Washington, for a number of years. Data summarizing the results of these tests for the lines listed in Table 2 are given in Table 3. Quality characteristics of several of these selections are comparable to 'Wanser' and 'Hatton'. One selection, OR CR 8313 has performed very well in both yield and baking trials and is now under increase for possible release.

Table 3. Long-term milling and baking data for selected lines from the 1987 hard red winter wheat elite yield trial of the cereals breeding program, Oregon State University

Selection	Test weight	Flour yield	Milling score	Flour protein	Water absorption	Mixing time	Loaf volume	Crumb score	Number of site years
	lbs/bu	%		%	%	min	cc	1-9[1/]	
Wanser	62.8	70.6	85.8	9.8	62.2	4.1	857	3.9	15
Hatton	65.1	71.5	85.5	9.4	62.2	4.3	849	3.8	5
Batum	59.1	70.8	82.6	10.9	64.7	2.6	936	4.8	4
OR CR8313	63.2	70.9	85.4	10.7	65.2	5.2	914	3.0	13
OR CR8602	62.4	67.5	82.3	9.6	64.0	5.5	780	4.7	3
OR CR8603	62.6	69.8	84.7	10.2	62.1	3.2	721	5.3	3
OR8300282	61.7	69.3	79.4	11.1	63.5	2.6	763	4.0	1
OR8301455	61.6	65.3	75.3	9.7	63.1	4.8	691	8.0	1
OR8302306	59.3	70.6	82.8	10.6	59.6	2.4	767	8.0	1
Ave	62.0	69.6	82.6	10.2	63.0	3.9	808	5.1	

1/ 1 = excellent, 9 = unsatisfactory.

HARD WHITE WINTER WHEAT (HWW)

Interest in the production of HWW to replace some HRW production in North America has increased greatly in recent years and breeding programs in Kansas. Montana, and California have initiated major efforts in the development and marketing of HWW. Hard white wheat lines may have a particular appeal in certain foreign markets where flour extraction rates are high and where the resulting reddish color of flour obtained from high extractions of HRW is considered undesirable.

Yield trials of HWW selections occupied 5% of the yield trial acreage this year and included a preliminary yield trial which included 102 unreleased lines. Selected yields obtained in this trial are given in Table 4. These and other HWW lines have been advanced into a replicated preliminary yield trial now being grown at Pendleton, Moro, and Corvallis. This collection of 65 selections will form the nucleus of a HWW varietal development program in coming years, should such a program be in the best interest of the Oregon wheat industry.

Grain samples from all HWW selections advanced from the 1987 HWW preliminary yield trial are now undergoing quality evaluation at OSU and at the Western Wheat Quality Laboratory. Additional steps are being taken at OSU to ascertain what specific flour quality characteristics will be desired by foreign buyers interested in HWW purchases.

Table 4. Mean yield comparisons for selections of soft white, hard red, and new hard white winter wheat grown near Pendleton, Oregon, in 1987

Selection	Yield
	bu/A
Stephens (SWW)	117.8
Hill 81 (SWW)	126.2
Malcolm (SWW)	127.4
Wanser (HRW)	71.1
Centura (HRW)	70.9
Hatton (HRW)	63.3
Batum (HRW)	84.0
OR 840296	121.4
OR 860116	128.6
OR 860124	126.8
OR 860126	133.4
OR 860341	128.0
OR 860765	122.6
OR 860792	131.8
Ave	103.1

SPRING WHEAT

Spring-planted wheat occupied about 5% of the yield trial acreage and included HRS, SWW, and durum wheats. Efforts to identify good-quality hard red spring cultivars for the Pendleton area have intensified. ORS8508 and ORS8510, lines originally from International Maize and Wheat Improvement Center (CIMMYT) in Mexico have good hard red quality and have yielded 105% and 98%, respectively, of 'McKay' over a three-year period (Table 5). Quality characteristics for these lines are reported in Table 6. In addition to these two lines being considered for release, there are some newer cultivars from Argentina with excellent quality. Four Argentine lines -- 487005, 487006, 487007, and 487009 -- have been yield-tested for two years in Pendleton (Table 7).

Other market classes of spring wheat are also being evaluated. ORS8413 is a hard white spring with promising quality and an excellent yield record. In a dryland situation it has yielded 105% of both 'McKay' and 'Borah' (Table 5). Under irrigation (at Madras) this line has over a three-year period yielded 124% of 'McKay'. ORS8413 is being considered for release and breeders seed is being grown.

DURUM WHEAT

The western spring durum nursery was grown in Pendleton for the second year. Promising lines from that nursery are listed in Table 8. The two lines identified by OSU from the CIMMYT material, GA'S' and CARC 'S,' have yielded 103% and 102.5% respectively of WPB 881 under dryland conditions over a two-year period. Under irrigation (at Madras), GA 'S' was 110% of

WPB 881 and CARC 'S' was 107% in the two years of testing. This year there will be approximately 150 new durum lines under yield test at Pendleton.

With the encouragement of the people at the Pendleton Flour Mills and to focus further on domestic needs, the durum breeding program has been expanded. Emphasis will be place on developing a winter durum variety with competitive yields with soft white winter wheat and acceptable pasta quality. The breeding approach will be to cross winter and spring durum lines to achieve the desired level of winter hardiness with the good quality from spring materials. In addition, spring durum lines obtained from the CIMMYT will continue to be evaluated.

RUSSIAN APHID

The arrival of the Russian aphid in Oregon brings additional potential problems for wheat producers and a breeding program has been established to develop varieties resistant or tolerant to this insect. It will be necessary to identify genetic sources of resistance or tolerance and then to breed this resistance or tolerance into adapted varieties.

As a result of the OSU international involvement, several wheat lines that are reported to have genetic factors for resistance to the Russian aphid have been received from South Africa. Preliminary research in the U.S. suggests that the Russian aphid resistance of these lines may not be useful in Oregon since we may have a strain of the Russian aphid different from that present in South Africa. There is some disagreement among scientists regarding this point. Screening techniques developed in South Africa will be used to evaluate these South African varieties for resistance to Russian aphids now present in Oregon.

At the same time, crosses are being made between the South African lines and adapted varieties such as 'Stephens.' Should the genetic factors for resistance present in the South African material prove to be useful in Oregon, an accelerated system of advancing generations within the breeding program will be undertaken so that if the Russian aphid becomes a major problem growers will not be required to invest in chemical controls.

Table 5. Yield data for 1987 and a three year average for selected hard red spring cultivars grown at Pendleton

Selection	Yield 1987	Yield 3-year average
	- - - - - bu/A - - - - - -	
McKay	60	58
Borah	59	58
WB906R	61	57
ORS8508	66	61
ORS8509	67	64
ORS8510	58	57
ORS8511	65	63
ORS8512	60	59
ORS8518	62	61
ORS8418	57	59
ORS8413 (Hard White)	62	61
Ave	61.5	59.8

Table 6. Six-year quality data summary on selected spring hard red cultivars and checks

Selection	Test weight	Flour yield	Flour protein	Water absorption	Mixing time	Loaf volume	Crumb score
	- - lbs/bu - -		- - - - % - - - -		min	cc	1-9 1/
Borah	62.7	71.1	11.6	62.9	3.0	949	2.5
McKay	61.8	70.3	11.1	62.9	5.2	1,015	2.2
ORS8508	62.8	68.9	11.4	64.5	3.3	944	2.8
ORS8510	62.7	69.4	11.4	64.5	4.3	958	2.8

1/ 1 = excellent, 9 = unsatisfactory.

Table 7. Yield comparisons of U.S. and Argentine selections for 1986, 1987, and the two-year average at Pendleton

Selection	Yield		
	1986	1987	2-year ave
	bu/A		
McKay	64	60	62.0
Borah	63	59	61.0
WB906R	58	61	59.5
4870005	64	65	64.5
4870006	64	61	62.5
4870007	64	59	61.5
4870009	61	55	58.0
Ave	62.6	60.0	61.3

Table 8. Yield data on selected entries from the western durum nursery (1987 and a two-year average) grown at Pendleton

Selection	Yield	
	1987	2-year ave
	bu/A	
Modoc	55	57.5
WPB 881	61	58.5
Lloyd	63	60.5
Yavaros 79	58	58.5
D0079209	59	58.0
FLD87050	59	--
Stockholm	57	59.0
GA'S' (CD22344)	60	60.5
CARC'S' (CD24831)	56	60.0
PFI 86001	66	60.5
UC000606	57	60.5
UC000640	57	59.0
UC000714	61	--
WPB884-206	56	--
FLD87336	56	--
PBS03113	62	--
Ave	58.9	59.3

BREEDING DWARF BUNT (TILLETIA CONTROVERSA KUHN) RESISTANT WINTER WHEATS

M. F. Kolding, W. E. Kronstad, and C. Love[1]

Dwarf Bunt often referred to by the acronym TCK from its scientific name Tilletia controversa and its describer Kuhn, is a frustrating problem to the Pacific Northwest winter wheat industry. At times it has caused severe crop losses. Growers have learned to rotate crops and have generally accepted the more resistant wheat varieties, so the probability of a widespread epidemic is low. Dollar losses due to TCK induced yield reductions are difficult for the wheat industry to substantiate. However, lost wheat sales to "TCK-free customer countries" (sales not realized due to TCK contaminated wheat) have put the northwest at a substantial disadvantage to countries providing TCK-free wheat.

Oregon wheat farmers in the TCK areas have substantially reduced virulent inoculum in their soils by growing legumes, barley, and spring wheat for several years. This does not, however, insure that a particular field is free from TCK spores. A three-cycle wheat-summer fallow rotation could lead to disastrous infections (Table 1).

Table 1. Dwarf smut (Tilletia controversa, Kuhn) infected plants found in contemporary winter wheats in 1986 near Flora, Oregon, where the previous crops were fallow, wheat, fallow, wheat, fallow

Variety	Plants infected	Variety	Plants infected
	%		%
Malcolm	99	Tyee	65
Hill 81	99	Daws	60
Yamhill	99	Dusty	50
Stephens	90	Crew	40
Kharkoff	90	Lewjain	30
John	80	Sprague	30
Tres	70	ORFW-301	85

OBJECTIVES

Objectives of the program are twofold: to improve winter wheat germplasm by incorporating a broader base of specific and general resistance to dwarf bunt, snow molds, and Cephalosporium; and to select and release new winter wheat varieties from the improved germplasm.

[1] Senior instructor, Hermiston Agricultural Research and Extension Center, Hermiston, Oregon 97878; professor and research assistant, Crop Science Department, Oregon State University, Corvallis, Oregon 97331.

METHOD

A method known as "progressive cycling" in the breeding program is being used to attain dwarf smut resistance in winter wheats. Each cycle consists of the following steps.

1. Winter wheat heterogeneous populations are screened for resistance to endemic dwarf smut races, snow molds, and Cephalosporium near Flora, Oregon.

2. The more resistant types are brought to the Hermiston site for seed increase where select types are crossed to adapted types.

3. Seed increases planted near Flora and Hermiston are sent to Corvallis for foliar disease evaluation, specific crosses, and preparation for common bunt (*Tilletia caries*) resistance screening.

4. Selections are tested for common bunt resistance by Corvallis personnel at the Hermiston location.

5. New lines are sent to USDA-ARS personnel at Aberdeen, Idaho, for advanced dwarf smut resistance screening.

6. Selections are tested for yield potential near Flora and Hermiston.

7. Advanced selections are entered into more comprehensive trials such as the western regional and the eastern Oregon trials.

8. The progressive cycle continues.

RESULTS AND DISCUSSION

The "progressive cycle" breeding system for the development of more satisfactory winter wheats for the dwarf smut problem area started in 1972. A collection of types reported to have different TCK resistance genes was grown for several years near Flora, Oregon. Very few survived the winters, or were resistant to the TCK races endemic to the area. Resistant lines such as SM-4, SM-11, CI 14106, Thule III, PI 178210, and PI 178201 did not survive across seasons. They were used in primary crosses with high-quality wheats.

Concurrently, Robert Metzger, retired geneticist ARS-USDA, verified resistance in his common smut screening trials. He also provided more desirable plant types having both the survivors and other gene sources in their pedigrees.

As the germplasm base became larger and seed more abundant, yield trials were established near Flora. In 1986, 1000 selections were tested for yield and disease resistance. In addition there were 750 new lines and bulk populations evaluated in the same field as reported in Table 1. Also, Corvallis personnel now complete new and specific hybridizations, maintain the common bunt races, apply them to the selections, plant, determine infection percentages, and report which genes are involved.

Trials were conducted at the Hermiston Agricultural Research and Extension Center in 1987 to evaluate maximum yield potential for 21 trials of advanced and heterogeneous populations. Six trials were planted near Haines for 1987, but they were abandoned due to a lack of TCK infestations. Data in Table 2 presents some evidence of progress when using the alternate and complimentary sites near Flora and Hermiston. The entries from the cross FW81422 are second-cycle selections from a modified population in 1984. The ones made in 1983 from the original population were discarded. Hopefully the newer ones, which appear to have the potential yield capacity of Lewjain, have the excellent resistance of Triticum timopheevi (TT). The FW81454-301 syn.ORFW-301 selection is being tested in a western regional nursery (Table 3). At eight locations its yields were at least equal to the common short-stature wheats grown in the Pacific Northwest. ORFW-301 also compared favorably to the more popular soft white winters in the eastern Oregon white wheat trial in 1987 (Table 4). It must be noted, however, that it had an 85% infection rate (Table 1). Plants were selected from the population and placed in the 1986 common smut screening trials where they were inoculated with races 39, 43, and 55. These races are virulent to 10 genes for resistance. Eleven selections had less than 5% of their heads infected. Now, those 11 will cycle through the system.

Table 2. Yield, date headed, and plant ht of "second-cycle" selections from a cross of the excellent Triticum timopheevi (TT) source of (TCK) Tilletia controversa resistance from two trials grown on the Hermiston Agricultural Research and Extension Center, Hermiston, Oregon

Identity number	Pedigree or name	Yield	Date headed	Plant ht
		bu/A	mo/day	in.
	Trial 7065			
1. CI 17909	LEWJAIN	116	5/10	36
2. FW81422-S4009	TT/2*P-101/2/LUKE	127	5/16	40
3. CI 13968	NUGAINES	117	5/16	44
	Trial 7074			
1. FW81422-S4001	TT/2*P-101/2/LUKE	106	5/14	40
2. FW81422-S4008	TT/2*P-101/2/LUKE	107	5/18	36
3. FW81422-S4002	TT/2*P-101/2/LUKE	110	5/18	38
4. FW81454-301	DAWS/SM-4/2/MDM/SM-11	109	5/13	36
5. CI 17909	LEWJAIN	106	5/14	38

Table 3. Average grain yield of FW81454-301, syn ORFW-301, and four white winter wheats tested at eight locations in a regional yield nursery

Variety	Yield
	bu/A
ORFW-301	86.6
Dusty	82.5
Stephens	80.8
Nugaines	75.7
Oveson	74.1

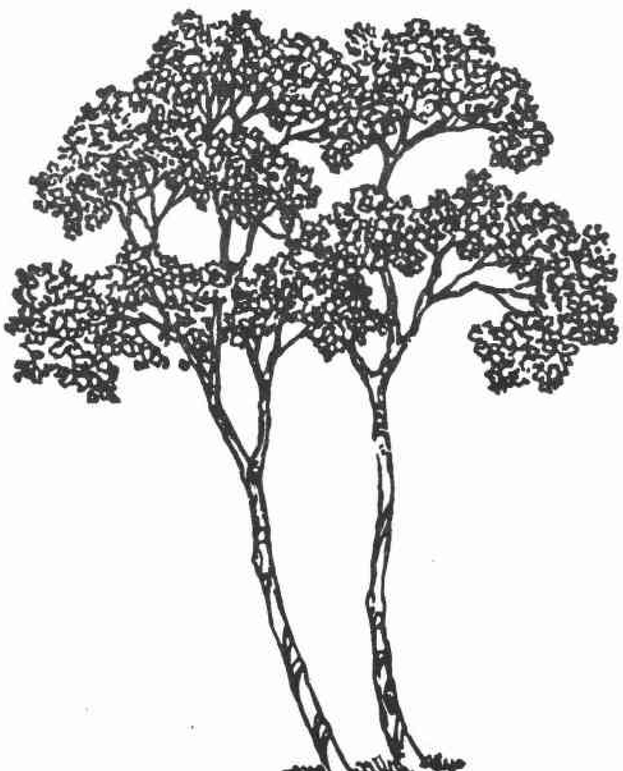
Table 4. Grain yields of eight white winter wheats tested in yield trials near Hermiston, Boardman, and Ontario, Oregon

Variety	Hermiston	Boardman	Ontario	Average
	- - - - - - - - - - - - - -	bu/A	- - - - - - - - - - - - -	
1. McDermid	98	102	139	113
2. Daws	114	114	136	121
3. Stephens	110	108	159	126
4. Dusty	115	114	155	128
5. Malcolm	122	122	149	131
6. ORFW-301	108	124	162	131

Grain yields in Table 5 are considerably above the Hermiston location grain yields presented in the previous tables. They are also as good or better than yields from other trials in the same field. This method of selecting for disease resistance and yield capacity at Flora and Hermiston appears useful for identifying potential varieties for a greater area than the TCK problem area.

Table 5. Grain yields of the highest-yielding 1986 selections from the f-4 bulks grown near Flora and tested at the Hermiston Agricultural Research and Extension Center in 1987

Name	Pedigree	Yields
		bu/A
1. FW83070-F6006	M81-663,LUKE*2/PI178210/SPN	142
2. FW83117-F6007	SPN*2/FW75536F701,PI178383/OM/2/CI13438	119
3. FW84012-F6008	FW83090/LEWJAIN"	108
4. FW84104-F6011	SPN*2/THULE III/2/FW83830-DWF	123
5. FW84107-F6028	SPN*2/THULE III/2/FW81439	142
6. FW84108-F6009	SPN*2/THULE III/2/FW81439	149
7. FW84111-F6005	SPN*2/FW75536F701/2/CO723595	124
8. FW84112-F6008	SPN*2/FW75536F701/2/FW81439	143
9. FW84132-F6007	SPN*2/FW75536F701/2/FW81439	129
10. FW84137-F6001	SPN*2/FW75536F701/2/LEWJAIN	122
11. FW84109-F6003	SPN*2/FW75536F701/2/FW74706	146



WINTER BARLEY VARIETAL DEVELOPMENT: PENDLETON, 1987

P. Hayes, A. Corey, N. Scott, M. Moore, and R. Knight[1]

INTRODUCTION

The goal of the Oregon State University barley breeding program is to develop high-yielding, input-efficient, multiple-use barley varieties. Multiple-use varieties offer the grower marketing options: grain can enter malt or feed channels. The higher proteins demanded by the malt industry (11-13%) make the multiple-use goal realistic: a good malt barley is a good feed barley.

We intend to exploit the yield advantage of winter barley and provide the Oregon grower with a competitive product appropriate for domestic and/or export markets. The emphasis on winter habit is a reflection of a worldwide trend; for example, substantial European barley acreage is now planted to winter malting and multiple-use varieties.

The barley breeding program uses multiple-location evaluation of material developed through classical and new genetic techniques. Principal testing locations (Hyslop, Moro, and Barnett-Rugg Ranch), provide selection opportunities for disease resistance, drought and cold tolerance, and agronomic potential. A modified bulk breeding method is used to improve materials in the mainstream breeding program. Double haploid techniques are being used to reduce the time required for varietal development.

MATERIALS

Four nurseries and one special study were grown at the Barnett-Rugg Ranch in 1986-87: 1) two elite nurseries, the winter barley elite line trial (WBELT) and the winter barley quality trial (WBQT); 2) one advanced nursery, the advanced late yield trial (ALYT); 3) one preliminary nursery, the winter barley preliminary yield trial (WBPYT); and 4) the thesis study of Nusret Zencirci, an assessment of scald infections on feed and malt quality.

RESULTS

The WBELT and WBQT, consisting of 44 and 23 entries, respectively, represent elite lines in the final stages of evaluation prior to regional testing. Yields of selected WBELT entries and checks are shown in Table 1.

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[1] Assistant professor, senior research assistant, senior instructor, and senior research assistant's, Crop Science Department, Oregon State University, Corvallis, Oregon 97331.

Table 1. Yields of selected winter barley feed lines grown at Pendleton in 1987

Line	Head type	Test weight	Yield 1987	Yield ave
		lb/bu	- - - - lb/A - - - -	
Scio	6-row	51	4681	4862 (5 yr)
Hesk	6-row	51	4346	4318 (2 yr)
Kamiak	6-row	54	4140	4065 (4 yr)
ORWF8328[1/]	6-row	51	5509	5054 (2 yr)
ORWF8410[1/]	6-row	53	5343	5641 (4 yr)
ORWF8411[1/]	6-row	52	4973	5316 (4 yr)
ORWF8413[1/]	6-row	52	4668	4761 (4 yr)
OR1861168	6-row	54	5365	5365 (1 yr)

[1/] In Western Regional Winter Barley Nursery.

There are some exciting prospects. ORWF 8328 and 8410 are doing well in the Western regional barley nursery; the latter shows exceptional long-term performance at Pendleton, OR1861168 was competitive in its first year of WBELT testing. Yields of selected WBQT entries and checks are shown in Table 2. Substantial progress has been made with the WBQT lines in terms of meeting American Malting Barley Association quality standards. It is encouraging that these lines, including the 2-rows, are yielding as well as the feed types.

Table 2. Yields of selected winter barley lines with possible malting quality grown at Pendleton in 1987

Line	Head type	Test weight	Yield 1987	Yield ave
		lb/bu	- - - - lb/A - - - -	
Scio	6-row	52	4095	5023 (5 yr)
Wintermalt	6-row	52	4840	4549 (4 yr)
ORW8406[1/]	2-row	56	5323	5104 (4 yr)
ORW8407[1/]	6-row	52	5335	5509 (4 yr)
OR1861164	2-row	53	5781	5781 (1 yr)
OR1861016	2-row	55	6025	6025 (1 yr)

[1/] In Western Regional Winter Barley Nursery.

SOILBORNE PATHOGENS OF CEREALS IN EASTERN OREGON: DEVELOPMENT OF A RESEARCH STRATEGY

R. W. Smiley[1]

Wheat and barley crops in eastern Oregon are damaged by several soilborne plant pathogenic fungi and nematodes. The diseases caused by these infectious agents differ regionally, with each being an important constraint to production in one locality or another. It is also common to find several agents co-existing as participants in disease complexes in some regions and some plants. Diseases of concern include Cephalosporium stripe, strawbreaker foot rot, dryland foot rot, take-all, Rhizoctonia root rot, Pythium root rot, dwarf bunt, common bunt, pink and speckled snow molds, and cereal cyst nematode.

Each of the diseases named above are worthy of in-depth research, but it is impossible to develop a program that adequately addresses each of them. Priorities must be established. Considerations in this process include 1) the economic importance of each disease; 2) the amount of knowledge already available to growers, extension agents and service and supply personnel; 3) an estimate of the potential importance of each disease in the future; 4) the potential for acquiring adequate funding from a balanced group of sponsors; and 5) the achievement of a diversity of studies that address growers needs in at least two or three regions of eastern Oregon.

Based upon these considerations, my program has focused its early efforts on in-depth studies of the biology and control of Rhizoctonia root rot (50%), cereal cyst nematode (35%), and short-term chemical control studies of strawbreaker foot rot (15%). Well-recognized programs in the Pacific Northwest have placed or are placing a high level of emphasis on Cephalosporium stripe (Tim Murray-WA, Bill Bruehl-WA, and Maury Weise-ID), strawbreaker foot rot (Tim Murray and Bob Powelson-OR), dryland foot rot (Jim Cook-WA), take-all (Jim Cook, Bob Powelson, and Neil Christenson-OR), Pythium root rot (Jim Cook), dwarf and common bunts (Jim Hoffman-ID and Ruben Duran-WA), and snow molds (Bill Bruehl and Don Huber-ID). Control of snow molds is currently emphasized in southern Idaho and Utah.

The least amount of information available to cereal producers relates to damage caused by Rhizoctonia root rot and the cereal cyst nematode. Both diseases remain of uncertain importance to the future of cereal production in eastern Oregon, especially in view of the changes occurring in tillage and crop management systems in the region. Both diseases have the potential for causing high levels of damage. These diseases have, therefore, become emphasized during the early years of my research program in Oregon; Rhizoctonia root rot and cereal cyst nematode studies are conducted mainly in Umatilla and Union counties, respectively. Additional attention is given to chemical control strategies for strawbreaker foot rot, with emphasis on the occurrence of this disease in Sherman County. The cereal cyst nematode is emphasized in a separate paper in this special report; other diseases will be featured in future issues.

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[1] Superintendent and professor, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon 97801.

CEREAL CYST NEMATODE (<u>HETERODERA</u> <u>AVANAE</u>) RESEARCH AND SURVEY IN EASTERN OREGON

R. W. Smiley, J. Pinkerton, R. Ingham,
G. Newcomb, G. Cook, and P. Zwer[1]

The cereal cyst nematode was first discovered in the Pacific Northwest in western Oregon during 1974. Subsequent finds occurred in the Palouse region of eastern Washington during 1983, in eastern Oregon (Union County) during 1984, and in southeastern Idaho during 1986. This nematode is, therefore, now known to encircle Oregon's wheat belt; the Columbia Basin, Columbia Plateau, and Palouse Prairie. It poses a potentially high but yet unknown actual risk for production of cereals in eastern Oregon.

For comparative purposes, the cereal cyst nematode has infested about five million acres in southern Australia (a temperate climate area with dry summers and 9 to 24 in. of rainfall), and causes annual losses of at least 70 million U.S. dollars in the production of spring cereals in that country. Application of a nematicide as a band under the seed is required to attain adequate yields on nearly one-half million acres in the moderate-to-high-yielding areas of southern Australia. Nematicides are expensive ($5 to $7/A), special application equipment is required on the drills, and a special soil assay is required ($2.50/A) to detect high-risk fields. This nematode interacts with certain root pathogens, such as <u>Rhizoctonia</u> <u>solani</u> and <u>Gaeumannomyces</u> <u>graminis</u> var. <u>tritici</u>. Yield losses are more from their combination than from the additive effects of either pathogen alone. In 1986, a wheat crop in Union County yielded 11 bu/A on an irrigated circle, after the crop was damaged by this nematode and complicating agronomic factors. Similar-appearing fields or portions of fields were observed and damage from the nematode and associated root rots was confirmed during 1987. However, yields were not documented.

Systematic research on the cereal cyst nematode and its damage to cereals is not being conducted elsewhere in the western United States. Research is required to reduce the possibility that damage to production of cereals may occur in the Columbia Plateau and Basin when the nematode spreads to these areas. Because a survey of the region has not been conducted, we do not know if the nematode has already spread to these leading cereal-producing regions of eastern Oregon. The potential is high, because spreading can occur with the movement of soil from infested fields. Soil movement occurs on animals, shoes, equipment, and plant materials (seed potatoes, mint root stocks, or potted ornamentals) that are transported out of infested areas, and on soil moving via wind and water erosion. Previous experiences world-wide have shown that newly infested areas are typically not discovered within the first 5 to 10 years after the nematode has been introduced into a new field or region. Opportunities for spread of this pest in eastern Oregon occur almost continuously.

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[1] Professor, Oregon State University, Columbia Basin Agricultural Research Center, Pendleton 97801; plant pathologist, Oregon Dept. of Agriculture, Plant Division, Salem 97310; assistant professor, OSU, Dept. of Botany and Plant Pathology, Corvallis 97331; nematology research associate, OSU Extension Service Plant Clinic, Corvallis 97331; extension agent, OSU - Union County Extension Service, La Grande 97850; assistant professor, OSU, Columbia Basin Agricultural Research Center, Pendleton, OR 97801.

An informal survey during 1986 showed that the cereal cyst nematode was present in 8 of 12 fields sampled in Union County, with populations ranging from very low (33/qt of soil) to extremely high (24,300/qt). Fields were selected to include a diversity of soils, positions in the county, and cropping histories. None of the fields had visible damage or were experiencing a known yield constraint. During 1987 it was further determined that cysts of the cereal cyst nematode were present on soil falling from potatoes that were being placed into storage. We have not yet examined the possibility that the nematode may be transported from the storages to the potato fields in the Columbia Basin and elsewhere, where wheat is typically produced in rotation with potatoes. A preliminary chemical control trial on a field with a low to moderate level of infestation showed that banding Temik below the seed at planting increased yields of winter and spring wheat by 29 and 25%, respectively, and of winter and spring barley by 6%.

The cereal cyst nematode is considered to be of minor importance in western Oregon, mostly because cropping systems and crop growth stages in that region are not coordinated with the nematode's egg hatching and most active feeding period. This is not likely to hold true in eastern Oregon, where plants are often in the most susceptible juvenile state at a time when the egg hatch might be expected. This possibility remains speculative because details of the nematode's life cycle have not been studied in the eastern region. We have determined, however, that at least some eggs hatch in Union County prior to the onset of spring-time growth of winter wheat. Additionally, the pathotypes (races or strains) of cereal cyst nematode in eastern Oregon, eastern Washington, and southern Idaho have not been identified. Different biotypes of this nematode have different specificities for attacking different cereals or grasses; the host specificity for this pathogen in the Pacific Northwest has not been precisely determined. More than 10 biotypes are known to occur elsewhere in the world.

Our research on cereal cyst nematode is a cooperative venture among personnel in several agencies and locations. These efforts focus upon the following objectives:

A. Conduct field studies to establish crop management systems (rotations, chemical treatments, tillage practices, cultivar recommendations, etc.) best suited for minimizing the damage from this pathogen.

B. Assay soils from fields in the Columbia Plateau and Basin, and other areas where soils may have been moved, to determine if they have also become infested with this nematode.

C. Identify the pathotype(s) present in Union and Washington counties and, in so doing, determine which crop species are at greatest risk of damage.

CROP MANAGEMENT SYSTEMS

A long-term (five-year) cropping systems study was established on a heavily infested soil in Union County during 1987. The trial consists of 11 crop rotations with tillage and weed control variables. Each treatment is replicated four times. The rotations will assist in determining the effect of non-susceptible crops (alfalfa, peas, rape) and short- or long-term fallow on damage levels to subsequent wheat crops.

Various sequences of wheat, barley, and Kentucky bluegrass are included in these treatments. Tillage management variables will examine an Australian report that the disease can sometimes be reduced by using no-till practices. to determine if this can be confirmed in our region. The weed control variables examine the damage to wheat following production of alfalfa that is either free from or contaminated with grassy weeds. Populations of the nematode must be monitored regularly in each treatment of the study to enable accurate interpretation of results after five years.

Chemical control and host resistance studies were established at the same location. The chemical control plot places emphasis on seed treatments with experimental nematicides recently shown to effectively manage the soybean cyst nematode in Alabama. This treatment, if effective on wheat, will provide an environmentally preferred alternative to treatment of soil with a more mobile nematicide such as Temik. Seed treatments are also more likely than soil treatments to become cost-effective on wheat. The second study consists of a comparison of selected cultivars of wheat, barley, and triticale to determine their relative tolerances to damage from this nematode. The treatments are paired, with four rows treated with nematicides and the other four rows untreated, to remove the inherent productivity differences that occur for these cereals and their cultivars. This portion of the study is directed by Dick Smiley, and assistance is provided by each of the other authors. A formal approach to breeding of wheats resistant to the cereal cyst nematode is being initiated by Pamela Zwer.

DETERMINE THE EXTENT OF NEMATODE SPREAD

A survey of sites in eastern Oregon where infested soil may have been moved in the past has been initiated. The survey emphasizes farms that have produced crops in the Columbia Basin as well as in areas that are now known to be infested, farms that purchase plant materials that may be contaminated with infested soil, and research centers that have served as home base for experimental equipment used in fields or areas now known or thought to be infested. This survey is coordinated by Jack Pinkerton, with assistance from Dick Smiley, Russ Ingham, Gene Newcomb, Gary Kiemnec (OSU Extension Crop Scientist at EOSC, La Grande), Mike Stoltz, and Fred Lundin (Extension Service agents in Umatilla and Morrow counties, respectively). Soil will be collected from selected fields, using an intensive and systematic sampling system required for studies of nematode populations that occur in localized "hot spots." Each sample will consist of numerous (about 50) scoops or cores of soil that represent sampling areas of five acres or less.

IDENTIFICATION OF THE PATHOTYPE

This identification procedure involves bioassays conducted with more than 20 exotic varieties of barley, oats, and wheat from all over the world. These indicator species and varieties (the bioassay concept is similar to race determinations for rust diseases) are standardized internationally and have, therefore, been imported from three other continents. The assay is very demanding in that it is difficult to assure that this pathogen will exhibit its full potential for damaging roots in controlled environment studies, and in that the tests must be performed with precisely known numbers of nematodes per unit of soil volume. The success of this procedure is required before further information on the biology, host range, and aggressiveness of the pathotype in eastern Oregon can be determined and reported. The tests will be performed at Corvallis, as they cannot be performed at Pendleton unless it is found the nematode is present at the research center. This portion of the work is coordinated by Russ Ingham and Jack Pinkerton, with assistance from Dick Smiley, Gordon Cook, and others in the project.

PERFORMANCE OF YIELD-ENHANCING AGENTS IN WINTER WHEAT

D. F. Grabe, F. E. Bolton, and C. Garbacik[1]

Yield trials were conducted for the second year to determine response to several compounds purported to have yield-enhancing effects on winter wheat. The products tested included YEA!, containing chitosan, a derivative of crabshell; amplify-D, containing sodium phosphates and adenosine monophosphate; Cardak, containing super slurper, a starch derivative; and Golden X, containing Aspergillus oryzae in a carrier of sand washings. Another treatment consisted of passing the seed through a Bio-Mag magnetic seed treater. Controls consisted of untreated seed and seed treated with Vitavax 200.

The products were applied to Vitavax-treated seed at rates recommended by the suppliers. Three wheat varieties were used: 'Hill 81,' 'Malcolm,' and 'Stephens.' Plots were established at Hyslop Farm, near Corvallis, and the Columbia Basin Agricultural Research Center, near Moro. The experimental design was a randomized complete block with four replications.

Yields at Moro were about the same as in 1986, but yields at Corvallis were much lower than last year due to moisture stress. None of the products increased wheat yields at either location (Table 1), confirming the findings of 1986.

Yield trials were re-established in the fall of 1987. In addition, the effects of seed-moisturizing on wheat yields will be studied. Commercial moisturizing equipment has been developed in Canada and is being promoted as a way of increasing crop yields. The seed-moisturizing process involves soaking seed in water under vacuum before planting.

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[1] Professor, associate professor, and research assistant, Crop Science Department, Oregon State University, Corvallis, Oregon 97331.

Table 1. Yields of winter wheat treated with yield-enhancing agents

Seed	Corvallis				Moro			
treatment	Stephens	Hill-81	Malcolm	Ave	Stephens	Hill-81	Malcolm	Ave
	bu/A							
				1987 Harvest				
YEA!	71.0	76.6	73.8	73.8	49.8	29.5	49.0	42.8
Cardak	78.1	70.8	73.8	74.2	57.2	31.7	52.4	47.1
Amplify	74.2	72.8	74.2	73.7	58.0	35.8	53.2	49.0
Golden X	74.4	77.4	76.3	76.0	45.3	27.9	48.3	40.5
Bio-Mag	77.1	79.1	71.2	75.8	52.9	35.6	55.4	48.0
Vitavax-200	73.2	69.9	75.6	72.9	58.0	33.3	49.0	46.7
Untreated	78.8	77.8	72.5	76.4	52.8	33.8	43.9	43.5
Ave	76.2	74.9	73.9	75.0	53.4	32.5	50.2	45.4
LSD 0.05				NS				NS
				1986 Harvest				
YEA!	131.1	136.1	134.3	133.9	34.7	41.2	38.5	38.2
Cardak	134.5	128.2	138.4	133.7	35.0	40.4	36.7	37.4
Amplify	131.8	142.4	135.0	136.7	37.0	38.7	37.7	37.8
Golden X	132.8	140.9	137.7	137.2	30.3	41.3	41.4	37.7
Bio-Mag	135.1	137.1	136.6	136.3	35.9	39.2	40.0	38.4
Vitavax-200	133.8	141.0	141.6	138.8	33.3	39.8	38.4	37.2
Untreated	129.7	141.1	137.4	136.1	34.3	41.2	41.4	40.0
Ave	132.7	138.1	137.4	136.1	34.4	40.3	39.2	37.9
LSD 0.05				NS				NS

LIQUID STARTER FERTILIZERS ON WINTER WHEAT AND BARLEY IN NO-TILL PLANTINGS

F. E. Bolton[1]

INTRODUCTION

Phosphate fertilization rarely resulted in significant yield increases during the past 30 years. Soil tests generally show an adequate amount of phosphates in the upper 12-14 in. of the profile in most areas of the Columbia Basin. During the past seven or eight seasons (except 1985), grain yields have been high; however, phosphorus deficiency symptoms were sometimes observed. These observations led to the present field trials reported herein.

METHOD

Stephens winter wheat and Hesk winter barley were seeded in no-till fallow with a strip-till planter which tilled a 4-in. wide seed row set on 16 in. centers. Solution 32 was applied between rows with a spray boom attached to the front of the planter unit ahead of the row tiller blades. Atrazine, at 0.5 lb/A, was added to the fertilizer solution and applied simultaneously. Liquid starter fertilizer was applied slightly above the seed in the seed row using a separate manifold system.

Trials were seeded on September 18, 1985, and September 30, 1986. During both seasons, plots emerged to uniform stands within 12 days. Seeding rates were 65 and 75 lb/A for Stephens winter wheat and Hesk winter barley, respectively.

RESULTS

Both wheat and barley responded to nitrogen applications during both years (Table 1). Starter fertilizer, containing phosphate and sulfur, increased yields of Stephens wheat in 1986, but in 1987 only the starter phosphate treatment resulted in a significant yield increase.

Hesk winter barley responded significantly to the phosphate-sulfur combination in 1986, but like Stephens wheat, showed increased yields in 1987 only to the starter phosphate treatment.

SUMMARY

Natural soil phosphorus is apparently being depleted, after 80 years or more of cultivation, to a level where phosphate fertilizer will be required to maintain current yield levels. Relatively small amounts of phosphate will probably be adequate to satisfy the deficit in the near future. Starter fertilizers in the liquid form is a convenient, efficient way to satisfy the phosphorus requirement.

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[1] Associate professor of agronomy, Crop Science Department, Oregon State University, Corvallis, Oregon 97331.

Table 1. Liquid Starter Fertilizer Trial -- Moro Station -- 1986 and 1987

Fertilizer[1/] treatment	1986	LSD[2/]	Fertilizer treatment	1987	LSD
		Stephens Winter Wheat			
	(bu/A)			(bu/A)	
1	25.9	A	1	49.1	A
4	40.6	B	4	55.3	B
2	40.7	B	5	55.9	CB
3	42.1	CB	2	57.2	CB
5	42.7	C	3	57.6	C
		Hesk Winter Barley			
	(lb/A)			(lb/A)	
1	1981	A	1	4299	A
2	2776	B	2	4761	B
4	2866	B	4	4761	B
3	2926	B	5	4799	B
5	3236	C	3	5248	C

[1/] 1 = 0 nitrogen, 0 starter fertilizer (Control).
2 = 50 pounds nitrogen applied at Solution 32 at planting between rows.
3 = Same as above + 3.5N-12P (10-34) per acre dribbled in row.
4 = Same as above + 3.9N-8.6S (12-0-0-26, ThioSul) per acre dribbled in row.
5 = Same as above + 7.5N-12P-8.6S (10-34 + 12-0-0-26) per acre dribbled in row.

[2/] Means with the same letter are significantly different at 0.05 level.

SOURCE AND METHOD OF NITROGEN FERTILIZER AND HERBICIDE APPLICATIONS IN WINTER WHEAT, MORO 1987

F. E. Bolton[1]

INTRODUCTION

Control of grassy weeds, especially Bromus species (cheatgrass), continues to be a serious problem in dryland wheat production. Cost of currently registered herbicides often increases production costs, in the lower yielding areas, beyond economic levels. Previous trials have shown that low rates (0.5 lb ai/A) of Atrazine applied at planting gave good control of grassy weeds at relatively low cost ($1.50-$2.00/A). Also,that Atrazine, and several other herbicides used to control grassy weeds, can be applied in a liquid nitrogen (N) fertilizer-herbicide mix, which would decrease costs even lower.

Before this technique can be considered as a viable production practice, several questions need to be answered: 1) will liquid fertilizer materials (Solution 32), sprayed in a band on the surface between the planted rows, give a yield response equal to anhydrous ammonia injected into the soil at the same rate? 2) are liquid fertilizers (Solution 32) and water equally effective as carrier solutions for herbicides? 3) are grassy weeds effectively controlled using this method?

METHODS

Plot design was a randomized split block with three replications, with method of N fertilizer application as main plots. Anhydrous ammonia (50 lbs N/A) was injected two months prior to seeding on conventionally prepared stubble mulch land. All plots were seeded to Stephens winter wheat at 65 lb/A with a John Deere HZ split packer grain drill with 16 in. row spacing. Herbicides were applied with a spray boom attached to the drill frame ahead of the planting shoes. Flat fan nozzles were centered between the planted rows and positioned such that the spray pattern met at the middle of the seed row, but did not overlap, which gives a lower rate of liquid over the planted row.

RESULTS

Table 1 shows that source and method of application of N in this trial resulted in grain yields that were not statistically different. Field observation of grassy weed populations showed that Atrazine and Extrazine gave better control when applied with Solution 32 as a carrier solution than with water. This reflected in the grain yield at harvest (Table 2). The opposite effect was observed in the Metribuzin treatment, although the effect on grain yield was not significant.

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[1] Associate professor of agronomy, Crop Science Department, Oregon State University, Corvallis, Oregon 97331.

Table 1. Source and method of nitrogen application, Moro, 1987

Source of N	Method	Rate	Yield
		lb/A	bu/A
0	--	0	45.7
Anhydrous Ammonia	Injected	50	47.4
Solution 32	Band-Sprayed	50	50.5

Table 2. Effect of herbicide carrier solutions on winter wheat yields, Moro, 1987

Carrier Solution	Herbicide	Rate	Yield[1/]
		lb ai/A	bu/A
Water	Atrazine	0.5	46.4
Solution 32	Atrazine	0.5	52.7
Water	Extrazine	0.75	45.9
Solution 32	Extrazine	0.75	52.1
Water	Metribuzin	0.5	52.5
Solution 32	Metribuzin	0.5	50.4

[1/] All treatments received 50 lbs N/A as anhydrous ammonia soil-injected (water-herbicide) or Solution 32 (herbicide carrier) band-sprayed at seeding.

SUMMARY

Anhydrous ammonia, soil-injected or solution-banded between the rows at seeding, showed equal effects on grain yield as a source and method of N application. Atrazine and Extrazine controlled grassy weeds better when Solution 32 was used as carrier. Metribuzin controlled grasses more effectively when water was the carrier solution.

These results are preliminary from one year and location. The trial is being repeated in 1987-88 with additional replications at the Moro Station for more definitive information.

CEREAL CULTIVAR TOLERANCE TO TYCOR AND PICLORAM

D. J. Rydrych[1]

INTRODUCTION

Field plantings of winter wheat in 1985 and 1986 were found to be affected by Picloram (Tordon) that had been used in fallow or stubble for the control of field bindweed in prior seasons. The growth suppression was not in itself an unknown result of Picloram residues in the soil. Label warnings caution the use of Picloram for field bindweed control because some yield suppression can be experienced the first season after treatment. However, the yield suppressions were being expressed as seed sterility, a factor that had not been noticed in prior research. An experiment was initiated on the Pendleton Station in 1987 to study the effect of Picloram residues in the soil and post-emergence Tycor application on floret sterility of several winter cereal varieties. The results of the Picloram study and the corresponding Tycor tolerance is summarized in this report.

MATERIALS AND METHODS

The research was conducted on Walla Walla silt loam soil on the Pendleton Station, nine miles northeast of Pendleton, Oregon. Seven winter cereal varieties (Stephens, Hill 81, Dusty, Oveson, Tres, Nugaines winter wheats, and SC10 winter barley) were planted in a split plot experimental design with four replications for the 1986-87 season. Picloram was applied preplant surface at 2 pt/A on September 22, 1986, to simulate actual soil residues from a herbicide treatment for perennial weed control. Cereal varieties were drilled into the treated plots on October 1, 1986. Tycor was applied to the varieties post-emergence on November 13, 1986, when the seedlings had developed two to three tillers.

RESULTS AND DISCUSSION

There was a dramatic effect from Picloram residues in the soil based on readings taken on tillers/ft, plant height, crop injury, and total yield (Table 1). The most important result of this study was the large differences in crop injury among the varieties. The most sensitive variety to Picloram residues was Stephens, with only 760 lb/A total yield. Hill 81 and Nugaines were also suppressed by Picloram to a large degree. Winter barley (Scio) was the most tolerant cereal in the study with 3690 lb/A of total crop yield. Wheat varieties with fair tolerance to Picloram included Oveson, Dusty, and Tres.

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[1] Professor, Columbia Basin Agricultural Research Center, Oregon State University, Pendleton, Oregon 97801.

Crop injury ratings varied from 80% (Stephens) to only 5% (Scio) (Table 1). The injury was expressed not only in height reduction and tiller suppression but also in the lack of development of endosperm in each kernel. Sensitive varieties had numerous sterile seeds per spikelet. The sterile florets were not able to develop into normal kernels and therefore failed to produce a measurable yield. The most sensitive variety (Stephens) had only about two normal kernels per spikelet, with the rest being sterile. However, the surviving kernels were heavier than normal based on 100 seed weights (Table 1).

Table 1. Cereal variety tolerance to Picloram.[1/] OSU-CBARC, Pendleton, OR

Variety	$Tiller/ft^2$	Plant ht	100 Seed wt	Crop injury	Grain yield
	no.	in.	g	%	lb/A
Stephens	35	28	5.2	80	760
Hill-81	32	29	4.1	60	1270
Nugaines	57	34	3.9	55	1700
Oveson	42	32	5.0	25	1950
Dusty	48	30	3.8	20	2820
Scio (barley)	40	40	3.9	5	3690
Tres	37	32	4.0	22	2030

[1/] Picloram applied @ 2 pt/A - Sept 22, 1986 (preplant).

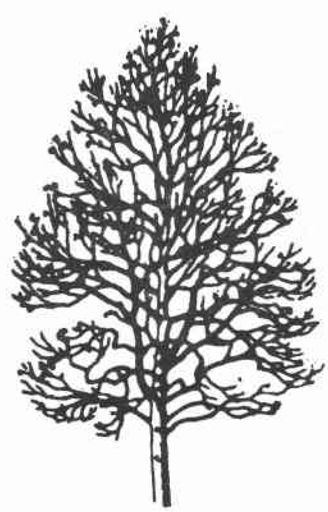
More resistant wheat varieties such as Oveson, Dusty, and Tres had more normal seed development in the head. The winter barley variety "Scio," showed little or no effect from the Picloram and seed development was normal. Since Nugaines was used in early Picloram studies, it was included here for comparison with newer varieties. However, Nugaines was also found to be nearly as sensitive to Picloram as Stephens. Observations in the field support the results of the Picloram study in that winter barley seems to be much more resistant than winter wheat to Picloram soil residues. In addition, Dusty, Oveson, and Tres seem to be much more resistant than Stephens and would be better choices to use in known Picloram sites. When Picloram is applied in wheat fields for the control of field bindweed, a certain amount of yield suppression can be expected the first crop season. This restriction and caution is stated on all Picloram herbicide labels. Yields are usually not affected the second season regardless of cereal variety. This preliminary study is being expanded in 1988 to include other cereal varieties.

Tycor has a much shorter soil life than Picloram and is applied selectively in the cereal crop for cheatgrass control. Six of the seven cereal varieties were quite tolerant to post-emergence application of Tycor (Table 2). Hill 81 is quite sensitive to Tycor and would not be useful in this type of rotation. However, Stephens, Oveson, Tres, Dusty, and Nugaines winter wheats, and Scio winter barley are very tolerant to Tycor . This is good news for wheat growers because there are enough resistant cereal varieties to select when using a Tycor system. Tycor is not registered for use in cereals at this time but is being considered for release in 1989. Tycor would be a very useful cheatgrass herbicide because cereal varieties in general are quite tolerant from the seedling stage to late tillering. Several new cereal cultivars are being evaluated for the 1988 season.

Table 2. Cereal variety tolerance to Tycor.[1/] OSU-CBARC, Pendleton, OR

Cereal variety	Tillers/ft^2	Plant ht	Seed wt	Crop injury	Grain yield
	no.	in.	g	%	lb/A
Stephens	37	35	.05	0	5120
Hill-81	13	32	.04	75	1870
Nugaines	57	34	.04	0	4060
Oveson	51	40	.04	0	5330
Dusty	58	38	.03	0	5190
Scio (barley)	50	41	.04	2	4850
Tres	47	41	.03	0	4400

[1/] Tycor applied @ 2 lb/A - Nov 13, 1986 (2 to 3 tiller stage).



WHEEL TRACK DAMAGE IN CEREALS

D. J. Rydrych and D. E. Wilkins[1]

INTRODUCTION

Equipment traffic on small wheat seedlings can cause permanent yield reductions according to research conducted in 1969 and again in 1987. Trials in 1969 in Pendleton showed that tractor wheel tracks caused a 25% yield reduction in the damaged rows. However, when the damage is averaged over total field area, the yield loss was less than 3.2%, a much more acceptable damage level. With the availability of different types of herbicide spraying equipment, a study was implemented in 1987 to compare wheel track damage of several different commonly used spray application systems.

Experiments were established in four counties in 1987 to study the effect of herbicide sprayer traffic on seedling winter wheat. Trials were established near Helix, Wasco, Elgin, and La Grande, Oregon. Randomized grain samples were taken from one-acre fields that had been covered by several types of powered sprayer vehicles. The vehicles used in this study included a combine sprayer (Wasco), wheel tractor (Elgin), swamp buggy (La Grande), and a 3/4-ton truck sprayer (Helix). Rows were selected that had been run over completely by the vehicle tires and compared with adjacent rows that were not damaged. Final yield calculation was based on a 48-ft swath with one set or pair of wheel tracks. Two 10-ft rows of grain were sampled from each set of wheel tracks and compared with two normal rows. Four replications were made of each treatment. The percent of field surface was determined by the drill row widths that were used in the original planting operation. Three of the sites had 7-in. row spacings and one site had 16-in. row spacings. If one or two rows were damaged in a 7-in. spacing, the row spacing in the damaged area was used to determine the actual field loss. The results of the study are recorded in Tables 1 and 2.

RESULTS AND DISCUSSION

Field experiments at four eastern Oregon sites in 1987 showed that there was a yield decrease in the wheel tracks of all herbicide sprayers. Average grain yield reductions were 31% (La Grande), 38% (Elgin), 20% (Wasco), and 19% (Helix). Yield reduction from all of the combined sites averaged 29% or 26 bu/A in the damaged rows. When yields of damaged rows were compared with those of normal rows (Table 1) they were not statistically different. Yield losses based on total field area averaged only 78 lb/A (La Grande), 135 lb/A (Elgin), 76 lb/A (Wasco), and 58 lb/A (Helix). The average of all four experiments showed that wheat yield losses were limited to 86 lb/A, or only 1.43 bu of grain. This was far below the statistical level needed for significant differences (Table 1).

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[1] Professor, Columbia Basin Agricultural Research Center, Oregon State University; and agricultural engineer, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801.

Table 1. Wheel track damage in wheat. OSU-CBARC - eastern Oregon-1987

Location	Yield		Loss[1/]	
	wheel track	normal	wheel track	true field
	lb/A			
La Grande[2/]	3470 b	5030 a	1560	78
Elgin	4380 b	7060 a	2680	134
Wasco	2660 b	3340 a	780	77
Helix	4710 b	5870 a	1160	58

1/ Yield loss based on 48-ft swath with one set of tracks.

2/ LSD (.05) 1480 lb/A La Grande - 16 Apr 87 (growth stage - 9 to 12 leaf, 3 to 4 tiller)
LSD (.05) 599 lb/A Elgin - 19 Feb 87 (growth stage - 6 to 8 leaf, 2 to 3 tiller)
LSD (.05) 395 lb/A Wasco - 1 Apr 87 (growth stage - 10 to 14 leaf, 6 to 7 tiller)
LSD (.05) 370 lb/A Helix - 7 Apr 87 (growth stage - 8 to 10 leaf, 3 to 4 tiller)

Means within rows containing the same letter are not significantly different at the .05 level based on the DRM test.

Yield reductions caused by vehicular wheel tracks was probably due to wheat tiller injury. The La Grande location was monitored for tiller production in both the damaged and normal rows (Table 2). There were 14 fewer tillers/ft^2 in the damaged rows than in the normal rows. Tiller reduction from vehicle traffic averaged 31% for the La Grande experiment.

Table 2. Wheel track damage on tiller production in winter wheat. OSU-CBARC - La Grande, Oregon-1987

Treatment[1/]	Grain yield					Tillers[2/]				
	R1	R2	R3	R4	Ave	R1	R2	R3	R4	Ave
	lbs/A					per ft^2				
Wheel track row	3620	3540	3460	3250	3468	28	40	32	27	32
Normal row	4090	5630	6000	4400	5030	45	48	50	39	46
Yield loss	470	2090	2540	1150	1562	17	8	18	12	14

1/ 16 Apr 87 (growth stage - 9 to 12 leaf, 3 to 4 tillers).

2/ Tiller loss based on a 48-ft swath with one set of tracks.
LSD (.05) = 1480 lb/A.

Tiller reduction and yield loss in the damaged rows due to herbicide sprayer traffic was quite severe. However, winter wheat losses are an acceptable cost of weed control if there are only one set of wheel tracks for each 48-ft swath. One set of wheel tracks reduced wheat yield 1.43 bu/A based on the four eastern Oregon experiments, which is not statistically significant. It would take more than three sets of wheel tracks in a 48-ft swath to statistically comprise a severe yield loss, and this much traffic would be unlikely for most herbicide spray equipment.

GREEN PEA RESPONSE TO LIME IN A WHEAT-PEA ROTATION

P. E. Rasmussen and D. E. Wilkins[1]

INTRODUCTION

Soils in the Pacific Northwest are gradually becoming acid from the use of ammonium-based nitrogen (N) fertilizer. Where annual precipitation is above 16 in., 30 years of N fertilization has lowered the soil pH below 6.0. When the pH drops below 5.7, legume yields may be substantially reduced. Wheat and barley yields are usually not lowered until the pH reaches 5.3. In 1984, more than 45% of the soils in northern Idaho had a soil pH less than 5.6, and crops were responding to lime application (Mahler and McDole, 1985; 1987).

Soil pH in southeastern Washington and northeastern Oregon is not as low as in northern Idaho, but it is approaching 5.6 in many soils. To investigate acidity effects in this area, winter wheat response to lime was determined in 1986 at two of the three integrated pest management sites for wheat/pea production (Wilkins et al., 1985). Lime response by peas in the wheat pea rotation was measured in 1987.

MATERIALS AND METHODS

The experimental design was a 2 x 2 factorial with four replications, and included two rates of lime (0 and 1.5 tons/A) and two rates of N (0 and 100 lbs N/A). Ag-lime (-100 mesh) was applied at both locations in August 1985. 'Hill 81' winter wheat was seeded in October 1985 and harvested in July 1986. Nitrogen was applied as ammonium nitrate-sulfate on February 27, 1986. 'Dark Skin Perfection' green peas were seeded April 1 at the Ferrel site and April 15 at the Meiners site. No lime or N were applied to the peas. Peas were harvested June 17, 1986, at Ferrel's and January 29, 1986, at Meiners. Fresh weight, tenderometer, and percent of market-size peas were determined at harvest.

Soil pH (1:2 soil/water solution) was determined in October 1985 at wheat seeding and in April 1987 at pea seeding. Soil at the Ferrel site is a Walla Walla silt loam and at the Meiners site a Palouse silt loam.

RESULTS AND DISCUSSION

Surface soil (0-8 in) at the Ferrel and Meiners sites had a pH of 5.9 and 5.7, respectively, at the time of liming (Table 1).

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[1] Soil scientist and agricultural engineer, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801.

Table 1. Soil pH (1:2 soil/water) of limed and unlimed soil 2 and 20 months after lime application, Ferrel and Meiners sites

Soil depth	Ferrel		Meiners	
	unlimed	limed	unlimed	limed
in.	- - - - - - - - - - - - - - -pH-	- - - - - - - - - - - - - - -		
		Oct 1985		
0-4	5.9	7.1	5.7	6.4
4-8	5.8	6.3	5.7	5.9
8-12	6.8	6.8	6.3	6.3
		Apr 1987		
0-4	6.0	6.5	5.6	6.2
4-8	5.9	6.3	5.6	5.8
8-12	6.4	6.4	6.2	6.4

Application of 1.5 tons of lime/A in 1985 to the Ferrel site increased the 0-8 in. pH to 6.7 (7.1 and 6.3 at 0-4 and 4-8 in, respectively). Corresponding 1985 pH at the Meiners site after liming with 1.5 tons lime/A was 6.1 (6.4 and 5.9 for 0-4 and 4-8 in). By 1987 the 0-8 in. pH was 6.4 at Ferrel's and 6.0 at Meiners, or 0.5 and 0.3 units above the original pH at these sites.

Liming at either site did not increase fresh pea yield, marketable percentage, tenderometer, or vine growth of peas (Table 2). No visual responses to lime were evident at either location during the growth of peas. No change in disease incidence with liming was measured at the Meiners site. Mahler and McDole (1987) report critical soil pH levels of 5.6 for peas and 5.3 for wheat grown in northern Idaho. Our results the past two years agree with their data. We found no response to liming in either wheat or peas with soil pH of 5.9 and 5.7. But the present pH also suggests that much of the wheat/pea area may be nearing the point where liming is necessary to maintain pea yield.

REFERENCES

1. Mahler, R. L. and R. E. McDole. 1987. Effect of soil pH on crop yield in northern Idaho. Agron. J. 79:751-755.

2. Mahler, R. L. and R. E. McDole. 1985. The influence of lime and phosphorus on crop production in northern Idaho. Communications in Soil Science Plant Analysis 16:485-499.

3. Wilkins, D. E., L. L. Baarstad, and J. M. Kraft. 1985. Integrated pest management research for pea production, p 50-54. Special Report 738, Oregon State University Agricultural Experiment Station, Corvallis.

Table 2. Effect of liming on fresh pea yield, percent marketable peas, tenderometer, and vine yield of 'Dark Skin Perfection' peas, Ferrel and Meiners sites, 1987

Lime status	Ferrel Site N residual -	Ferrel Site N residual +	Ferrel Site Ave	Meiners Site N residual -	Meiners Site N residual +	Meiners Site Ave
			Fresh pea yield[1/] (lb/A)			
Unlimed	3291	3272	3281 a	2451	2577	2514 a
Limed	3361	3543	3452 a	2639	2696	2668 a
			Marketable peas[2/] (% of total)			
Unlimed	74	75	74 a	79	77	78 a
Limed	77	76	76 a	78	77	78 a
			Pea tenderometer rating			
Unlimed	101	106	104 a	93	93	93 a
Limed	103	104	104 a	92	93	93 a
			Vine yield-dry (cwt/A)			
Unlimed	30.7	27.0	28.9 a	29.0	32.2	30.6 a
Limed	29.0	30.7	29.9 a	32.7	32.3	32.5 a

1/ Adjusted to 100 tenderometer.

2/ Peas 5/16 and 7/16 in. diameter.
Averages followed by same letter are not significantly different at P = 0.10.

TILLAGE IMPACTS ON WATER INFILTRATION

J. L. Pikul, Jr., J. F. Zuzel, and R. N. Greenwalt[1]

Surface runoff can be a major source of soil and water loss in the inland Pacific Northwest. Water limits crop yields throughout most of the region. Rough plowing or disking in the fall of the year are practices used to increase water infiltration and reduce water runoff, especially in areas where frozen soil is anticipated.

Shallow tillage significantly improves water intake and its benefits have been observed. Preferential water flow paths through macropores created by tillage are most important for improving water infiltration; however, internal water drainage and soil hydraulic properties associated with tillage are not well understood. Water flow in macropores depends on hydraulic connectivity, geometrical structure, tortuosity, roughness, and other properties of the macropore system. Soil type, soil water content at time of tillage, speed of travel, and type of tillage tool are all variables that need consideration when making recommendations of the type of tillage required to produce a stable soil structure with high infiltration rates.

Crop residue on the surface decreases water erosion. Residue also reduces frost penetration by decreasing heat loss from the soil. Even in the absence of snow cover, crop residue on the surface can reduce frost penetration by an average of 35% compared to treatments where residue is removed. Therefore, a management strategy of maintaining surface residue cover to reduce erosion and frost penetration, and tillage to increase water infiltration, is needed to limit water runoff and soil erosion.

The purpose of this short communication is to report on field studies conducted to investigate the impact of tillage on water infiltration into soils. The hypothesis is that large voids created by fall tillage are stable over the winter period and that these voids are instrumental in providing and maintaining high overwinter infiltration rates.

METHODS

Water infiltration studies were conducted near Helix, Oregon[2], on a Walla Walla silt loam soil. Historically this field has been in a winter wheat-summer fallow rotation. Normal tillage sequence has been spring disking, followed by spring tooth harrow and rodweeding during the summer. Winter barley (Hesk) was planted in lieu of winter wheat in the fall of 1985. Barley was harvested during August of 1986, leaving about 1.5 tons/A crop residue on the surface. In early October 1986 three tillage treatments were established: no tillage of barley stubble (NT), chiseled barley stubble (C), and paraplowed barley stubble (P).

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[1] Soil scientist, hydrologist, and hydrologic technician, USDA-ARS, Columbia Plateau Conservation Research Center, P.O. Box 370, Pendleton, Oregon.

For the C treatment, chiseling was done with 3 in.-wide twisted shank chisels spaced at 13 in. to a depth of 8 to 10 in. Paraplowing was done to a depth of 8 to 10 in. with shank spacing of 20 in. The paraplow lifts and fractures the soil without inversion. Water content of the top 12 in. of soil was 11%, by volume, at the time of tillage. A tillage depth of about 10 in. was used in order to fracture a high-density soil layer that was found at this field site.

The Palouse rainfall simulator was used as a sprinkler infiltrometer to apply water at a constant rate to duplicate plots in each treatment. Water drop size created by the simulator emulates the natural storm rain drop size occurring in the inland Pacific Northwest.

RESULTS AND DISCUSSION

Soil bulk density, as measured in March 1987, is shown in Fig. 1 for the P, C, and NT treatments. In the case of NT, bulk density measurements were taken in 0.8-in. depth increments. By sampling in small depth increments a distinct high-density soil layer was identified on the NT treatment. At about the 4-in. depth there is a tillage pan with a maximum bulk density of 85 lb/ft^3. This pan is thought to be a consequence of shallow rodweedings during the summer of 1985. Rodweeding creates a special combination of soil layers designed to conserve water during the summer months. Typically a low-bulk-density layer overlies a high-density layer at about the rodweeding depth.

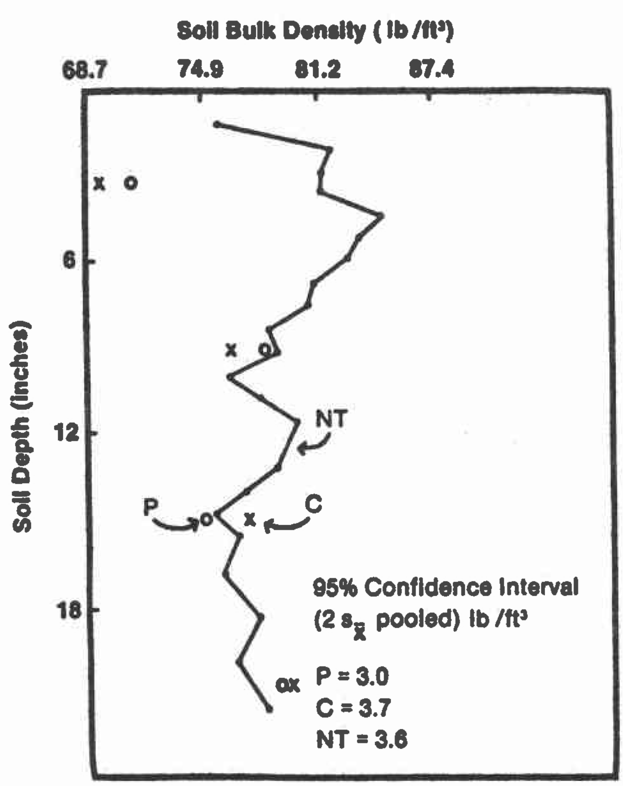

Fig. 1 Depth distribution of soil bulk density for the no-till (NT), chiseled stubble (C), and paraplowed stubble (P) treatments.

Soil bulk density of the P and C treatment for the 0- to 6-in. layer was less than the NT treatment (Fig. 1). There was no difference in bulk density between the P and C treatment. However, there is a difference in soil structure, created by tillage, and distribution of macroporosity on the P and C treatment.

Tillage in October 1986 fractured the top 10 in. of soil, creating numerous macropores. Macroporosity was determined on soil samples obtained in March 1987. Structural features found in these samples provided evidence that macroporosity created by fall tillage was stable over winter (Table 1). Results shown in Table 1 were obtained from soil samples having a cross-sectional area of 49 in^2. Macroporosity is the fraction of large soil voids in a representative cross section of soil. Large voids are operationally defined as pore features with an area greater than 0.02 by 0.02 in. A computer-generated image for the P treatment at the 4-in. soil depth is shown in Fig. 2. This image is used as an example to show the arrangement of soil voids and clods in a 16-in^2 horizontal cross section taken from the tillage path.

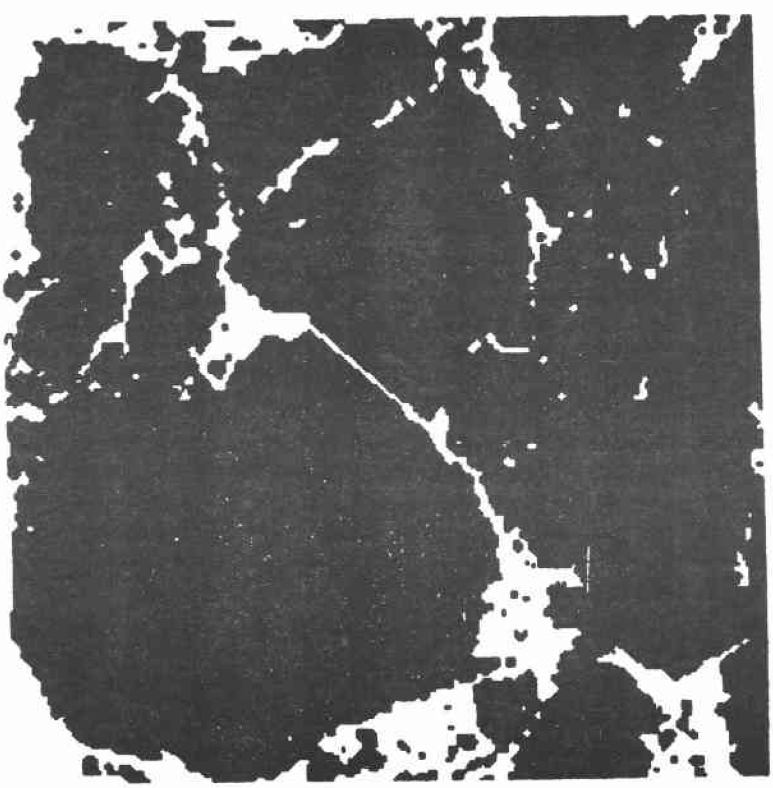

Fig. 2 Computer generated image of soil structure at the 4 inch depth for the paraplow treatment. Black and white areas are soil clods and voids, respectively.

Table 1. Areal macroporosity at different soil depths for the paraplow and chisel treatment

Soil Depth	Paraplow	Chisel
in.	- - - - - % [1/] - - - -	
3	14.5	20.7
4	12.4	13.7
5	6.9	14.8
6	9.7	10.8
7	7.9	7.1
8	11.0	5.1
10	17.2	0.5

1/ Areal macroporosity at each depth is the fraction of macropores in a 49-in^2 horizontal soil cross section.

Macroporosity for the C treatment decreased linearly with depth from about 20% at the 3-in. depth to less than 1% at 10 in. (Table 1). This is in contrast to the P treatment where macroporosity decreased with depth to a minimum of 6.9 and then increased to a maximum of 17.2% at the 5- and 10-in. depths, respectively. Macroporosity was less than 1% of the area at all depths on the NT treatment.

Depth of tillage, geometry of the tillage tool, shank spacing, and other factors determine the amount of macroporosity. Water infiltration depends on connectivity of the macropores in the soil and open flow paths to the soil surface. Infiltration rate was greatest on the P and C treatments and least for the NT treatment (Fig. 3). Infiltration curves for one replication are shown in Fig. 3. Final infiltration rates for two replications are shown in tabular form in Fig. 3. Final infiltration was greatest on the P, followed by the C and NT treatment, with respective infiltration rates of 0.93, 0.90, and 0.36 in./hr.

Water transmission characteristics of the macropore system on the C and P treatments are different. Infiltration measurements were made using a 3.28-ft by 3.28-ft infiltration frame. Only one shank path was located within the infiltration frame for the P treatment. The C treatment had two shank paths within the infiltration frame. Figure 3 indicates there is no difference in infiltration characteristics of the P compared to the C treatment. However, it must be considered that the P treatment has about one-half the loosened soil volume compared to the C treatment. Hydraulic effectiveness of the macropore system in transmitting water is determined, in part, by geometrical structure and tortuosity of soil voids. These results suggest that the macropore system created by the paraplow is more effective in transmitting water than that of the chisel.

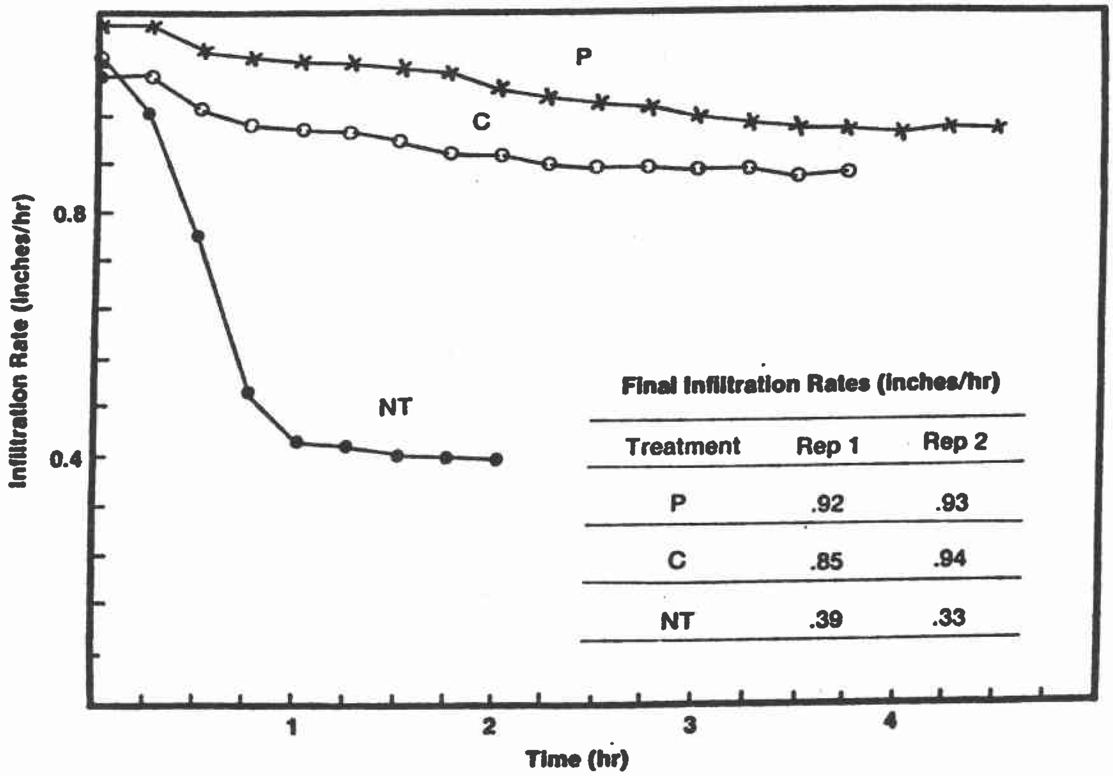

Fig. 3 Measured water infiltration for the no-till (NT), chiseled stubble (C), and paraplow (P) treatments. Infiltration measurements were made during 19, 21, and 23 March 1987 for the NT, C, and P treatments, respectively.

SUMMARY AND CONCLUSIONS

Field studies were conducted to measure water infiltration and soil macroporosity. Tillage treatments were established in the fall of the year; treatments included paraplowed stubble, chisel stubble, and no-till. The extent of soil settling overwinter is uncertain; however, water infiltration and macroporosity measurements conducted in March provide evidence that macroporosity created by fall tillage was not destroyed over winter. Water infiltration was greatest on the P and C treatments and least on the NT treatment.

Horizontal soil sections were used to reveal an arrangement of voids and solids that are unique to the P and C treatments. Although the depth distribution of macropore area was different on the P and C treatment, there was no difference in average macropore area, in the top 10 in. of soil, between the P and C treatment. Infiltration rates on the P and C treatment were the same; however the loosened soil volume within the infiltration frame on the P treatment was about one-half that of the C treatment. These infiltration measurements, together with the macroporosity measurements, suggest that the geometry of the macroporosity on the P treatment is hydrologically more effective in channeling water flow than that found on the C treatment.

EMERGENCE OF WINTER WHEAT IN A DRY AUTUMN

B. Klepper, D. E. Wilkins, T. R. Toll, and C. Reeder[1]

INTRODUCTION

In 1987, the three months from August 1 to October 30 were drier than for any previous fall of the past 40 years in most of the wheat-growing areas of eastern Oregon. During this record dry spell, some wheat farmers planted at the usual time in late September or early October, while others waited for the expected autumn rains. Those who planted in October had to choose between planting deep to reach the stored soil moisture below the dust mulch and "dusting in" the crop so that the expected autumn rains would germinate the seed. Deep planting carries the risk that seed will not be placed in soil sufficiently moist to allow successful germination, that it will be planted so deep that the seedling will not be able to emerge, or that the soil above the seed will become crusted by a rain so that seedlings will fail to emerge. However, "dusting in" the seed reduces early growth and seedling establishment, making seedlings more susceptible to winter damage, because they enter the winter as weak one- or two-leaved plants and because shallow planting forces the crown to be set close to the soil surface. Late planting presents problems also - small, weak seedlings going into winter, questions of being able to get equipment onto the land soon after the rains, and small amount of plant cover for erosion control. This study was undertaken to determine the emergence and early stand establishment of winter wheat planted at two depths in mid-October (during the drought) and in November after rain had wetted the seedbed.

PLANTING DATA

Seeds of winter wheat (*Triticum aestivum* L "Stephens") were planted with a John Deere HZ deep-furrow drill with 16-in. row spacing in a Walla Walla silt loam soil at the Reeder farm near Helix, Oregon. Seeding was done on October 23, 1987, and on November 12, 1987, after 0.9 in. of rain had fallen during early November. These planting dates gave 379 growing degree days (GDD) with base temperature 0°C from seeding to Jan 1 for the early planting and only 188 GDD to January 1 for the late planting. Seeding depths were 0.5-(shallow) and 2.5 in. (deep) each time. Seeding rate was 110 lb/A or 28 seeds/ft of row. There were three replications of each treatment.

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[1] Plant physiologist, agricultural engineer, biological technician, USDA-ARS, Columbia Plateau Conservation Research Center, and rancher, Pendleton, Oregon 97801.

RESULTS AND DISCUSSION

Soil moisture

Soil samples at the early planting time were taken in 2-in. increments for soil moisture determination. Soil moisture values for the early planting time were 4.6 ± 1.7% at the 0 to 2 in., 14.3 ± 1.4% at the 2 to 4 in., and 17.6 ± 1.7% at the 4- to 6-in. depth. Thus soil moisture was adequate for germination below about 2.3-in. (Figure 1), assuming that 11% moisture is required and assuming that the drill did not influence either moisture distribution or reference point of the surface. Soil moisture at the late planting time was sufficient for germination throughout the seed zone.

Soil temperature

Soil temperature at 2-in., at the time of early seeding, was 50°F during the day and 35°-40°F during the night. During emergence of the early seeded plots the 2 in. soil temperature was 30°-40°F days and 25°-30°F nights. Soil temperature at 2 in., during the late seeding, was 35°-40°F days and 30°-35°F nights. The 2-in. soil temperature has remained at 25°F from the middle of December 1987 to February 1988 when this article was written.

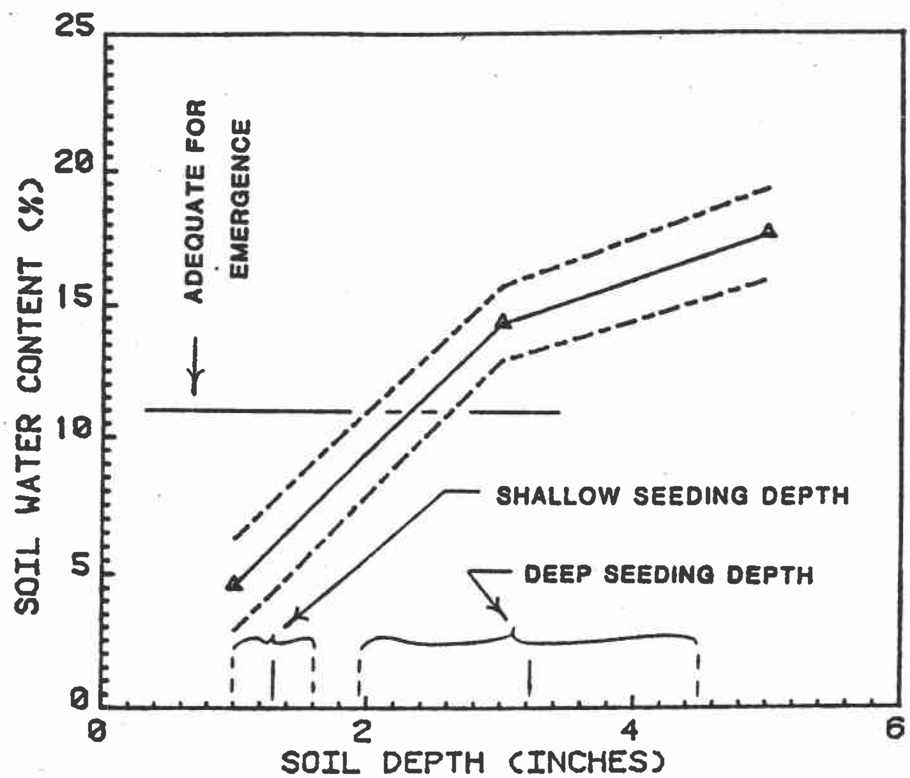

Fig. 1. Soil water status at time of early seeding.

Emergence - early planting

Emergence counts were made every 50 GDD, beginning 100 GDD after planting for two 6.6-ft of row in each plot (a total of six per treatment). Final stand counts and the range of GDD required for 50% emergence are shown in Table 1. Figure 2 shows emergence as percent of final stand for the early seeding planted deep. Four of these rows showed rapid emergence with the emergence leveling off at about 21 plants/ft of row (about 75% of the seed planted). These rows with rapidly emerging plants required about 135 GDD for 50% of the plants to emerge. The two rows showing slow and depressed emergence had maximum emergence of 18 and 17 plants/ft of row (or 64 and 61% of seed planted). Rate of emergence in these rows was also slow, and required 155 and 205 GDD for 50% of the plants to emerge, respectively.

Table 1. Stand counts and GDD to 50% emergence for shallow- and deep-planted plots planted early and late

	Plant Stand	Range to 50% emergence
	(plants/ft row)	(GDD)
Early seeded		
Shallow	25.3 ± 1.7	205-230
Deep	20.9 ± 2.8	135-205
Late seeded		
Shallow	19.4 ± 3.8	145-190
Deep	17.2 ± 2.6	190-195

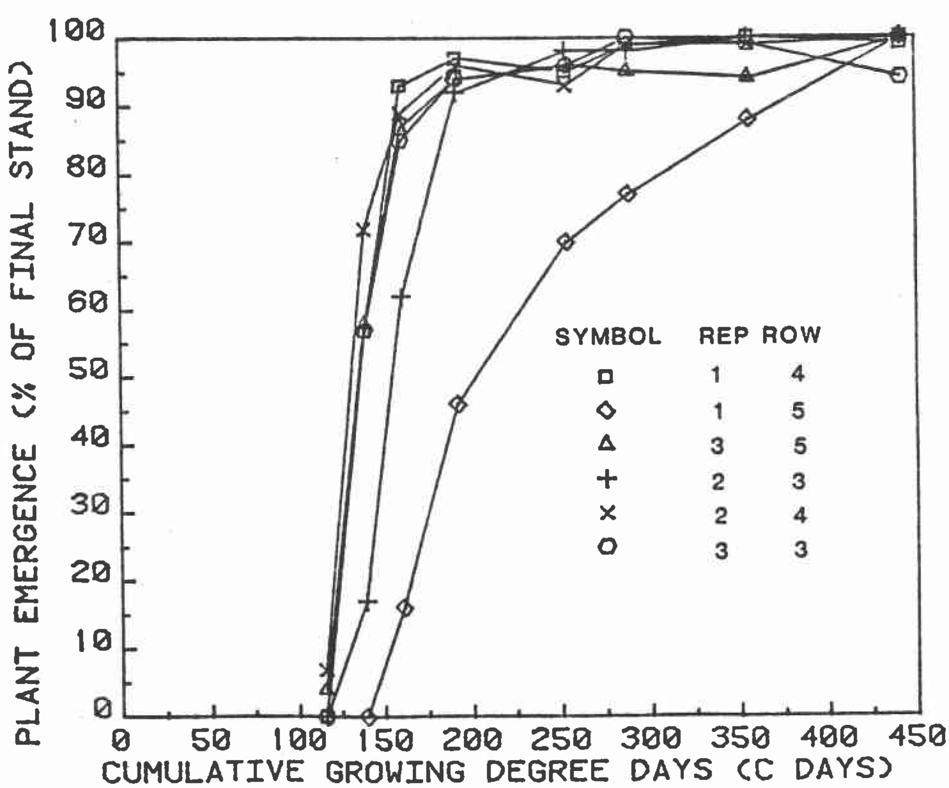

Fig. 2. Seedling emergence from early deep-seeded wheat.

Apparently the seeds were placed into conditions that were unfavorable to emergence in these particular rows, giving local spots in the field depressed stands.

Two of the rows in the shallow-planted, early seeded plots had little, if any, emergence because the drill seed tubes plugged. Excavation adjacent to the sample sites confirmed that no seed were present. Data from these two rows were not included in the analysis. Emergence is shown in Fig. 3 for the four rows which gave reasonable emergence. These plants required 205-230 GDD from seeding to 50% emergence but the final stands were high, more than 24 plants/ft of row (85% of planted seed). Figure 3 shows (arrow) that the rain in early November came 95 GDD after planting. It took from 110 to 135 GDD for 50% of the plants to emerge after the rain. On average this was less heat units than required for the deep-planted material, however the plants had a shorter distance to grow to emerge since they were planted shallower. The shallow-planted seed may have been primed by absorption of some water from surface soil prior to the rain to shorten the time required for emergence.

On January 15, plants in the early planted plots were fully emerged and had about 1.6 main stem leaves in the shallow-planted plots and 2.2 main stem leaves in the deep-planted plots. This difference in leaf number resulted from the longer time (about 60 GDD) required for emergence in the shallow-planted plots.

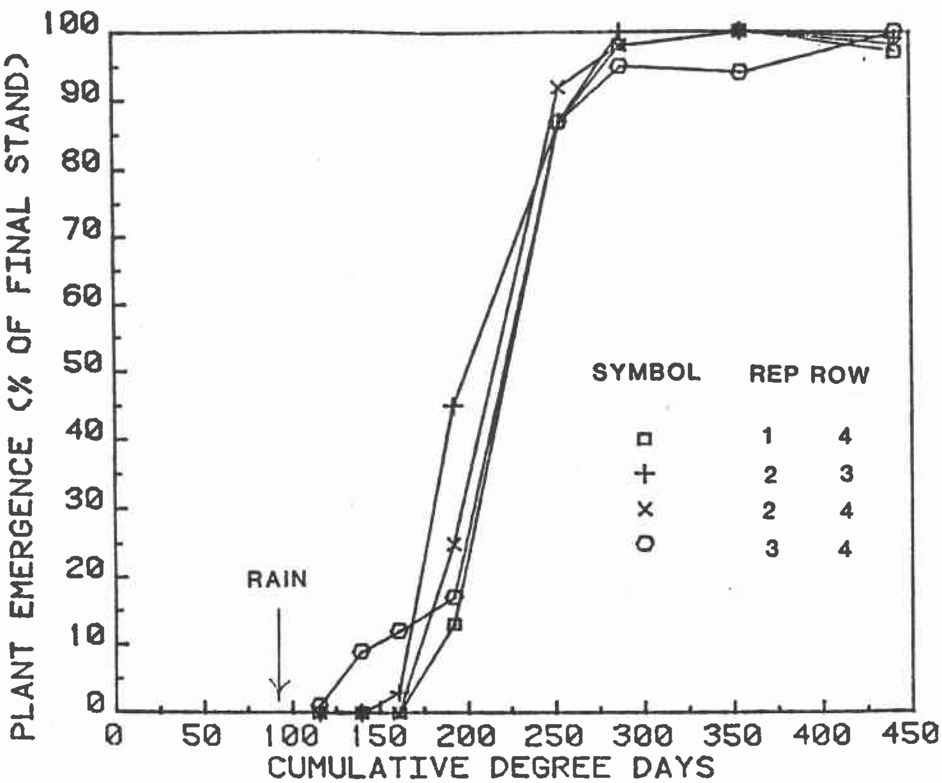

Fig. 3. Seedling emergence from early shallow-seeded wheat.

On February 9, 1.6-ft lengths of row were excavated to remove all plants and unemerged seedlings in the early planted plots. For the emerged seedlings, seed depths (referenced to soil surface after seeding) were 0.7 ± 0.3 in. for the shallow and 2.6 ± 0.7 in. for the deep-seeded plots. Reference to Figure 1 will show that all of the seed placed at the shallow depth in the early seeding was planted into soil too dry to promote germination and emergence. The deep-planted seeds were generally into good moisture. The lifting action of the HZ opener plus removal of dry surface soil from over the row by the drill results in seed placement about 0.6 in. deeper from the original soil surface than the samples indicate. Thus 0.6 in. has been added to the measured 2.6 in. to reference the seed depth to the original surface which was used as the reference for the soil water determinations. This adjusted value (3.2 in.) shows that most of the deep-planted seed were in adequate moisture for emergence (Fig. 1).

The total number of seedlings recovered on February 9 (28.4 and 29.8 plants/ft of row) was in good agreement with the nominal planting rate (28 seed/ft), but for deep-planted seed about 20% failed to emerge (Table 2).

<u>Emergence - late planting</u>

The shallow-planted material got to 50% emergence slightly earlier than the deep-planted ones probably because they had a shorter distance to the soil surface (Fig. 4). The GDD to 50% emergence in these late-planted plots was similar to the value found in the deep-seeded, early planted plots (Table 1). The percent of planted seed which emerged was depressed, however, to 61 to 69% of the seed planted (Table 1). Excavation showed that 7 to 10% of the late planted seedlings were germinated but unable to emerge (Table 2).

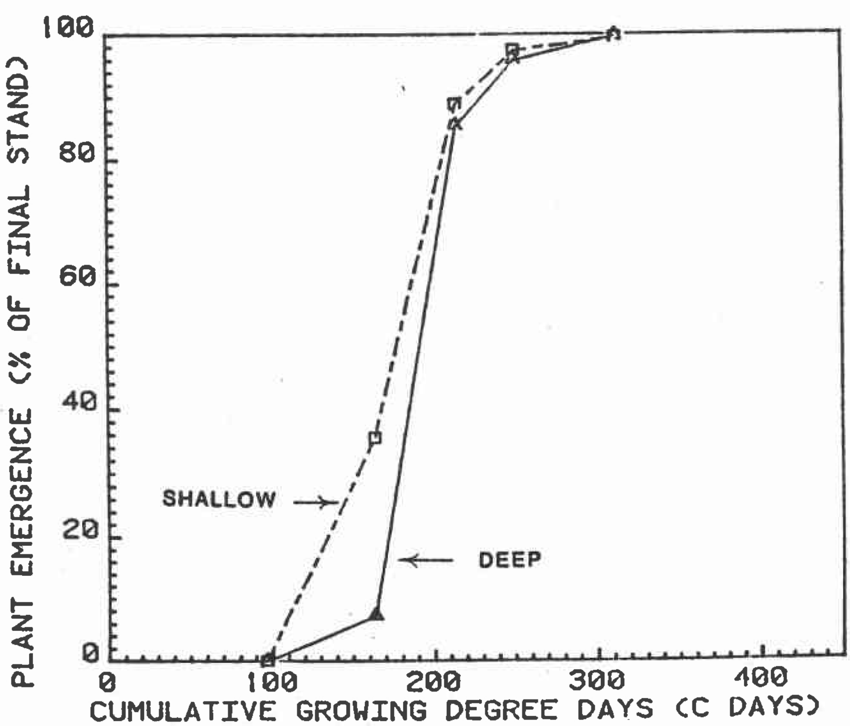

Fig. 4. Effect of seeding depth on plant emergence for late seeding.

Table 2. Stands of emerged and unemerged seedlings from the early and late-planted plots seeded shallow and deep.

Planting Depth	Emerged	Unemerged	Total
	(plants/ft of row)		
Early Seeded			
Shallow	27.8 ± 5.2	0.6 ± 0.7	28.4 ± 5.5
Deep	23.9 ± 3.7	5.9 ± 3.6	29.8 ± 4.5
Late Seeded			
Shallow	25.1 ± 3.8	1.8 ± 1.3	26.9 ± 3.3
Deep	19.8 ± 1.6	5.8 ± 3.0	25.6 ± 1.9

SUMMARY

These results illustrate the problems which can occur with a drought during seeding time. As expected, the late-planted material emerged slowly during the cold months and provided practically no cover over winter. Spotty stands were more serious problems in the early planted material, especially when planted deep.

SHOULD I DOUBLE FALLOW?

R. E. Ramig and L. G. Ekin[1]

In years of drouth or large reductions in seeded acreage as authorized by the national farm program, we are frequently asked the question, "Should I double fallow?" This question arises naturally because an acreage of conservation reserve land (set aside) is available for double fallowing and little water may be stored during a dry fallow season. With the advent and use of commercial fertilizer and herbicides, the main purpose of fallow is to conserve and store water and thus stabilize production from year to year.

Requirements for successful double fallow are similar to those for fallow and are as follows:

1. Insufficient crop-year precipitation to permit economical returns from annual cropping.

2. Depth of soil that will store and hold 6.0 or more in. of available water in the soil profile (five ft or greater).

3. Soil texture that maintains a moderate water infiltration rate of 0.10 to 0.30 in./hr when not frozen.

4. Soil texture that will store 1.3 to 1.9 in. of available water/ft of soil.

5. A conservation tillage-planting system that maintains at least 30% residue on the soil surface after seeding to reduce soil erosion by water; or where soil erosion by wind is the primary concern, maintains at least 1000 lb/A of flat small grain residue equivalent on the soil surface during the critical wind erosion period.

Ritzville silt loam or similar soils meet the first four requirements where they are five or more ft in depth to basalt rock. The fifth requirement can be met by prudent use of herbicides, proper type and time of tillage, and successful fertilization and seeding practices.

We have studied water conservation and storage in single-fallow (fallow-wheat) and double-fallow (fallow-fallow-wheat) sequences in semi-arid parts of Morrow County, Oregon near Lexington, Ione, Cecil, and Ella, Oregon, since 1982. From 10,000 to 20,000 acres are double fallowed in this area annually. The objectives of this study were to determine differences, if any, in water storage by single and double fallow, and to evaluate the efficiency of water storage in the two systems.

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[1] Soil scientist and agricultural research technician, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon, 97801.

METHODS

Tillage for single fallow was accomplished by Tom Martin, Lexington, Oregon. The sequence of operations was as follows:

1. In March, after harvest the previous July, stubble land was chiseled twice to a depth of 5 to 6 in. with chisels spaced 12-in. spacing. The second chisel operation is at cross angle to the first. Rodweeding follows immediately to seal voids and slow evaporation of water.

2. In normal precipitation years, fallow was fertilized and rodweeded in one operation in June. If the soil was very dry, fertilizer application is delayed until September or October just before seeding.

3. Fallow was rodweeded as necessary to control weeds, during the summer, usually two to three more times before seeding. The last rodweeding was just before seeding to kill any germinated or emerged cheat grass.

4. Wheat was seed (60lb/A) in late September or October.

Tillage for double fallow was performed by Eric Anderson, Ione, Oregon. The operations sequence was as follows:

1. In October or November, after wheat harvest in July, 0.4 lb (a.i.) atrazine plus 0.25 oz (a.i.) Glean/A was applied. Rains carried the herbicide into the soil and killed germinating seeds. Glean may control or repress Russian thistle growth for as long as two years. However, it is important to use exact rates, as overlapping may give temporary soil sterilization.

2. In March, areas with heavy stubble (> 4 tons/A), except field borders where turning was done, were double disked. Immediately after disking the entire field was subsurface tilled with a sweep to a depth of 4.5 to 5.0 in. to leave stubble uniformly distributed. If stubble was light (< 4 tons/A) only a sweep was used. Fallow was rodweeded once during summer only if needed.

3. In March of the following year the fallow was cultivated to a depth of 4 to 5 in. with a IHC vibra-shank cultivator. Tillage depth was maintained at a uniform depth to distribute residue uniformly. Fallow was rodweeded as necessary to control weeds, usually two or three times.

4. About September 1, 30-40 lb/A of wheat was seeded into moist soil with John Deere HZ drills with 16-in. row spacing.

5. Dry fertilizer was broadcast-applied in January as required by soil test. In some years, ammonia fertilizer was injected into the fallow land after the vibra-shank cultivation in 3 above.

Soil water measurements were made by foot-depth increments with a neutron probe at harvest, and approximately March 1 of the fallow and crop years to determine water conservation and storage. Measurements were made on three replications of each treatment.

RESULTS

Average and range of precipitation, water storage in 8-ft soil profile, and water storage efficiency in single-fallow (F-W) and double-fallow (F-F-W) sequences in Morrow County, Oregon, for the five-year (1982-86) period are presented in Table 1. An average of 6.0 in. of water was stored in the 8-ft soil profile during the 20-month water storage period in the F-W sequence. This was 32% of the precipitation for the storage period. In the F-F-W sequence, 8.1 in. of water was stored in the 8-ft soil profile during the 32-month storage period which was 27% of the precipitation. For this five-year period (1982-86), double fallow stored 2 in. more water than single fallow. This additional stored water can increase wheat production from 5 to 7 bu/A/in. of water. The amount of yield increase from this

Table 1. Average and range of precipitation, water storage in 8-ft soil profile, and water storage efficiency in single fallow (F-W) and double fallow (F-F-W) sequences in Morrow County, Oregon, for the five-year (1982-86) period. Ritzville silt loam soil

Factor	Average	Range
1. Fallow-wheat rotation (20-month water storage period):		
a. Precipitation from harvest to March 1 of crop year (in.)	19.13	16.80-21-90
b. Water gained in 8-ft soil profile (in.)	6.0	4.5-7.3
c. Efficiency of water storage (%)	32	24-42
2. Fallow-fallow-wheat rotation (32-month water storage period):		
a. Precipitation from harvest to March 1 of crop year (in.)	30.02	28.88-31.04
b. Water gained in 8-ft soil profile (in.)	8.1	6.7-9.3
c. Efficiency of water storage (%)	27	22-32

additional water may be modified by such factors as seeding date, crop stand, fertilizer program, weed competition, plant disease and insect infestation.

Soil water extraction, recharge, and availability for one cycle in each sequence is shown in Fig. 1 and 2. Water below the "minimum point of depletion" (MPD) is too slowly available to maintain crop growth. Water in excess of "field carrying capacity" (FCC) drains through the soil profile. Available water (FCC-MPD) averages 1.6 in./ft in Ritzville silt loam soil, or 12.8 in./8 ft of soil. The previous wheat crop did not remove all the available water below 2 ft at the Martin site (Fig. 1) and below 4 ft at the Anderson site (Fig. 2). Top soil at both sites dried below the MPD.

Soil water storage in the F-W sequence (Fig. 1) for the 8 months following harvest was 3.9 in. (horizontal lined area), or 62% of total (6.26 in.) precipitation. Water storage during the next 12 months was 2.8 in. (vertical lined area), or 27% of total precipitation (10.54 in.). Total water storage was 6.7 in. or 40% of the 20-month precipitation.

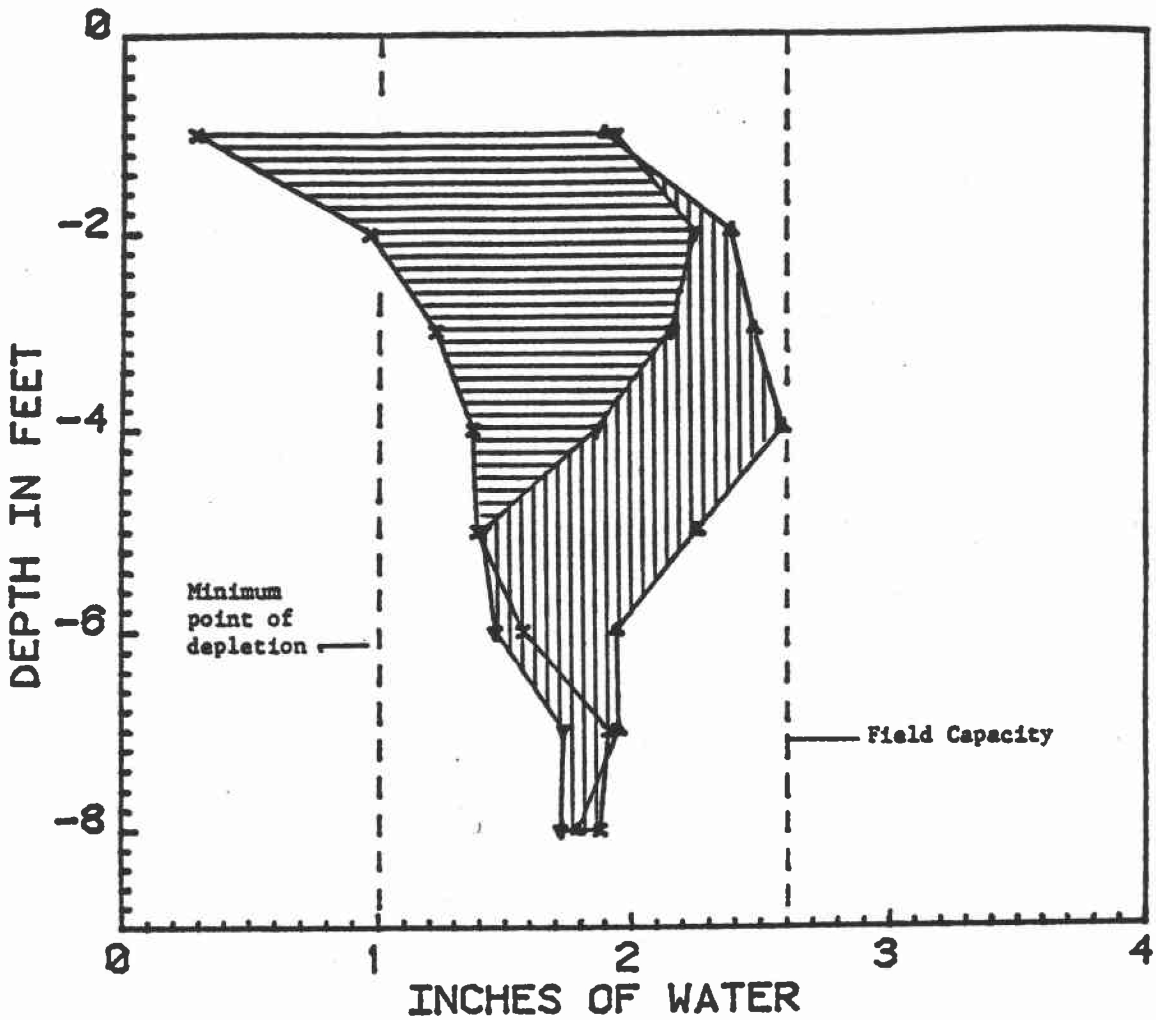

Fig. 1. Water storage profiles in fallow-wheat sequence, Tom Martin farm, Ione, OR. [horizontal lines] — water storage from 8-22-84 to 3-6-85 = 3.9 in. [vertical lines] — water storage from 3-6-85 to 3-13-86 = 2.8 in.

Soil water storage in the F-F-W sequence (Fig. 2) for the 8 months following harvest was 3.2 in. (horizontal lined area), or 42% of the 7.59 in. precipitation. Water storage during the next 12 months was 1.7 in. (vertical lined area), or 16% of the 10.64 in. precipitation. Sixty percent of this precipitation had occurred during the March-October period and much was lost by evaporation. Water storage in the third period, the next 12 months, was 3.2 in. (diagonal lined area), or 30% of the 10.61 in. precipitation. About 80% of this precipitation occurred after wheat was seeded in September and well tillered plants enhanced infiltration. Late rainfall had not drained to FCC in the 2-, 3-, and 4-ft depths at time of the last measurement. The final water storage was 8.1 in. or 28% of the 32-month precipitation.

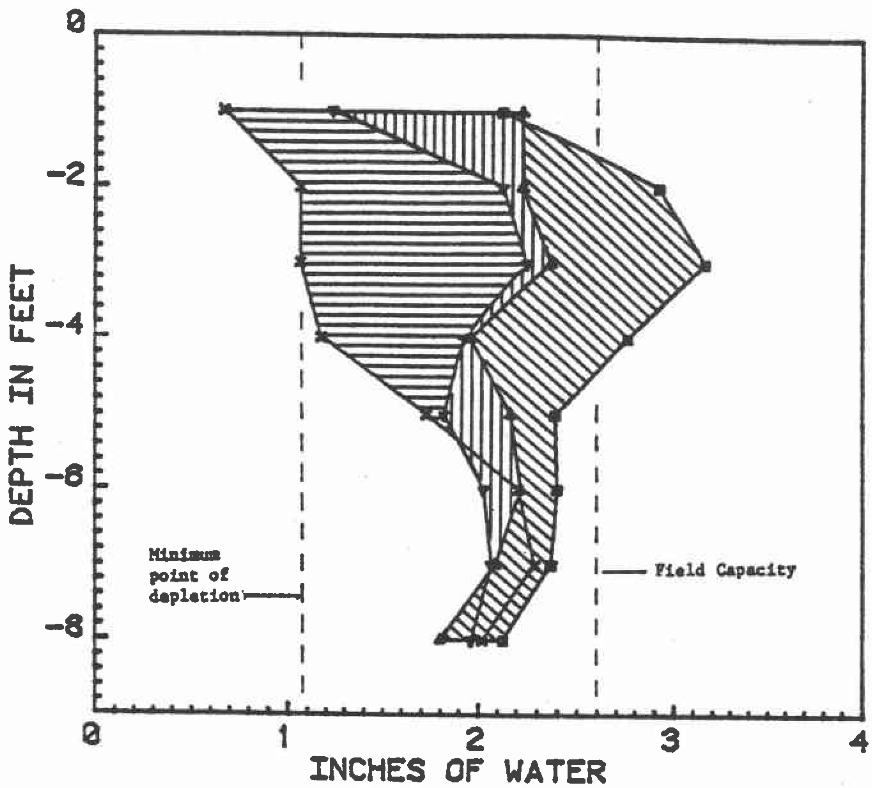

Fig. 2. Water storage profiles in fallow-fallow-wheat sequence, Eric Anderson farm, Ione, OR. [horizontal lines] water storage from 7-5-83 to 3-7-84 = 3.2 in. [vertical lines] water storage from 3-7-84 to 3-6-85 = 1.7 in. [diagonal lines] water storage from 3-6-85 to 2-28-86 = 3.2 in.

In conclusion, double fallow in the Ione-Ella area of Morrow County, Oregon, has stored about 2 in. more water than single fallow. This is not highly efficient water storage. However, two years of fallow may be required to wet the deep soil profile adequately for economic crop production in years of below normal precipitation. Use of best crop management practices, such as early September seeding, establishing good stands, use of adequate fertilizer balanced to the soil water supply, weed control, and plant disease and insect control contribute to the growth of a robust wheat crop. Such crops provide excellent ground cover for soil erosion protection from both wind and water and enhance water infiltration. Deep vigorous root systems extract the available water stored deep in the soil, and the crop responds with excellent production. In years of normal precipitation, differences in production between one-year fallow and two-year fallow may be small.

RAINFALL AT THE PENDLETON AND MORO EXPERIMENT STATIONS

R. E. Ramig[1]

Weather, next to crop prices, is the most important factor in a farmer's business. In fact, weather (drought, floods, frost) often has a strong influence on crop yields and consequent prices. It is estimated that crop yields are limited 70% of the time by lack of adequate water or by drought. Thornthwaite (2) has defined drought as "the condition in which the amount of water needed for transpiration by plants and evaporation from soil exceeds the amount available in the soil." Critchfield (1) differentiates drought into three classes: permanent drought associated with arid climates, as in the Sahara desert; seasonal drought, which occurs in climates with distinct annual periods of dry weather; and drought due to precipitation variability. Seasonal drought occurs every year with our wet winter-dry summer climate. We are also suffering additional drought in 1988, due to precipitation variability.

Precipitation at the Pendleton Experiment Station during the last 50 years (1938-87) is presented by months, September-February, March-August, and September-August in Table 1. Similar data for the Sherman Experiment Station is presented in Table 2. September-February is the water storage season, March-August the growing season, and September-August the total crop year. A cursory examination of Tables 1 and 2 reveals considerable variability in monthly precipitation. This variability is summarized and presented in Tables 4 and 5 for the Pendleton and Moro Experiment Stations, respectively.

Many people frequently ask whether precipitation for a certain month, season, or crop year is more or less than average; drier or wetter than a certain year; or the driest or wettest on record. Precipitation at the Pendleton and Sherman Experiment Stations has been ranked from driest to wettest by months, seasons, and crop years for the 50-year period in Tables 3 and 6. Once you know the precipitation at one of these stations for any of these intervals, you can find the answers to the above questions by referring to Tables 3 or 6.

Determining the relative ranking of precipitation for the water storage season may assist one in making decisions whether to recrop, seed a drought evading crop, or fallow to conserve more water. These tables give only historical data and should not be used to forecast precipitation.

REFERENCES

1. Critchfield, Howard J. 1966. General Climatology. Prentice-Hall,Englewood Cliffs, New Jersey.

2. Thornthwaite, C. W. 1947. Climate and Moisture Conservation. Am. Geogrs. 37:2-88.

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[1] Soil scientist, USDA-ARS, Columbia Plateau Conservation Research Center, Pendleton, Oregon 97801.

Table 1. Precipitation (in.) by months, Sept-Feb, Mar-Aug, and crop-year total with 50-year (1938-87) averages at the Pendleton Experiment Station, Pendleton, Oregon

Crop year	Sept	Oct	Nov	Dec	Jan	Feb	Total Sept-Feb	Mar	Apr	May	June	July	Aug	Total Mar-Aug	Total year	Crop year
1938	0.30	0.84	2.43	2.31	1.77	2.30	9.95	1.49	1.98	0.69	1.55	0.08	0.00	5.71	15.74	1938
1939	0.23	1.53	2.04	1.10	1.29	1.90	8.09	2.23	0.66	0.41	0.69	0.35	0.00	3.99	12.43	1939
1940	0.30	0.89	0.03	3.01	2.15	3.97	10.35	2.78	1.84	0.30	0.07	0.74	0.00	4.99	16.08	1940
1941	2.34	1.96	2.14	1.73	1.21	0.99	10.37	0.93	1.23	3.03	3.24	0.03	1.04	8.43	19.87	1941
1942	1.86	1.86	2.43	2.47	1.42	1.82	11.86	0.69	1.63	2.04	3.17	1.22	0.17	7.53	20.78	1942
1943	0.00	1.13	3.28	4.09	1.89	0.84	11.23	1.94	2.59	1.43	2.12	0.23	0.59	8.08	20.13	1943
1944	0.00	2.13	0.45	1.07	0.62	2.42	6.69	0.91	2.39	0.73	0.95	0.02	0.19	4.98	11.88	1944
1945	1.11	0.47	1.23	0.78	2.17	2.29	8.05	2.90	1.70	2.30	0.49	0.00	0.07	7.39	15.51	1945
1946	1.45	0.53	3.67	1.94	2.39	1.05	11.03	1.70	0.80	2.95	1.29	0.17	0.08	6.74	18.02	1946
1947	0.69	2.35	1.90	1.99	1.14	0.49	8.56	1.29	2.29	0.75	3.13	0.63	0.24	7.46	16.89	1947
1948	0.64	2.82	2.49	3.30	1.86	1.93	13.04	1.21	2.61	2.55	2.37	1.74	0.00	8.74	23.52	1948
1949	0.74	0.68	1.74	3.68	0.34	2.44	9.62	1.61	0.41	1.34	0.23	0.04	0.00	3.59	13.25	1949
1950	0.70	0.88	2.15	1.27	2.67	1.27	8.94	2.18	1.29	0.85	3.13	0.11	0.33	7.45	16.83	1950
1951	0.17	4.20	2.78	2.87	2.45	1.47	13.94	1.83	0.70	0.47	1.24	0.10	0.00	4.24	18.28	1951
1952	0.53	3.08	1.69	1.39	1.16	1.87	9.72	1.10	1.15	1.35	2.43	0.00	0.00	6.03	15.75	1952
1953	0.55	0.12	0.51	2.37	3.71	2.01	9.27	2.33	1.51	2.28	1.29	0.00	0.58	7.41	17.26	1953
1954	0.00	1.09	2.17	2.45	1.89	0.75	8.35	0.88	0.95	0.92	1.53	0.67	1.11	4.28	14.41	1954
1955	0.61	1.01	1.26	1.50	1.30	0.73	6.41	1.31	2.18	1.35	0.49	1.15	0.00	5.33	12.89	1955
1956	1.06	2.33	3.19	2.53	3.64	1.36	14.11	0.94	0.12	4.38	0.95	0.33	1.35	6.39	22.18	1956
1957	0.06	1.95	0.65	1.64	1.76	1.69	7.75	3.36	0.83	2.79	0.71	0.03	0.06	7.69	15.53	1957
1958	0.67	2.46	1.33	2.47	2.74	1.52	11.19	1.63	3.54	1.70	2.05	0.00	0.02	8.92	20.13	1958
1959	0.41	0.18	2.41	3.45	2.96	2.30	11.71	1.58	0.85	1.42	1.14	0.17	0.74	4.99	17.61	1959
1960	2.26	0.95	0.50	0.73	1.82	1.20	7.46	2.25	1.28	2.03	0.72	0.00	0.88	6.28	14.62	1960
1961	0.82	1.55	2.84	0.87	0.71	3.27	10.06	1.98	1.59	1.64	1.07	0.09	0.21	6.28	16.64	1961
1962	0.39	0.86	1.59	2.23	0.91	0.73	6.71	2.49	1.12	3.40	0.26	0.00	0.67	7.27	14.65	1962
1963	1.18	2.70	2.04	1.79	1.15	1.88	10.74	1.01	2.35	0.62	0.27	0.57	0.58	4.25	16.14	1963
1964	0.68	0.42	3.04	1.28	1.74	0.41	7.57	1.24	0.74	0.15	1.29	1.12	0.23	3.42	12.34	1964
1965	0.61	1.24	1.81	4.43	3.84	0.47	12.40	0.21	1.16	1.03	1.37	0.75	1.33	3.77	18.25	1965
1966	0.20	0.51	2.28	0.45	2.35	0.71	6.50	1.72	0.51	0.43	0.99	1.14	0.17	3.65	11.46	1966
1967	0.46	1.10	2.30	2.86	2.80	0.32	9.84	1.51	1.60	0.95	0.55	0.04	0.00	4.61	14.49	1967
1968	0.56	1.17	1.30	0.76	0.74	2.39	6.92	1.04	0.21	0.65	1.11	0.34	0.77	3.01	11.04	1968
1969	0.83	1.36	2.71	2.65	2.62	0.78	10.95	0.43	2.31	1.26	0.75	0.06	0.00	4.75	15.76	1969
1970	0.65	1.41	0.44	2.39	5.23	1.50	11.62	1.87	1.05	0.62	0.85	0.11	0.05	4.39	16.17	1970
1971	1.02	1.40	2.22	1.02	1.44	0.77	7.87	1.28	1.65	1.66	3.14	0.63	0.33	7.73	16.56	1971
1972	1.42	1.72	3.14	3.93	1.15	1.70	13.06	2.11	1.35	1.50	0.91	0.76	0.35	5.87	20.04	1972
1973	0.49	0.66	1.14	2.47	0.89	0.89	6.54	1.27	0.58	1.03	0.12	0.00	0.09	3.00	9.63	1973
1974	1.77	1.24	5.86	4.40	1.29	2.00	16.56	1.50	3.64	0.38	0.33	1.30	0.00	5.85	23.71	1974
1975	0.02	0.35	1.56	1.76	3.73	1.68	9.10	0.97	1.72	0.68	0.69	0.05	1.38	4.06	14.59	1975
1976	0.00	2.16	1.47	3.40	2.13	1.09	10.25	1.69	1.65	1.21	0.58	0.04	2.58	5.13	18.00	1976
1977	0.44	0.53	0.47	0.59	0.90	0.57	3.50	1.72	0.46	1.70	0.31	0.12	2.21	4.19	10.02	1977
1978	1.54	0.69	1.79	3.19	2.27	1.71	11.19	1.40	3.50	0.81	1.27	0.59	1.37	6.98	20.13	1978
1979	1.61	0.00	1.68	2.28	1.31	1.54	8.42	1.74	1.82	1.15	0.18	0.12	2.08	4.89	15.51	1979
1980	0.17	2.56	2.31	1.05	2.85	1.55	10.49	2.12	1.20	2.45	1.42	0.23	0.18	7.19	18.09	1980
1981	1.24	2.96	1.81	1.99	1.26	2.31	11.57	2.30	1.29	2.30	2.12	0.40	0.02	8.01	20.00	1981
1982	1.51	1.62	2.41	3.27	2.61	1.86	13.28	1.99	1.54	0.48	1.12	1.02	0.50	5.13	19.93	1982
1983	1.68	2.68	1.46	2.69	1.63	2.97	13.11	3.90	1.23	2.08	1.92	1.00	0.68	9.13	23.92	1983
1984	0.82	0.91	2.79	3.44	0.99	2.56	11.51	3.23	2.37	2.11	2.05	0.05	1.25	9.76	22.57	1984
1985	0.98	1.18	3.43	1.96	0.69	1.49	9.73	1.33	0.65	0.89	1.42	0.05	0.98	4.29	15.05	1985
1986	1.54	1.34	2.66	1.27	2.38	3.04	12.23	1.94	0.83	1.79	0.09	0.61	0.19	4.65	17.68	1986
1987	1.87	0.91	3.41	0.95	2.08	1.31	10.53	1.85	0.83	1.63	0.62	0.47	0.06	4.93	15.99	1987
50-yr. ave.	0.82	1.41	2.05	2.19	1.92	1.60	9.99	1.70	1.47	1.45	1.24	0.39	0.51	6.76	16.75	

Table 2. Precipitation (in.) by months, Sept-Feb, Mar-Aug, and crop-year total with 50-year (1938-87) averages at the Sherman Experiment Station, Moro, Oregon

Crop year	Sept	Oct	Nov	Dec	Jan	Feb	Total Sept-Feb	Mar	Apr	May	June	July	Aug	Total Mar-Apr	Total Year	Crop Year
1938	0.33	0.89	2.49	1.86	1.01	1.63	8.21	2.24	0.62	0.11	1.09	0.21	0.03	4.30	12.51	1938
1939	0.14	2.06	1.01	0.73	0.72	1.06	5.72	0.93	0.03	0.23	0.50	0.26	0.00	1.95	7.67	1939
1940	0.37	0.21	0.03	2.09	2.13	3.38	8.21	0.89	2.18	0.36	0.08	0.42	0.00	3.93	12.14	1940
1941	0.92	1.87	1.87	1.32	2.07	0.97	9.02	0.45	0.96	1.24	0.55	0.21	0.58	3.99	13.01	1941
1942	0.83	1.03	1.84	2.17	1.67	2.04	9.58	0.24	0.61	1.74	0.66	0.52	0.11	3.88	13.46	1942
1943	0.05	0.44	4.35	3.21	2.55	1.36	11.96	1.14	1.27	0.35	1.04	0.00	0.73	4.53	16.49	1943
1944	0.00	2.78	0.97	0.81	0.72	1.18	6.46	0.40	1.18	0.16	1.22	0.00	0.00	2.96	9.42	1944
1945	0.33	0.46	1.62	0.80	1.55	1.85	6.61	0.62	0.48	2.20	0.00	0.00	0.23	3.53	10.14	1945
1946	0.71	0.67	1.89	3.17	1.15	0.69	8.28	1.04	0.18	0.34	1.56	0.24	0.14	3.50	11.78	1946
1947	0.23	0.93	1.11	0.42	1.06	0.85	4.60	0.77	1.00	0.12	1.42	0.44	0.00	3.75	8.35	1947
1948	1.95	3.48	2.52	0.55	2.12	1.99	12.61	0.74	0.89	1.13	1.70	0.32	0.26	5.04	17.65	1948
1949	1.36	0.56	2.20	2.56	0.31	1.39	8.38	1.34	0.15	0.51	0.11	0.00	0.00	2.11	10.49	1949
1950	0.21	0.58	1.99	0.62	2.98	1.02	7.40	1.31	0.56	0.13	1.73	0.06	0.00	3.79	11.19	1950
1951	0.15	3.53	2.11	2.49	2.64	2.10	13.02	1.27	0.33	1.23	0.35	0.61	0.00	3.79	16.81	1951
1952	0.33	1.69	2.17	1.57	1.23	1.13	8.12	0.41	0.18	0.60	2.27	0.00	0.00	3.46	11.58	1952
1953	0.42	0.00	0.42	2.87	4.89	1.30	9.90	0.74	1.29	1.78	0.87	0.00	0.88	5.56	15.46	1953
1954	0.11	0.55	2.80	2.12	3.26	0.61	9.45	0.76	0.38	0.96	0.38	0.33	0.06	2.87	12.32	1954
1955	0.58	0.78	1.33	0.60	0.74	0.76	4.79	1.06	1.33	0.69	0.30	0.43	0.00	3.81	8.60	1955
1956	0.72	1.30	2.82	2.85	3.57	1.20	12.46	0.69	0.01	1.75	1.69	0.13	0.31	4.58	17.04	1956
1957	0.34	1.38	0.11	0.90	0.46	0.86	4.05	3.33	0.87	1.43	0.11	0.23	0.29	6.26	10.31	1957
1958	0.98	1.15	0.86	2.07	2.34	2.70	10.10	0.97	1.16	0.86	1.58	0.02	0.00	4.59	14.69	1958
1959	0.43	0.16	2.45	1.38	2.78	0.93	8.13	1.23	0.19	0.50	0.29	0.03	0.00	2.24	10.37	1959
1960	0.83	0.77	0.10	0.43	1.03	1.02	4.18	1.58	1.01	1.63	0.16	0.00	0.24	4.62	8.80	1960
1961	0.23	0.69	2.24	1.02	0.96	3.31	8.45	2.00	0.86	1.26	0.85	0.20	0.12	5.29	13.74	1961
1962	0.07	0.44	1.48	1.72	0.22	1.04	4.97	0.74	0.75	1.96	0.05	0.00	0.87	4.37	9.34	1962
1963	0.36	1.90	1.83	1.98	0.78	0.95	7.80	1.17	2.12	0.64	0.14	0.45	0.62	5.14	12.94	1963
1964	1.63	0.50	1.56	1.36	0.60	0.25	5.90	0.60	0.15	0.08	1.30	0.04	0.18	2.35	8.25	1964
1965	0.16	0.60	1.69	6.11	1.65	0.16	10.37	0.63	0.72	0.32	0.59	0.17	1.04	3.47	13.84	1965
1966	0.08	0.36	2.07	0.51	2.45	0.54	6.01	0.78	0.06	0.02	0.13	1.31	0.00	2.30	8.31	1966
1967	0.47	0.74	3.14	1.84	0.91	0.03	7.13	0.55	1.47	0.39	0.32	0.00	0.00	2.73	9.86	1967
1968	0.26	0.74	0.84	0.54	0.97	1.04	4.39	0.16	0.10	0.74	0.10	0.15	1.52	2.77	7.16	1968
1969	0.33	1.04	2.67	2.09	1.93	0.44	8.50	0.63	0.84	0.84	1.99	0.00	0.00	4.30	12.80	1969
1970	0.52	0.76	0.53	2.00	3.96	1.27	9.04	0.88	0.38	0.33	0.22	0.00	0.00	1.81	10.85	1970
1971	0.13	0.68	2.36	1.21	1.63	0.12	6.13	1.28	0.84	0.93	0.81	0.20	0.09	4.15	10.28	1971
1972	1.36	0.45	1.50	1.03	2.25	0.26	6.85	1.44	0.40	0.45	1.70	0.07	0.55	4.61	11.46	1972
1973	0.57	0.43	0.83	1.62	1.09	0.34	4.88	0.40	0.21	0.34	0.25	0.00	0.07	1.27	6.15	1973
1974	0.90	0.85	3.70	3.99	1.29	0.97	11.70	1.30	1.18	0.38	0.02	0.41	0.00	3.29	14.99	1974
1975	0.00	0.37	1.02	1.39	2.01	1.47	6.26	1.25	0.46	0.53	0.84	0.40	1.26	4.74	11.00	1975
1976	0.00	1.17	1.34	1.26	1.25	0.93	5.95	0.95	1.06	0.14	0.06	0.79	1.17	4.17	10.12	1976
1977	0.04	0.10	0.43	0.20	0.18	0.63	1.58	0.50	0.08	2.70	0.28	0.37	0.90	4.83	6.41	1977
1978	0.88	0.22	2.00	3.22	2.80	1.31	10.43	0.70	1.42	0.43	0.44	0.63	1.32	4.94	15.37	1978
1979	0.33	0.01	0.79	0.69	1.59	1.54	4.95	0.99	1.06	0.28	0.10	0.07	1.05	3.55	8.50	1979
1980	0.53	2.59	2.23	0.65	3.41	1.83	11.24	0.94	0.89	1.27	1.37	0.16	0.11	4.74	15.98	1980
1981	0.42	0.79	1.73	2.95	1.52	1.22	8.63	0.65	0.41	1.06	1.15	0.20	0.00	3.47	12.10	1981
1982	0.92	0.82	1.99	4.73	1.10	0.72	10.28	0.55	1.45	0.37	1.15	0.21	0.40	4.13	14.41	1982
1983	1.42	1.96	1.08	1.89	1.40	2.43	10.18	2.74	0.61	1.96	0.39	0.80	0.60	7.10	17.28	1983
1984	0.52	0.62	2.45	2.31	0.17	1.07	7.14	2.34	1.32	0.97	1.09	0.17	0.00	5.89	13.03	1984
1985	0.53	0.86	3.18	0.41	0.27	0.97	6.22	0.44	0.14	0.63	0.92	0.05	0.14	2.32	8.54	1985
1986	1.11	1.09	1.19	1.12	1.84	2.39	8.74	0.98	0.34	0.35	0.06	0.54	0.07	2.34	11.08	1986
1987	1.52	0.45	1.53	0.78	1.68	1.10	7.06	1.54	0.28	0.99	0.29	0.78	0.11	3.99	11.05	1987
50-yr ave.	0.55	0.97	1.73	1.72	1.66	1.21	7.84	1.02	0.73	0.81	0.73	0.25	0.32	3.86	11.70	

Table 3. Monthly, Sept-Feb, Mar-Aug, and crop-year precipitation (in.); ranked from driest to wettest year, for 50-year (1938-87) period at Pendleton Experiment Station, Pendleton, Oregon

Sept	Yr	Oct	Yr	Nov	Yr	Dec	Yr	Jan	Yr	Feb	Yr	Sept-Feb Total	Yr	Mar	Yr	Apr	Yr	May	Yr	June	Yr	July	Yr	Aug	Yr	Mar-Aug total	Yr	Crop yr total	Yr
0.00	76	0.00	79	0.03	40	0.45	66	0.34	49	0.32	67	3.50	77	0.21	65	0.12	56	0.15	64	0.07	40	0.00	53	0.00	38	3.09	73	9.63	73
0.00	44	0.12	53	0.44	70	0.59	77	0.62	44	0.41	64	6.41	55	0.43	69	0.21	68	0.30	40	0.09	86	0.00	52	0.00	39	3.63	49	10.02	77
0.00	43	0.18	59	0.45	44	0.73	60	0.69	85	0.47	65	6.50	66	0.69	42	0.41	49	0.38	74	0.12	73	0.00	73	0.00	40	4.12	68	11.04	68
0.00	54	0.35	75	0.47	77	0.76	68	0.71	61	0.49	47	6.54	73	0.88	54	0.46	77	0.41	39	0.18	79	0.00	60	0.00	69	4.34	51	11.46	66
0.02	75	0.42	64	0.50	60	0.78	45	0.74	68	0.57	77	6.69	44	0.91	44	0.51	66	0.43	66	0.23	49	0.00	58	0.00	67	4.34	39	11.88	44
0.06	57	0.47	45	0.51	53	0.87	61	0.89	73	0.71	66	6.71	62	0.93	41	0.58	73	0.47	51	0.26	62	0.00	62	0.00	55	4.55	70	12.34	64
0.17	80	0.51	66	0.65	57	0.95	87	0.90	77	0.73	62	6.92	68	0.94	56	0.65	85	0.48	82	0.27	63	0.00	45	0.00	52	4.65	67	12.43	39
0.17	51	0.53	46	1.14	73	1.02	71	0.91	62	0.73	55	7.46	60	0.97	75	0.66	39	0.62	70	0.31	77	0.02	44	0.00	51	4.77	64	12.89	55
0.20	66	0.53	77	1.23	45	1.05	80	0.99	84	0.75	54	7.57	64	1.01	63	0.70	51	0.62	63	0.33	74	0.03	41	0.00	49	4.81	69	13.25	49
0.23	39	0.66	73	1.26	55	1.07	44	1.14	47	0.77	71	7.75	57	1.04	68	0.74	64	0.65	68	0.49	55	0.03	57	0.00	48	4.96	66	14.41	54
0.30	38	0.68	49	1.30	68	1.10	39	1.15	72	0.78	69	7.87	71	1.10	52	0.80	46	0.68	75	0.49	45	0.04	76	0.00	74	5.19	44	14.49	67
0.30	40	0.69	78	1.33	58	1.27	50	1.15	63	0.84	43	8.05	45	1.21	48	0.83	86	0.69	38	0.55	67	0.04	49	0.02	58	5.32	85	14.59	75
0.39	62	0.84	38	1.46	83	1.27	86	1.16	52	0.89	73	8.09	39	1.24	64	0.83	87	0.73	44	0.58	76	0.04	67	0.02	81	5.40	63	14.62	60
0.41	59	0.86	62	1.47	76	1.28	64	1.21	41	0.99	41	8.35	54	1.27	73	0.83	57	0.75	47	0.62	87	0.05	84	0.05	70	5.45	86	14.65	62
0.44	77	0.88	50	1.56	75	1.39	52	1.26	81	1.05	46	8.42	79	1.28	71	0.85	59	0.81	78	0.69	75	0.05	85	0.06	87	5.46	87	15.05	85
0.46	67	0.89	40	1.59	62	1.50	55	1.29	74	1.09	76	8.56	47	1.29	47	0.95	54	0.85	50	0.69	39	0.05	75	0.06	57	5.49	75	15.51	79
0.49	73	0.91	84	1.68	79	1.64	57	1.29	39	1.20	60	8.94	50	1.31	55	1.05	70	0.89	85	0.71	57	0.06	69	0.07	45	5.73	40	15.51	45
0.53	52	0.91	87	1.69	52	1.73	41	1.30	55	1.27	50	9.10	75	1.33	85	1.12	62	0.92	54	0.72	60	0.08	38	0.08	46	5.79	38	15.53	57
0.55	53	0.95	60	1.74	49	1.76	75	1.31	79	1.31	87	9.27	53	1.40	78	1.15	52	0.95	67	0.75	69	0.09	61	0.09	73	5.85	65	15.74	38
0.56	68	1.01	55	1.79	78	1.79	63	1.42	42	1.36	56	9.62	49	1.49	38	1.16	65	1.03	65	0.85	70	0.10	51	0.17	66	5.90	59	15.75	52
0.61	55	1.09	54	1.81	65	1.94	46	1.44	71	1.47	51	9.72	52	1.50	74	1.20	80	1.03	73	0.91	72	0.11	70	0.17	42	6.03	52	15.76	69
0.61	65	1.10	67	1.81	81	1.96	85	1.63	83	1.49	85	9.73	85	1.51	67	1.23	83	1.15	79	0.95	44	0.11	50	0.18	80	6.06	54	15.99	87
0.64	48	1.13	43	1.90	47	1.99	81	1.74	64	1.50	70	9.84	67	1.58	59	1.23	41	1.21	76	0.95	56	0.12	79	0.19	44	6.48	55	16.08	40
0.65	70	1.17	68	2.04	39	1.99	47	1.76	57	1.52	58	9.95	38	1.61	49	1.28	60	1.26	69	0.99	66	0.12	77	0.19	86	6.52	77	16.14	63
0.67	58	1.18	85	2.04	63	2.23	62	1.77	38	1.54	79	10.06	61	1.63	58	1.29	81	1.34	49	1.07	61	0.17	46	0.21	61	6.58	61	16.17	70
0.68	64	1.24	74	2.14	41	2.28	79	1.82	60	1.55	80	10.25	76	1.69	76	1.29	50	1.35	55	1.11	68	0.17	59	0.23	64	6.65	82	16.56	71
0.69	47	1.24	65	2.15	50	2.31	38	1.86	48	1.68	75	10.35	40	1.70	46	1.35	72	1.35	52	1.12	82	0.23	80	0.24	47	6.98	72	16.64	61
0.70	50	1.34	86	2.17	54	2.37	53	1.89	43	1.69	57	10.37	41	1.72	77	1.51	53	1.42	59	1.14	59	0.23	43	0.33	71	6.99	46	16.83	50
0.74	49	1.36	69	2.22	71	2.39	70	1.89	54	1.70	72	10.49	80	1.72	66	1.54	82	1.43	43	1.24	51	0.33	56	0.33	50	7.09	79	16.89	47
0.82	84	1.40	71	2.28	66	2.45	54	2.08	87	1.71	78	10.53	87	1.74	79	1.59	61	1.50	72	1.27	78	0.34	68	0.35	72	7.15	74	17.26	53
0.82	61	1.41	70	2.30	67	2.47	42	2.13	76	1.82	42	10.74	63	1.83	51	1.60	67	1.63	87	1.29	53	0.35	39	0.50	82	7.16	60	17.61	59
0.83	69	1.53	39	2.31	80	2.47	73	2.15	40	1.86	82	10.95	69	1.85	87	1.63	42	1.64	61	1.29	64	0.40	81	0.58	53	7.46	45	17.68	86
0.98	85	1.55	61	2.41	59	2.47	58	2.17	45	1.87	52	11.03	46	1.87	70	1.65	76	1.66	71	1.29	46	0.47	87	0.58	63	7.60	80	18.00	76
1.02	71	1.62	82	2.41	82	2.53	56	2.27	78	1.88	63	11.19	78	1.94	43	1.65	71	1.70	77	1.37	65	0.57	63	0.59	43	7.75	76	18.02	46
1.06	56	1.72	72	2.43	42	2.65	69	2.35	66	1.90	39	11.19	58	1.94	86	1.70	45	1.70	58	1.42	80	0.59	78	0.67	62	7.78	57	18.09	80
1.11	45	1.86	42	2.43	38	2.69	83	2.38	86	1.93	48	11.23	43	1.98	61	1.72	75	1.79	86	1.42	85	0.61	86	0.68	83	7.89	50	18.25	65
1.18	63	1.95	57	2.49	48	2.86	67	2.39	46	2.00	74	11.51	84	1.99	82	1.82	79	2.03	60	1.53	54	0.63	47	0.74	59	7.94	62	18.28	51
1.24	81	1.96	41	2.66	86	2.87	51	2.45	51	2.01	53	11.57	81	2.11	72	1.84	40	2.04	42	1.55	38	0.63	71	0.77	68	7.99	53	19.87	41
1.42	72	2.13	44	2.71	69	3.01	40	2.61	82	2.29	45	11.62	70	2.12	80	1.98	38	2.08	83	1.92	83	0.67	54	0.88	60	8.07	56	19.93	82
1.45	46	2.16	76	2.78	51	3.19	78	2.62	69	2.30	38	11.71	59	2.18	50	2.18	55	2.11	84	2.05	84	0.74	40	0.98	85	8.33	47	20.00	81
1.51	82	2.33	56	2.79	84	3.27	82	2.67	50	2.30	59	11.86	42	2.23	39	2.29	47	2.28	53	2.05	58	0.75	65	1.04	41	8.43	81	20.04	72
1.54	86	2.35	47	2.84	61	3.30	48	2.74	58	2.31	81	12.23	86	2.25	60	2.31	69	2.30	45	2.12	43	0.76	72	1.11	54	8.69	71	20.13	78
1.54	78	2.46	58	3.04	64	3.40	76	2.80	67	2.39	68	12.40	65	2.30	81	2.35	63	2.30	81	2.12	81	1.00	83	1.25	84	8.90	43	20.13	43
1.61	79	2.56	80	3.14	72	3.44	84	2.85	80	2.42	44	13.04	48	2.33	53	2.37	84	2.45	80	2.37	48	1.02	82	1.33	65	8.92	42	20.13	58
1.68	83	2.68	83	3.19	56	3.45	59	2.96	59	2.44	49	13.06	72	2.49	62	2.39	44	2.55	48	2.43	52	1.12	64	1.35	56	8.94	58	20.78	42
1.77	74	2.70	63	3.28	43	3.68	49	3.64	56	2.56	84	13.11	83	2.78	40	2.59	43	2.79	57	3.13	50	1.14	66	1.37	78	8.94	78	22.18	56
1.86	42	2.82	48	3.41	87	3.93	72	3.71	53	2.97	83	13.28	82	2.90	45	2.61	48	2.95	46	3.13	47	1.15	55	1.38	75	9.50	41	22.57	84
1.87	87	2.96	81	3.43	85	4.09	43	3.73	75	3.04	86	13.94	51	3.23	84	3.50	78	3.03	41	3.14	71	1.22	42	2.08	79	10.48	48	23.52	48
2.26	60	3.08	52	3.67	46	4.40	74	3.84	65	3.27	61	14.11	56	3.36	57	3.54	58	3.40	62	3.17	42	1.30	74	2.21	77	10.81	83	23.71	74
2.34	41	4.20	51	5.86	74	4.43	65	5.23	70	3.97	40	16.56	74	3.90	83	3.64	74	4.38	56	3.24	41	1.74	48	2.58	76	11.06	84	23.92	83

Table 4. The average and range of precipitation at the Pendleton Experiment Station, Pendleton, Oregon, for selected intervals for a 50-year (1938-1987) period

Interval	Precipitation average	Precipitation range
	- - - - - - - - - - in. - - - - - - - - - -	
Sept	0.82	0.00 - 2.34
Oct	1.41	0.00 - 4.20
Nov	2.05	0.03 - 5.86
Dec	2.19	0.45 - 4.43
Jan	1.92	0.34 - 5.23
Feb	1.60	0.32 - 3.97
Sept-Feb	9.99	3.50 - 16.56
Mar	1.70	0.21 - 3.90
Apr	1.47	0.12 - 3.64
May	1.45	0.15 - 4.38
Jun	1.24	0.07 - 3.24
Jul	0.39	0.00 - 1.74
Aug	0.51	0.00 - 2.58
Mar-Aug	6.76	3.09 - 11.06
Crop-year	16.75	9.63 - 23.92

Table 5. The average and range of precipitation at the Sherman Experiment Station, Moro, Oregon, for selected intervals for a 50-year (1938-87) period

Interval	Precipitation Average	Precipitation Range
	- - - - - - - - - - in. - - - - - - - - -	
Sept	0.55	0.00 - 1.95
Oct	0.97	0.00 - 3.53
Nov	1.73	0.03 - 4.35
Dec	1.72	0.20 - 6.11
Jan	1.66	0.17 - 4.89
Feb	1.21	0.03 - 3.38
Sept-Feb	7.84	1.58 - 13.02
Mar	1.02	0.16 - 3.33
Apr	0.73	0.01 - 2.18
May	0.81	0.02 - 2.70
Jun	0.73	0.00 - 2.27
Jul	0.25	0.00 - 1.31
Aug	0.32	0.00 - 1.52
Mar-Aug	3.86	1.27 - 7.10
Crop-year	11.70	6.15 - 17.65

Table 6. Monthly, Sept-Feb, Mar-Aug, and crop-year precipitation (in.); ranked from driest to wettest year, for 50-year (1938-87) period at Sherman Experiment Station, Moro, Oregon

Sept	Yr	Oct	Yr	Nov	Yr	Dec	Yr	Jan	Yr	Feb	Yr	Sept-Feb total	Yr	Mar	Yr	Apr	Yr	May	Yr	June	Yr	July	Yr	Aug	Yr	Mar-Aug total	Yr	Crop yr total	Yr
0.00	75	0.00	53	0.03	40	0.20	77	0.17	84	0.03	67	1.58	77	0.16	68	0.01	56	0.02	66	0.00	70	0.00	70	0.00	66	1.27	73	6.15	73
0.00	76	0.01	79	0.06	37	0.41	85	0.18	77	0.12	71	4.05	57	0.24	42	0.03	39	0.03	37	0.02	67	0.00	67	0.00	69	1.81	70	6.41	77
0.00	44	0.07	37	0.10	60	0.42	47	0.22	62	0.16	65	4.18	60	0.40	73	0.06	66	0.08	64	0.05	62	0.00	62	0.00	39	1.95	39	7.16	68
0.04	77	0.10	77	0.11	57	0.43	60	0.27	85	0.25	64	4.24	37	0.40	44	0.08	77	0.11	38	0.06	73	0.00	73	0.00	40	2.11	49	7.67	39
0.05	43	0.16	59	0.42	53	0.51	66	0.31	49	0.26	72	4.39	68	0.41	52	0.10	68	0.12	47	0.06	53	0.00	53	0.00	70	2.24	59	8.25	64
0.07	62	0.22	78	0.53	70	0.55	48	0.60	64	0.44	69	4.79	55	0.44	85	0.14	85	0.13	50	0.08	52	0.00	52	0.00	55	2.30	66	8.31	66
0.08	66	0.36	66	0.79	79	0.60	55	0.72	44	0.54	66	4.88	73	0.45	41	0.15	64	0.14	76	0.10	43	0.00	43	0.00	84	2.32	85	8.35	47
0.11	54	0.37	75	0.83	73	0.62	50	0.72	39	0.61	54	4.95	79	0.50	77	0.15	49	0.16	44	0.10	44	0.00	44	0.00	44	2.34	86	8.50	79
0.13	71	0.43	73	0.84	68	0.65	80	0.74	55	0.63	77	4.97	62	0.55	82	0.18	52	0.23	39	0.11	45	0.00	45	0.00	81	2.35	64	8.54	85
0.14	39	0.44	62	0.86	58	0.69	79	0.78	63	0.69	46	5.72	39	0.55	67	0.18	46	0.28	79	0.11	69	0.00	69	0.00	49	2.73	67	8.60	55
0.15	51	0.44	43	0.97	44	0.73	39	0.91	67	0.72	82	5.90	64	0.60	64	0.19	59	0.32	65	0.13	60	0.00	60	0.00	47	2.77	68	8.80	60
0.16	65	0.45	87	1.01	39	0.78	87	0.96	61	0.76	55	5.95	76	0.62	45	0.21	73	0.33	70	0.14	49	0.00	49	0.00	74	2.87	54	9.34	62
0.21	50	0.45	72	1.02	75	0.80	45	0.97	68	0.82	37	6.01	66	0.63	69	0.28	87	0.34	73	0.16	58	0.02	58	0.00	67	2.96	44	9.42	44
0.23	47	0.46	45	1.08	83	0.81	44	1.01	38	0.85	47	6.13	71	0.63	65	0.33	51	0.34	46	0.22	59	0.03	59	0.00	50	3.29	74	9.86	67
0.23	61	0.50	64	1.11	47	0.90	57	1.03	60	0.86	57	6.22	85	0.65	81	0.34	86	0.35	86	0.25	64	0.04	64	0.00	51	3.46	52	10.12	76
0.26	68	0.55	54	1.19	86	1.02	61	1.06	47	0.93	59	6.26	75	0.69	56	0.38	54	0.35	43	0.28	85	0.05	85	0.00	52	3.47	81	10.14	45
0.33	69	0.56	49	1.33	55	1.03	72	1.09	73	0.93	76	6.46	44	0.70	78	0.38	70	0.36	40	0.29	50	0.06	50	0.00	59	3.47	65	10.28	71
0.33	52	0.58	50	1.34	76	1.12	86	1.10	82	0.95	63	6.61	45	0.74	62	0.40	72	0.37	82	0.29	79	0.07	79	0.00	58	3.50	46	10.31	57
0.33	38	0.60	65	1.48	62	1.21	71	1.15	46	0.97	74	6.85	72	0.74	53	0.41	81	0.38	74	0.30	72	0.07	72	0.03	38	3.53	45	10.37	59
0.33	79	0.62	84	1.50	72	1.26	76	1.23	52	0.97	85	7.06	87	0.74	48	0.46	75	0.39	67	0.32	56	0.13	56	0.06	54	3.55	79	10.49	49
0.33	45	0.67	46	1.53	87	1.32	41	1.25	76	0.97	41	7.13	67	0.76	54	0.48	45	0.43	78	0.35	68	0.15	68	0.07	73	3.75	47	10.85	70
0.34	57	0.68	71	1.56	64	1.36	64	1.29	74	1.02	50	7.14	84	0.77	47	0.56	50	0.45	72	0.38	80	0.16	80	0.07	86	3.79	51	11.00	75
0.36	63	0.69	61	1.62	45	1.38	59	1.40	83	1.02	60	7.40	50	0.78	66	0.61	83	0.50	59	0.39	65	0.17	65	0.09	71	3.79	50	11.05	37
0.37	40	0.74	67	1.69	65	1.39	75	1.52	81	1.04	68	7.80	63	0.88	70	0.61	42	0.51	49	0.44	84	0.17	84	0.11	42	3.81	55	11.05	87
0.42	53	0.74	68	1.73	81	1.51	37	1.55	45	1.04	62	8.12	52	0.89	40	0.62	38	0.53	75	0.50	61	0.20	61	0.11	80	3.88	42	11.08	86
0.42	81	0.76	70	1.83	63	1.57	52	1.59	79	1.06	39	8.13	59	0.93	39	0.72	65	0.60	52	0.55	71	0.20	71	0.11	87	3.93	40	11.19	50
0.43	59	0.77	60	1.84	42	1.62	73	1.63	71	1.07	84	8.21	38	0.94	80	0.75	62	0.63	85	0.59	81	0.20	81	0.12	61	3.99	87	11.46	72
0.47	67	0.78	55	1.87	41	1.72	62	1.65	65	1.10	87	8.21	40	0.95	76	0.84	71	0.64	63	0.66	38	0.21	38	0.14	46	3.99	41	11.58	52
0.52	84	0.79	81	1.89	46	1.84	67	1.67	42	1.13	52	8.28	46	0.97	58	0.84	69	0.69	55	0.81	41	0.21	41	0.14	85	4.13	82	11.78	46
0.52	70	0.82	82	1.99	50	1.86	38	1.68	87	1.18	44	8.38	49	0.98	86	0.86	61	0.74	68	0.84	82	0.21	82	0.18	64	4.15	71	12.10	81
0.53	80	0.85	74	1.99	82	1.89	83	1.71	37	1.20	56	8.45	61	0.99	79	0.87	57	0.84	69	0.85	57	0.23	57	0.23	45	4.17	76	12.14	40
0.53	85	0.86	85	2.00	78	1.98	63	1.84	86	1.22	81	8.50	69	1.04	46	0.89	48	0.86	58	0.87	46	0.24	46	0.24	60	4.30	38	12.32	54
0.57	73	0.89	38	2.07	66	2.00	70	1.93	69	1.27	70	8.63	81	1.06	55	0.89	80	0.93	71	0.92	39	0.26	39	0.26	48	4.30	69	12.51	38
0.58	55	0.93	47	2.11	51	2.07	58	2.01	75	1.30	53	8.74	86	1.14	43	0.96	41	0.96	54	1.04	37	0.27	37	0.29	57	4.37	62	12.80	69
0.71	46	1.03	42	2.17	52	2.09	40	2.07	41	1.31	78	9.02	41	1.17	63	1.00	47	0.97	84	1.09	48	0.32	48	0.31	56	4.53	43	12.94	63
0.72	56	1.04	69	2.20	49	2.09	69	2.12	48	1.36	43	9.04	70	1.23	59	1.01	60	0.99	87	1.09	54	0.33	54	0.40	82	4.58	56	13.01	41
0.83	60	1.09	86	2.23	80	2.12	54	2.13	40	1.39	49	9.45	54	1.25	75	1.06	76	1.06	81	1.15	77	0.37	77	0.46	37	4.59	58	13.03	84
0.83	42	1.15	58	2.24	61	2.17	42	2.25	72	1.47	75	9.58	42	1.27	51	1.06	79	1.13	48	1.15	75	0.40	75	0.55	72	4.61	72	13.46	42
0.88	78	1.17	76	2.36	71	2.31	84	2.34	58	1.54	79	9.90	53	1.28	71	1.16	58	1.23	51	1.22	74	0.41	74	0.58	41	4.62	60	13.74	61
0.90	74	1.30	56	2.45	84	2.49	51	2.45	66	1.63	38	10.10	58	1.30	74	1.18	44	1.24	41	1.30	40	0.42	40	0.60	83	4.74	75	13.84	65
0.92	82	1.38	57	2.45	59	2.56	49	2.55	43	1.83	80	10.18	83	1.31	50	1.18	74	1.26	61	1.37	55	0.43	55	0.62	63	4.74	80	14.41	82
0.92	41	1.69	52	2.49	38	2.85	56	2.64	51	1.85	45	10.28	82	1.34	49	1.27	43	1.27	80	1.42	47	0.44	47	0.73	43	4.83	77	14.69	58
0.98	58	1.87	41	2.52	48	2.87	53	2.78	59	1.99	48	10.37	65	1.44	72	1.29	53	1.43	57	1.56	63	0.45	63	0.87	62	4.94	78	14.99	74
1.11	86	1.90	63	2.67	69	2.95	81	2.80	78	2.04	42	10.43	78	1.54	87	1.32	84	1.63	60	1.58	42	0.52	42	0.88	53	5.04	48	15.37	78
1.36	49	1.96	83	2.80	54	3.17	46	2.98	50	2.10	51	11.24	80	1.58	60	1.33	55	1.74	42	1.69	86	0.54	86	0.90	77	5.14	63	15.46	53
1.36	72	2.06	39	2.82	56	3.21	43	3.26	54	2.39	86	11.70	74	2.00	61	1.45	82	1.78	53	1.70	78	0.63	78	1.05	79	5.56	53	16.49	43
1.42	83	2.59	80	3.14	67	3.22	78	3.41	80	2.43	83	11.96	43	2.24	38	1.47	67	1.96	83	1.73	87	0.78	87	1.17	76	5.89	84	16.81	51
1.52	87	2.78	44	3.18	85	3.99	74	3.57	56	2.70	58	12.46	56	2.34	84	1.74	37	1.96	62	1.99	76	0.79	76	1.26	75	6.26	57	17.04	56
1.63	64	3.48	48	3.70	74	4.73	82	3.96	70	3.31	61	12.61	48	2.74	83	2.12	63	2.20	45	2.27	83	0.80	83	1.32	78	6.81	37	17.28	83
1.95	48	3.53	51	4.35	43	6.11	65	4.89	53	3.38	40	13.02	51	3.33	57	2.18	40	2.70	77	2.63	66	1.31	66	1.52	68	7.10	83	17.65	48

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
57 Year Average	.76	1.38	1.94	2.19	1.90	1.51	1.67	1.48	1.35	1.31	.33	.47	16.29
1967-68	.56	1.17	1.30	.76	.74	2.39	1.04	.21	.65	1.11	.34	.77	11.04
1968-69	.83	1.36	2.71	2.65	2.62	.78	.43	2.31	1.26	.75	.06	0	15.76
1969-70	.65	1.41	.44	2.39	5.23	1.50	1.87	1.05	.62	.85	.11	.05	16.17
1970-71	1.02	1.40	2.22	1.02	1.44	.77	1.28	1.65	1.66	3.14	.63	.33	16.56
1971-72	1.42	1.72	3.14	3.93	1.15	1.70	2.11	1.35	1.50	.91	.76	.35	20.04
1972-73	.49	.66	1.14	2.47	.89	.89	1.27	.58	1.03	.12	0	.09	9.63
1973-74	1.77	1.24	5.86	4.40	1.29	2.00	1.50	3.64	.38	.33	1.30	0	23.71
1974-75	.02	.35	1.56	1.76	3.73	1.68	.97	1.72	.68	.69	.05	1.38	14.59
1975-76	0	2.16	1.47	3.40	2.13	1.09	1.69	1.65	1.21	.58	.04	2.58	18.00
1976-77	.44	.53	.47	.59	.90	.57	1.72	.46	1.70	.31	.12	2.21	10.02
1977-78	1.54	.69	1.79	3.19	2.27	1.71	1.40	3.50	.81	1.27	.59	1.37	20.13
1978-79	1.61	0	1.68	2.28	1.31	1.54	1.74	1.82	1.15	.18	.12	2.08	15.51
1979-80	.17	2.56	2.31	1.05	2.85	1.55	2.12	1.20	2.45	1.42	.23	.18	18.09
1980-81	1.24	2.96	1.81	1.99	1.26	2.31	2.30	1.29	2.30	2.12	.40	.02	20.00
1981-82	1.51	1.62	2.41	3.27	2.61	1.86	1.99	1.54	.48	1.12	1.02	.50	19.93
1982-83	1.68	2.68	1.46	2.69	1.63	2.97	3.90	1.23	2.08	1.92	1.00	.68	23.92
1983-84	.82	.91	2.79	3.44	.99	2.56	3.23	2.37	2.11	2.05	.05	1.25	22.57
1984-85	.98	1.18	3.43	1.96	.69	1.49	1.33	.65	.89	1.42	.05	.98	15.05
1985-86	1.54	1.34	2.66	1.27	2.38	3.04	1.94	.83	1.79	.09	.61	.19	17.68
1986-87	1.87	.91	3.41	.95	2.08	1.31	1.85	.83	1.63	.62	.47	.06	15.99
*1987-88	.04	0	1.44	1.61	2.60	.32	1.65						
20 Year Average	1.01	1.34	2.20	2.27	1.91	1.69	1.67	1.49	1.32	1.05	.40	.75	17.22

*Not included in 20 year average figures.

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
73 Year Average	.47	.77	1.65	1.72	1.81	1.04	1.00	.72	.85	.65	.24	.42	11.34
1967-68	.26	.74	.84	.54	.97	1.04	.16	.10	.74	.10	.15	1.52	7.16
1968-69	.33	1.04	2.67	2.09	1.93	.44	.63	.84	.84	1.99	0	0	12.80
1969-70	.52	.76	.53	2.00	3.96	1.27	.88	.38	.33	.22	0	0	10.85
1970-71	.13	.68	2.36	1.21	1.63	.12	1.28	.84	.93	.81	.20	.09	10.28
1971-72	1.36	.45	1.50	1.03	2.25	.26	1.44	.40	.45	1.70	.07	.55	11.46
1972-73	.57	.43	.83	1.62	1.09	.34	.40	.21	.34	.25	0	.07	6.15
1973-74	.90	.85	3.70	3.99	1.29	.97	1.30	1.18	.38	.02	.41	0	14.99
1974-75	0	.37	1.02	1.39	2.01	1.47	1.25	.46	.53	.84	.40	1.26	11.00
1975-76	0	1.17	1.34	1.26	1.25	.93	.95	1.06	.14	.06	.79	1.17	10.12
1976-77	.04	.10	.43	.20	.18	.63	.50	.08	2.70	.28	.37	.90	6.41
1977-78	.88	.22	2.00	3.22	2.80	1.31	.74	1.42	.43	.44	.59	1.32	15.37
1978-79	.33	.01	.79	.69	1.59	1.54	.99	1.06	.28	.10	.07	1.05	8.50
1979-80	.53	2.59	2.23	.65	3.41	1.83	.94	.89	1.27	1.37	.16	.11	15.98
1980-81	.42	.79	1.73	2.95	1.52	1.22	.65	.41	1.06	1.15	.20	0	12.10
1981-82	.92	.82	1.99	4.73	1.10	.72	.55	1.45	.37	1.15	.21	.40	14.41
1982-83	1.42	1.96	1.08	1.89	1.40	2.43	2.74	.61	1.96	.39	.80	.60	17.28
1983-84	.52	.62	2.45	2.31	.17	1.07	2.34	1.32	.97	1.09	.17	0	13.03
1984-85	.53	.86	3.18	.41	.27	.97	.44	.14	.63	.92	.05	.14	8.54
1985-86	1.11	1.09	1.19	1.12	1.84	2.39	.98	.34	.35	.06	.54	.07	11.08
1986-87	1.52	.45	1.53	.78	1.68	1.10	1.54	.28	.99	.29	.78	.11	11.05
*1987-88	.07	.01	.66	3.23	1.60	.21	1.25						
20 Year Average	.61	.80	1.67	1.70	1.70	1.10	1.04	.67	.78	.66	.30	.47	11.43

*Not included in 20 year average figures.

GROWING DEGREE DAYS