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# The Pendleton Agricultural Research Center, 1967-1992



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# THE PENDLETON AGRICULTURAL RESEARCH CENTER

## 1967 - 1992

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# Historical Background

The purposes and accomplishments of the Pendleton Experiment Station from 1928 to 1966 were recorded by M.M. Oveson and R.S. Besse in Oregon Agricultural Experiment Station Special Report 233. Quoting briefly from Special Report 233, "In 1928, Umatilla County Court purchased a 160-acre tract of good wheat land, representative of the area, at a cost of $30,000 and leased it to the State Agricultural College of the State of Oregon for use by 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 of the State Agricultural College of the State of Oregon." The initial objectives of "maintaining soil fertility and developing more profitable crop production" were expanded from 1967 through 1992 to maintaining and improving sustainable agriculture and the environment. Changes and accomplishments during these past 25 years are presented in this report.

Figure 1. Aerial view of the Pendleton Agricultural Research Center, 1987.

# Changing Agriculture 1967-1992

Dryland agriculture in the Pacific Northwest changed in a positive, progressive direction during this period. Productivity per acre and per hour of input increased dramatically. Contributing to increased productivity were the adoption of varieties with higher yield potential, improved pest control, and broader knowledge of requirements for optimum plant growth. Producers readily accepted new technology. The importance of agro-businesses supplying off-farm inputs and counsel steadily increased.

More powerful motors in tractors, combines, and trucks and improved machinery increased productivity per hour. Improved machinery provided means for more timely application of cultural practices such as seeding, pest control, and harvesting. Examples of machinery changes were green pea harvesting equipment changing from stationary viners to field viners (pea combines) to pod strippers on pea combines, introduction of head strippers on wheat combines, rotary harvesting combines, and hooded sprayers. Tillage machinery and drills were developed to successfully manage large quantities of straw and other plant residues on the soil surface.

Diseases, primarily soilborne, intensified in the near mono-culture of wheat-fallow or wheat-peas and a few new production problems appeared. Jointed goat grass invaded many dryland wheat fields. The spread of Russian wheat aphids into the Pacific Northwest presented an additional insect needing occasional control.

Wheat producers modified production practices to comply with federal agricultural subsidy programs and provisions of the Food Security Act (Farm Bill) of 1985. Greater emphasis was placed on maintaining plant residues on the soil surface and installing terraces to reduce erosion. Thousands of acres were planted to grass in the USDA Conservation Reserve Program (CRP) designed to alleviate erosion on highly-erodible, tilled land.

## Facilities and Personnel

Personnel occupied office space in the original OSU building from 1967 to 1970. An office and laboratory building was constructed in 1970 by the Agricultural Research Service - US Department of Agriculture (ARS-USDA), and both USDA and OSU personnel moved to the new building. The ARS location was named the Columbia Plateau Conservation Research Center (CPCRC), and included computer and library capabilities that were among the best for centers of comparable size.

The chemistry laboratory progressively changed from procedures requiring time-consuming hand labor to fully automated procedures. Neutron probes greatly facilitated the quantity and precision of measuring soil water content. Additional USDA support buildings, such as shops and storage sheds, were completed in 1976. Pesticide storage was upgraded, and new more stringent application and cleanup facilities were installed.

The objectives of CPCRC were defined and expanded after considerable public input. Emphasis was placed on researching problems peculiar to the Columbia Plateau, but still consistent with the national objectives of ARS. Staffing increases occurred from 1968 through 1979, and personnel added to the ARS staff had more diverse expertise such as an agricultural engineer, chemist, hydrologist, plant physiologist, and soil microbiologist.

The Oregon Agricultural Experiment Station merged the Pendleton Station and the Sherman Station into one administrative unit in 1970 with the name Columbia Basin Agricultural Research Center (CBARC). The Umatilla Station was merged administratively with CBARC from 1975 to 1985. During this period the Umatilla Station was renamed the Hermiston Research and Extension Center. The Pendleton and Sherman Stations continued to operate as a single unit.

Figure 2. The USDA-ARS office and laboratory building as completed in 1970.

The CBARC continued intensive input into development and release of cereal varieties and screening herbicide for weed control. An agronomist position to investigate irrigation potentials, other crops, and cultural practices was established in 1968. The irrigation research phase of this position was moved to the Hermiston Research Center. An extension position relating to soil conservation was established at Pendleton in 1984. Plant disease research was intensified in 1985 with the addition of a plant pathologist who also served as superintendent. Funds became available during the late 1980s to construct a large storage shed and a large greenhouse with headhouse, make extensive renovation to all other OSU buildings, and modernize vehicles and equipment.

Professional personnel, their area of expertise, and years at the Center are listed in Appendix Table 1. Research was aided by dedicated and highly productive secretaries, technicians, and part-time employees. Many scientists from foreign countries came to the Center for additional studies in wheat physiology, wheat diseases, or climate-erosion interactions. The Center provided instructors to Eastern Oregon State College for the crop production course from 1971 through 1982, and the soils course in 1978.

Communicating information to the public and promoting agricultural research received increasing attention. Publishing research results became a very positive part of the Center's responsibilities. Field days, twilight tours, and commodity meetings were held or attended to insure transfer of technology to user groups. Training and information exchanges with Extension and Soil Conservation Service (SCS) personnel were established. Starting in 1976, a special report was published annually in conjunction with the Center's field day. Respect for the quality of research conducted by the Center was indicated by the many invitations received by researchers to present information at meetings in Africa, Asia, Australia, and Europe.

A grasp of the broad range of research undertaken at the Center can be obtained by reading publication titles listed in Appendix Table 2. Indepth knowledge of a subject can be obtained by reading one or more publications relating to the subject of interest. Much of the information in academic publications was printed in less formal outlets such as newspapers, magazines, extension bulletins and circulars, and proceedings of meetings and conferences.

## Cereal Breeding and Adaptive Testing

The cereal breeding project continued to make crosses and selections of common white and club wheat, winter barley, and triticale. In recent years the cereal breeding project at Pendleton has concentrated on club wheat. This emphasis was in response to stripe rust epidemics suffered by club varieties being grown and continued consumer demand for club wheat. Services of the USDA Western Wheat Quality Laboratory at Washington State University were utilized for evaluating the new cultivars for milling, pastry, and baking quality.

The adaptive testing program grew thousands of selections and cultivars of wheat, barley, oats, triticale, and grain sorghum produced by plant breeders at the Center and received from cooperating plant breeders and the Rockefeller Foundation's International Wheat and Corn Program (CIMMYT) located

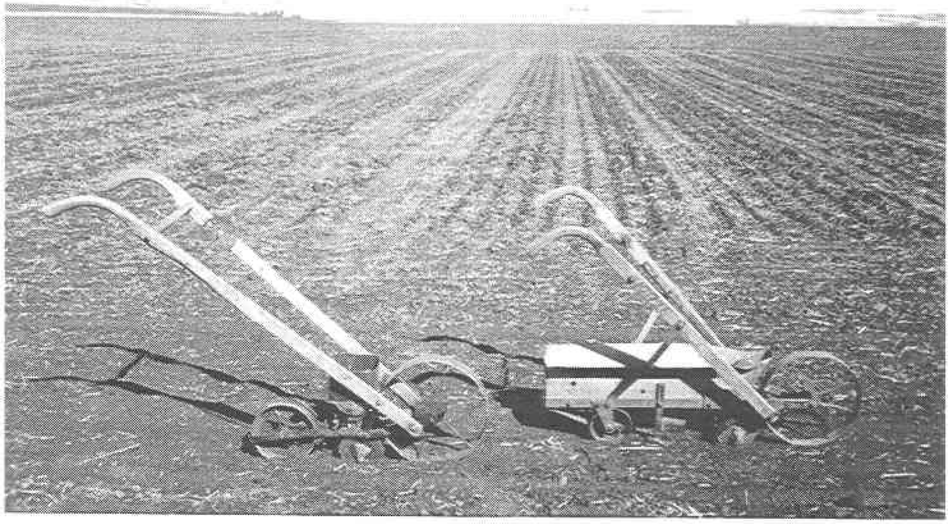

Figure 3. Older and newer plot seeding equipment. Changes in seeding equipment increased the number of plots planted and inproved reliability of results.

in Mexico. The growing of large numbers of crosses, selections, and cultivars was made possible by improved seeding and harvesting equipment that could plant and harvest small lots of seed. Computers became available for analyzing large quantities of research data.

Improved transportation enabled testing in grower's fields from Wallowa and Baker counties in the east to Wasco county in the west. The cooperation and support of growers, grower organizations, and industry was outstanding.

A feed grains project was initiated in 1969 at the request of the Oregon Wheat Growers League. The Oregon Legislature appropriated extra money in 1972, and following years, to support this project. Oregon State University, through the cooperation of cereal scientists at the Center and Corvallis, became world prominent in triticale breeding and development. Some of the serious adverse traits in developing improved winter triticale such as sterile florets, straw too weak and too tall, shriveled kernels, and head shattering were overcome.

Varieties developed and released at the Center were:

1967 - Ione winter barley
1968 - Adams spring wheat
1974 - Rew common soft white winter wheat
1976 - Faro club winter wheat
1980 - Mal winter barley
- Hesk winter barley
1984 - Flora winter triticale
1985 - Micah winter barley
1986 - Oveson common soft white winter wheat
1992 - Rohde club winter wheat
- MacVicar common soft white winter wheat
- Gwen winter barley
- Celia winter triticale

The Center accumulated yield, quality, and agronomic data on all varieties released by Pacific Northwest states. Wheat varieties grown extensively were Nugaines, Stephens, Hyslop, Malcolm, Hill 81, Daws, Dusty, Faro, and Tres. Stephens was the dominant variety since 1978 because of its ability to produce high yields of quality grain over a wide range of environmental conditions and management practices.

Winter wheat and barley yields in trials during this 25-year period increased more than 20 bushels per acre. The average yearly rate of increase in winter wheat yield continued earlier success; yield has risen since 1932 at a linear rate of 0.77 bushels per acre per year. Interactions of improved weed control, fertilizer, and timely application of cultural practices with higher yielding cultivars contributed to this phenomenal increase in wheat yield. Increases in yields of spring cereals were less than half the increases in winter cereals.

## Weed Control

Intensive weed control research was conducted continuously. Hundreds of potential herbicides were furnished by chemical companies for evaluation. Materials were tested alone and in combinations of rate, time, and method of application. Trials were located throughout the Columbia Basin and northeast Oregon on traditional and trashy fallow and on numerous non-irrigated and irrigated crops. Results and suggestions for herbicide usage were readily accepted by producers, agro-business dealers, and chemical company representatives. Recent research has placed emphasis on greater integration of biological, tillage, and chemical controls as a possibility for reducing the dependency on chemicals.

Field bindweed was displaced as the number one weed problem. Widespread use of Tordon and, later, other herbicides suppressed this weed. Controlling weeds in cereals shifted to earlier growth stages when results indicated greater weed control and higher grain yields compared to later control. Alfalfa hay quality improved when experimental results demonstrated the potential of using selective herbicides to eliminate winter annual weeds from alfalfa fields. Aerial application of pesticides increased as carrier rates decreased to very low quantities of water or other solutions.

Downy brome (cheatgrass) continued to plague stubble mulch and reduced-tillage fallow systems. Occasionally, downy brome seed in reduced-fallow systems did not have sufficient soil contact to induce germination during the fallow period. The seed remained viable and germinated with fall-planted cereals. More than 400 experimental compounds were screened between 1965 and 1977; many more were screened after 1977. Herbicides were found that could be applied preplant with or without soil incorporation or applied post-emergence. A patent was granted to the Center in 1990 for the "Inversion" system of selectively controlling weedy grasses and broadleave plants in cereals.

A persistent weed in winter cereals has been volunteer rye. A wide range of hormones, growth regulators, and selective herbicides were tested to reduce infestation. Selective control proved difficult. Partial control was obtained by "wicking" with a non-selective herbicide.

Sufficient populations of wild oats in some cereal and pea fields warranted renewed research on this weed. Several chemicals applied pre- or post-emergence proved effective in controlling wild oats.

Research indicated producers could modify their traditional moldboard plowing in summer fallow to include non-selective herbicide application. Timely application of chemicals reduced spring tillage by two operations. Also, non-selective herbicides provided growers an option of vegetation control when weather conditions did not permit mechanical tillage.

Jointed goatgrass, a winter annual grassy weed, became widespread in the Pacific Northwest. Goatgrass was a serious competitor in winter cereal fields; low populations were found to reduce grain yield as much as 25 percent. Selective removal from winter cereals proved to be very difficult. Reducing goatgrass infestations required tillage and rotations which did not allow seed production for 4 or more years.

Invasion of non-tilled land by biennial knapweed and yellow star thistle reduced forage production and added a menace to grazing livestock. Research did not find an economically feasible control. Kochia was another invader into eastern Oregon, and suggestions for it's control in grain fields were developed.

## Disease Control

Diseases, especially soil-borne diseases, became more of a limiting factor to cereal production. Increasing detrimental effects of disease were attributed to additional years of growing cereals, which provided a build-up of host materials and pathogens, and to the improvement of cultural practices and cultivars which had previously restricted grain yield.

The Pendleton Center continued close cooperation with USDA personnel who had established the Center as a location for conducting intensive trials in the search for resistance to common and dwarf smut in wheat and related species. Approximately 16,000 lines of cereals were evaluated. Those found resistant or tolerant to these diseases were given to plant breeders for incorporation into improved cultivars. Extensive cereal plantings were made in the Flora area to identify high-yielding lines with cold tolerance and resistance to dwarf smut and snow mold.

Although improved wheat cultivars grown by producers had considerable smut resistance, seed treatment with a fungicide was also required to assure control. A fungicide that consistently controlled cereal smuts and had a modest effect on suppressing other diseases was tested extensively during the early 1990's. Foliar-applied fungicides became available for controlling stripe rust and strawbreaker foot rot.

Weeds and volunteer grain were found to be guilty of serving as a "green bridge" between one cereal crop and the next for root diseases caused by several soilborne fungi. Disease pathogens moved from roots of dying plants to roots of emerging cereals when the time interval between weed control and planting was only a few days. Tillage or spraying a non-selective herbicide 2 or 3 weeks ahead of planting to control this"green bridge" proved vastly superior to tillage or spraying immediately ahead of planting.

Rhizoctonia was identified as infecting cereals and causing reduction in yield. *Rhizoctonia solani* was more damaging than other *Rhizoctonia* sp. Greater infection and damage was found on spring cereals than on winter cereals. Rhizoctonia severity decreased as the time interval between killing unwanted vegetation and the planting of a cereal

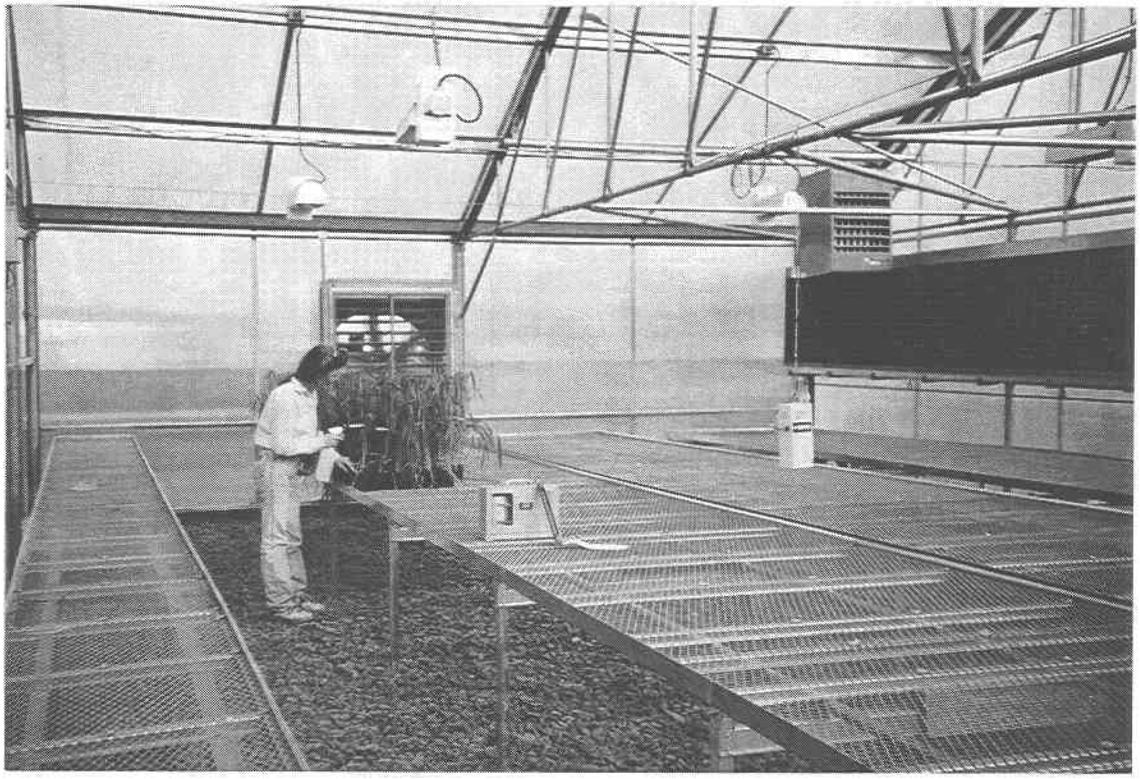

Figure 4. Starting to use the greenhouse completed in 1992. Greenhouse experiments contributed valuable information to the understanding and control of cereal diseases.

increased. Crop rotation, tillage, and banding fertilizer below the seed reduced the amount of damage. Fungicide control was not effective.

The cereal cyst nematode was identified in many fields in the Grande Ronde Valley in 1987. Significant loss of wheat yield was measured. Crop rotation reduced loss from the cereal cyst nematode as well as other soilborne diseases.

## Development of the Wheat Plant

Dynamic foresight and ingenuity went into investigating the physiological development of the winter wheat plant. New knowledge accumulated, extending from seed germination to plant maturity, was of sufficient importance that scientists at the Center received and accepted invitations to make presentations at regional, national, and international meetings.

Growth of the wheat plant is heat driven. Approximately 80 GDD (growing degree days, calculated using a Centigrade scale and a 0°C base) are needed to germinate a wheat kernel when soil moisture is adequate. Another 50 GDD are needed for each inch of coleoptile elongation to get the coleoptile to the soil surface. Seedling emergence delayed past the optimum time for emergence significantly reduces grain yield. For example, seedling emergence 40 days later than the optimum time reduced grain yield by 20 percent. Applying a few hundred gallons of water per acre to the dry seed furrow resulted in only a slight benefit to timely seedling emergence or grain yield.

The elongation of each new leaf on the young winter wheat plant requires an additional 100 GDD. Tillering starts at the base of the first leaf as the fourth leaf appears. Tillering continues systemically from the base of progressively higher leaves with approximately each additional 100 GDD. Later tillers produce smaller heads or are aborted. Tillering stops when internode extension (jointing) starts.

Each tiller grows its own root system. Winter wheat planted in warm soil can develop a sparse root system to a depth of 4 feet within 6 weeks after germination. Ten weeks later the root quantity may have increased three times. A thick straw-mulch delayed root growth slightly in early spring; mulched soils warmed slower than non-mulched soils.

An accumulation of 1,000 to 1,500 hours of over-winter temperatures below 50°F is required to trigger a physiological change (vernalization) within the winter wheat plant permitting it to begin reproductive growth. Year-to-year variability of late winter and early spring temperatures prevents establishing a precise calendar date when late-planted winter cereals will experience this required cold treatment. Without full cold treatment, winter wheat will yield less than early planted spring cereals.

Tissue development that becomes the head (single and double ridge phenological stage) starts soon after the tiller is initiated and before the tiller becomes visible without magnification. Spikelet formation starts about the time that internode elongation (jointing) starts. Florets develop during jointing and the boot stages of growth. The wheat plant might be considered to be optimistic; more tillers, spikelets, and florets are initiated than the plant can support. Abortion is believed to be related to food reserves and water stress within the plant, which are direct responses to growing conditions.

Kernels per head and kernel size increase as the length of time between head emergence and kernel maturity increases. High temperatures (over 92°F) hasten maturity and shorten the time available for the accumulation and transfer of photosynthetic products to the kernel.

A computer program, MODWHT3, which simulates growth and development of the winter wheat plant was constructed from knowledge created at the Research Center. More than 100 starting values were used to describe crop, environmental, and management conditions and responses. Output consisted of an extensive amount of information on wheat growth. Consequences of changes in management practices, as well as uncontrollable factors such as temperature and precipitation, became predictable.

## Precipitation, Water Storage, and Erosion

Water available to the growing plant is the most limiting factor in the area's dryland agriculture. Time of occurrence and quantity of precipitation are of critical importance. Of nearly equal importance is storage and use of precipitation. Research was continuously directed toward accumulating knowledge relating to water storage in the soil, crop use of water from the soil, runoff, and erosion.

Daily weather records have been kept by the Center since 1929 and by the Sherman Station since 1909. These and similar records were utilized via computers to establish the probability of erosive precipitation events and their effects on crop production, runoff, and soil erosion.

Analysis of precipitation records and wheat yields from a wheat-pea rotation concluded that each inch of overwinter precipitation increased wheat yield approximately 3.8 bushels per acre. In contrast, an inch of precipitation during flowering and grain filling increased yield 11.6 bushels per acre. Sufficient overwinter precipitation to wet the soil to a depth of 3 feet or more was essential to obtain average or above-average grain yields.

A soil surface with a high infiltration rate, few freeze-thaw cycles, and low evaporation contributed to the storage of more water and less soil erosion. Standing and partially incorporated stubble and straw favored these desirable conditions. Practices which maintained a rough soil surface increased infiltration and reduced runoff. However, soil roughness consisting of large clods increased evaporation in dry, windy winters and reduced storage of precipitation. Reduced tillage decreased soil compaction and reduced its ill effects of slower internal water movement, restricted root growth, and increased soilborne disease problems.

Storage of precipitation during the fallow winter averaged 60 to 70 percent. Unfortunately, percent stored was much lower when precipitation was below average and wind above average. Soil water was lost during the summer fallow period by evaporation and sometimes by drainage to depths below the rooting zone. Soil, where no-till fallowing was done, lost more water via evaporation than did tilled soil during the summer. Overwinter water storage during the cropping year was higher where straw residue remained on or near the soil surface. Soil storage of precipitation during the 18 months prior to the start of spring growth of winter wheat was 30 to 35 percent.

Figure 5. The neutron probe increased the speed and convenience of determining soil moisture

Soil planted to winter wheat that had 500 or more pounds per acre of straw on the surface did not freeze as deep as did soil with no straw on the surface. Freeze-thaw cycles reduced the structural strength of the soil surface, which resulted in secondary effects of reduced infiltration and increased potential for runoff and erosion. A model for estimating the occurrence of frozen soil was developed. This model provided information needed for runoff and erosion predictions, estimating freeze-thaw cycles, and planning activities requiring unfrozen soil.

Conditions contributing to runoff and erosion such as time and volume of precipitation, soil temperature, and soil surface characteristics were studied. Measurements of volume and duration of runoff, soil movement within and from a field, and effectiveness of terraces and grass waterways were parts of erosion research. As much as 60 to 80 percent of the annual soil loss often resulted from a single major thaw with snow melt or rain during the thawing. Frozen soil increased the potential for a major soil loss. Conservation tillage plus terraces nearly eliminated runoff except in extreme weather events. Grass waterways delivered runoff to waterways without an increase in the quantity of soil contained in the runoff.

Annual cropping, mostly with cereals, reduced erosion in those areas where over-winter precipitation recharged the soil. Use of non-selective and selective herbicides aided weed control; improved grain drill openers permitted maintaining residues on the soil surface. Banding N-P-S fertilizer at planting time was essential to the production of optimum yields.

Computer programs were developed to provide eastern Oregon and Washington growers with historical weather data. These programs provided users with average maximum and minimum temperatures, rainfall, and degree days above a selected temperature base at a location for a time period as short as 10 days to as long as a year. The data provided expected ranges useful for planning activities. Generated weather data, soil survey maps, and cropping practices were used to designate cropping zones in the Columbia Basin.

The Universal Soil Loss Equation (USLE) was developed many years ago as a national project to estimate soil loss by water erosion. Predicted losses were used to suggest best management practices for minimizing soil loss. The USLE was developed from water erosion measurements, predictions, and control technology east of the Rocky Mountains. Several of the primary causes of erosion in the Pacific Northwest were not incorporated into the USLE. Examples: (1) In the inland part of the Pacific Northwest, rain may occur when the soil is frozen and/or covered with snow. (2) Freeze-thaw cycles during the winter and early spring months result in a breakdown of the soil structure at the soil surface into structure having a lower infiltration rate. (3) Thunderstorms, with associated high volumes of precipitation and runoff characteristic of the Midwest, do not occur frequently.

Results from research, plus soil and crop management experiences in the Northwest, were used to modify the USLE into a revised equation (RUSLE) adapted to the Pacific Northwest. Variables such as soil depth, soil texture, slope, annual precipitation, and crops grown contributed to suggesting best management practices. Reduced tillage, more surface residues, terracing of longer or steeper slopes, and strip cropping were the primary recommendations for reducing soil erosion.

## Wheat Straw Management

Many studies consistently concluded that the primary beneficial effect of plant residue on the soil surface was reduced soil erosion. The importance of crop residue toward maintaining organic matter and soil nitrogen (N) in wheat-fallow cropping became very evident in the long-term residue management experiment. However, straw on the soil surface in many conservation tillage systems created numerous problems.

Research into the ill effects of uneven straw distribution by combines provided incentive for producers to modify combines to more evenly spread straw. Tillage and planting problems were solved by modifications of machinery. The effectiveness of herbicides and surface-applied fertilizers were reduced in proportion to the quantity of residue on the soil surface. Some disease problems intensified when straw did not completely decompose between one crop and the next.

Straw production and decomposition influenced tillage practices and erosion. Eighty to 100 pounds of straw were produced with each bushel of wheat under favorable growing conditions. When late-season growing conditions were less than optimum, such as deficient moisture or serious damage from disease, 125 pounds or more of straw per bushel of grain were measured. Straw production varied more than 25 percent between years.

Straw on the soil surface decomposed 60 percent as fast as incorporated straw. Straw with higher N and sulfur (S) content (over 0.5 percent N and 0.05 percent S) had an initial decomposition rate faster than straw with less N and S. Most decomposition occurred in the fall and spring when moisture and temperature were favorable for microorganisms (above 40°F).

## Machinery Design

Furrow openers on older cereal drills were designed primarily to operate in clean-tilled seedbeds; they did not operate successfully in seedbeds having adequate residue on the soil surface to minimize soil erosion. Furrow openers were redesigned to operate in fields with thousands of pounds of straw on the soil surface. The new opener minimized mixing of straw and soil in the seed furrow, placed fertilizer below the seed, and evenly spaced the seed at a uniform depth. Another valuable feature of improved furrow openers was minimal mixing of dry surface soil with moist soil in the seeding zone. Features of these openers were rapidly accepted by commercial producers of seeding equipment.

The mechanics and performance of devices used for the distribution of dry and liquid fertilizers and seed were investigated and improved. The recent development of head strippers for cereal combines started research into harvesting efficiency, effects of remaining residues on controlling erosion, and tillage management of the longer straw remaining after head stripping.

Paraplow tillage reduced the bulk density and resistance to penetration in compacted soil layers. Over-winter water infiltration increased as a result. Reduced bulk density and improved water infiltration did not have a positive effect on wheat yield; more water evaporation occurred from Paraplow-

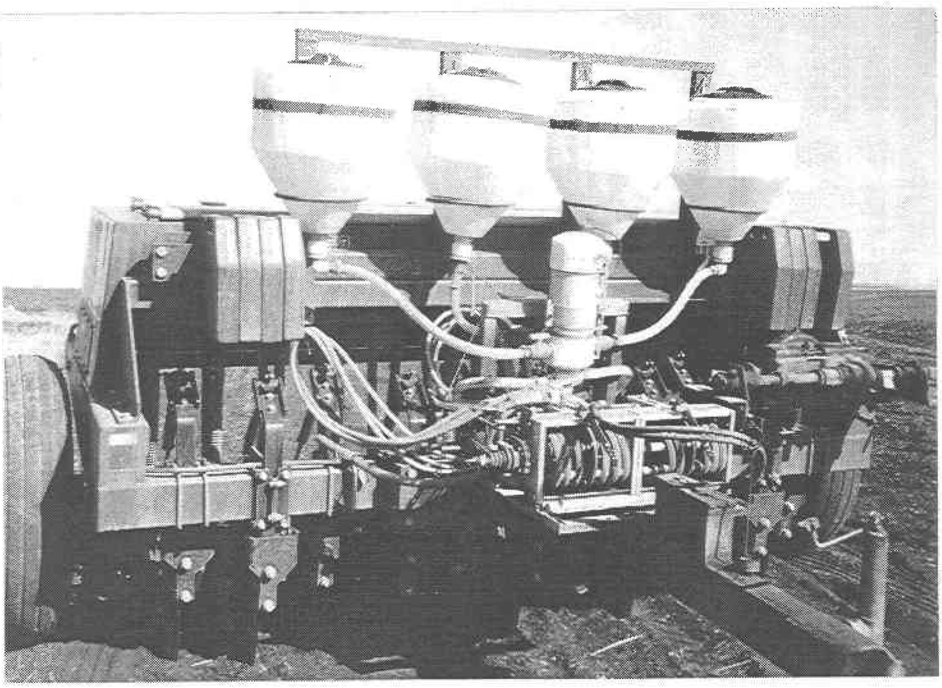

Figure 6. Research drill equipped for fertilizer placement and seeding through plant residues.

tilled soil. The beneficial effects of reduced bulk density and resistance to penetration of compacted layers was short lived (less than 1 year). This short-lived effect of Paraplow tillage on bulk density and water infiltration was consistent with the short-lived effects of deep chiseling or subsoiling.

## Long-Term Tillage and Management

Long-term tillage and residue management experiments started prior to 1967 were continued. The basic objectives were not altered, but wheat productivity, which was used to evaluate management practices, was enhanced by modernizing cultural practices. Improved cultivars were grown and rates of nitrogen fertilizer were increased. Ten-year average wheat yields from the residue management experiment provide an example of increased productivity. Average wheat yield from 1967 to 1976 was 68 bushels per acre and from 1977 to 1986 was 75 bushels per acre where 80 pounds of N per acre were applied to wheat in wheat-fallow cropping.

An experiment started in 1931 that involved managing residue in wheat-fallow cropping was continued. Included were analyses of soil characteristics resulting from different methods of managing straw residue and the addition of manure or pea vines. Soil organic matter and soil N declined at a linear rate with all management practices except when manure was added to each wheat crop. The least decline occurred when the straw was plowed under and 80 pounds of N per acre was applied to each wheat crop. Burning the straw in the fall increased the rate at which soil organic matter and soil N declined.

The Rockefeller Foundation included results from the long-term (1931-1992) wheat-fallow residue management experiment as part of a worldwide study of agricultural sustainability. Inputs, outputs (grain and straw), changes in soil characteristics, cost of production, and wheat price were analyzed. Biological sustainability of the soil resource was negative without technology improvement, but neutral with adoption of advancing technology. The linear decline in soil organic matter and soil N during the 60+ years of this experiment indicate a deteriorating soil resource. Most of the decline was due to biological oxidation of organic matter in the fallow year. The experiment has been conducted on sufficiently flat land where erosion contributed little to the decline in the soil resource. Increasing the return of organic matter, reducing tillage, and reducing erosion were suggested for improving the sustainability of wheat-fallow cropping.

An economic analysis of the wheat-fallow rotation indicated economic profitability slowly declining. The remarkable increase in grain yield coupled with nearly static wheat prices in recent years did not provide sufficient returns to offset increased costs of production. Costs of production included both on-farm inputs and off-farm costs such as those resulting from soil erosion.

Grain yields from soils of various depth within the long-term experiments provided data for establishing firmer relationships between stored soil moisture and N fertilizer needed for grain production. The difference in fertilizer N needed to produce optimum wheat yields on deep and shallow soils indicated more attention should be paid to soil depth when estimating the quantity of N to apply.

## Soil Fertility

Numerous experiments were conducted to evaluate time and rate of nitrogen (N) and sulfur (S) application to cereals and interactions with moisture available to the growing crop. Initially, these experiments were located in traditional bare fallow wheat cropping; in later years they were shifted to conservation tillage systems. Soil and tissue testing was examined with the intent of developing reliable guidelines for predicting how much N and S to apply. Soil testing for nitrate and moisture to a depth of several feet and sulfate in the upper 2 feet became a commonly used tool by cereal producers in estimating how much N and S fertilizer to apply.

Maintaining residues on the soil surface required as much as 50 pounds per acre more N for optimum wheat yield compared to areas with no surface residues. Greater efficiency was obtained by banding fertilizer in conservation tillage systems rather than by broadcasting fertilizers. Separation of seed and fertilizer was necessary to prevent seedling injury when more than 20 pounds per acre of N were applied. Low soil moisture and/or high temperatures increased the detrimental effects

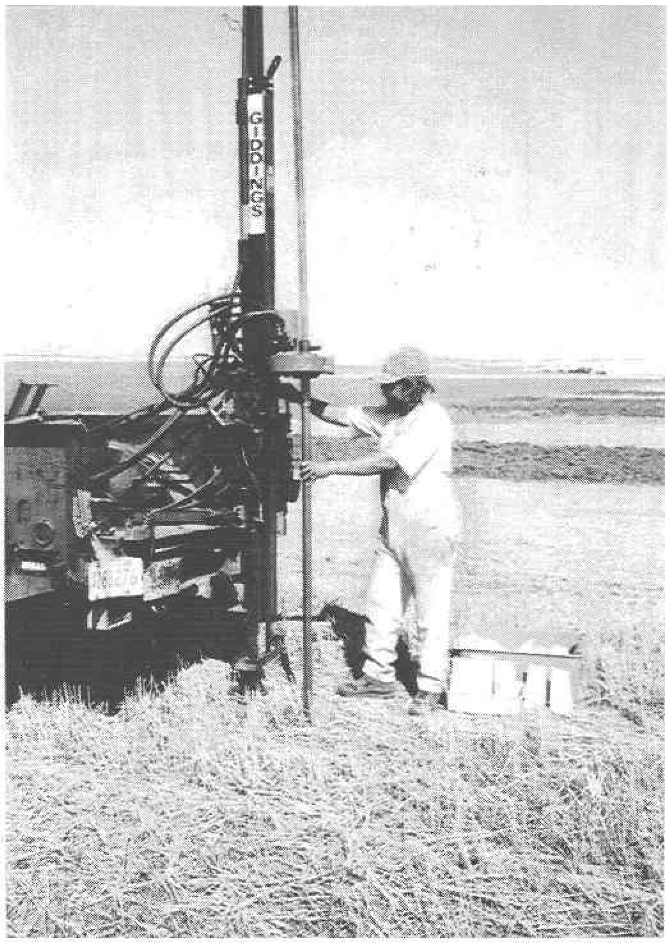


Figure 7. Hydraulic probe used for soil sampling.

of seed-fertilizer contact, as did placing fungicides and insecticides with the seed.

Increased use of N fertilizer, under certain conditions, gradually increased the protein content of soft white winter wheat until it became objectionally high for some consumers. The higher protein contents were associated with favorable early growing conditions and moisture stress during grain filling. Results from many years of fertilizer experiments, soil moisture measurements, and weather records were examined to determine the cause of the problem and thus aid in minimizing it.

Recovery of N by the wheat plant was related to the amount of N applied, but not to the N source. Application of more N than needed for optimum grain yields left more unaccounted-for N than did lower rates. Disposition of N not utilized by plants continued to be a question needing a firmer answer.

Response to applying S fertilizer was measured throughout the Columbia Basin and northeast Oregon. Residual response to sulfur application was measured in following cereal crops. Sulfur response was secondary to N response. Optimum grain yields from annual cropping in higher rainfall and/or shallow soil areas were obtained from banding N-P-S fertilizer at planting time.

A gradual decrease in soil pH was measured. This decrease was associated with the use of ammonium-based nitrogen and sulfur fertilizers. Application of lime in fields of pH 5.7 and 5.9 increased soil pH but did not increase the yield and test weight of wheat or the yield and quality of peas harvested for freezing.

Small areas of soil having undesirable characteristics for crop production exist within

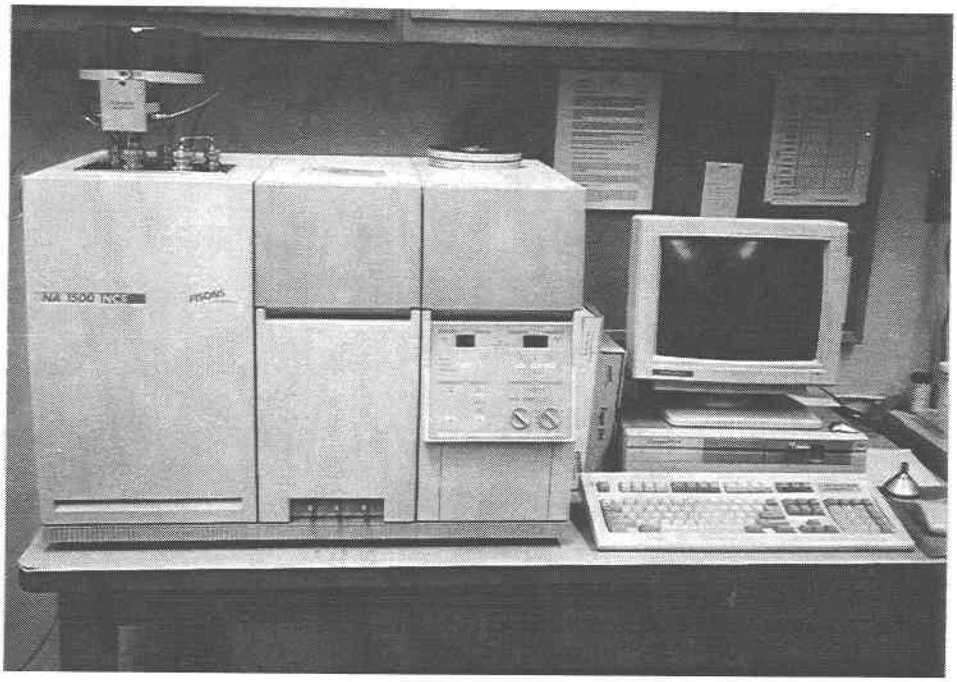

Figure 8. Automated analyzer used in the chemistry laboratory.

larger areas of cropped soil. The nuisance spots have received such names as slick spots and leopard spots. Some of the undesirable characteristics are slow water infiltration of the surface soil, slow internal drainage, and poor soil aeration when wet. Deep plowing these spots to a depth of 34 inches did not improve the yield or quality of wheat or peas. The poor soil physical condition of these leopard spots restrict response to applied fertilizer.

## Crop Rotations

Wheat yield following alfalfa averaged a few bushels per acre higher than wheat yield in wheat-fallow cropping; however, grain yield and quality were more erratic from year-to-year where wheat followed alfalfa. Interactions between precipitation, soil moisture depletion by alfalfa, and over-stimulation by nitrogen (N) residual from the alfalfa contributed to the higher year-to-year variation. Alfalfa yield averaged 1 ton per acre over the 4-year life of the stand. The 16-year rotation of 4 years of alfalfa and 12 years of alternating wheat and fallow was not as profitable as wheat-fallow cropping utilizing N fertilizer. Application of N fertilizer proved to be a more manageable method of supplying the N requirement of wheat. The rotation in which alfalfa was grown was discontinued.

Average yield of annually cropped winter wheat increased markedly after the introduction of semi-dwarf varieties and the application of nitrogen, phosphorus, and sulfur. Annually cropped wheat at the Center (16 inches of average annual precipitation) yielded 75 percent of wheat after fallow, or approximately 1.5 times as much over a 2-year period. However, grain yield and quality of annually cropped wheat continued to be more variable from year-to-year than grain yield in wheat-fallow cropping. This greater variability was a reflection of greater dependency of annual cropping on annual precipitation.

## Peas and Edible Legumes

Pea variety trials conducted by the Center assisted seedsmen, processors, and growers in identifying improved selections and cultivars of freezing and canning peas. The cultivar "Dark Skinned Perfection," the leading freezer pea grown in the 1970's and early 1980's, was replaced with several cultivars having superior yield and quality. The Center cooperated with the pea breeding program headquartered at the Irrigated Agricultural Research and Extension Center, Prosser, Washington. Primary objectives were to select breeding material with greater resistance to root diseases and to evaluate cultural practices contributing to the increasing severity of root diseases. Root diseases caused by species of Pythium and Fusarium increased with increased soil compaction. In seedling vigor studies, vigorous seedlings contributed most of the final growth and yield; small seedlings remained small throughout the growing season.

Computers provided a means for statistically examining many years of weather records and fresh pea yields for relationships between (1) air temperatures and yield and (2) precipitation and yield. Peas were very responsive to daily air temperatures. Above-average April temperature promoted rapid growth, earlier maturity, and higher yields. Daily maximum temperatures above 80°F during flowering and pod filling had an adverse effect on the yield of fresh peas. This adverse effect increased curvilinearly as the temperature increased above 80°F.

Fresh pea yields were related to soil moisture at planting time and precipitation during blooming and pod filling. Nearly 6.5 inches of October through March rainfall was needed to grow the pea vines. Each inch of precipitation during blooming and pod filling produced approximately 385 pounds per acre of fresh peas. Sixty four percent of the variation in pea yield between years was

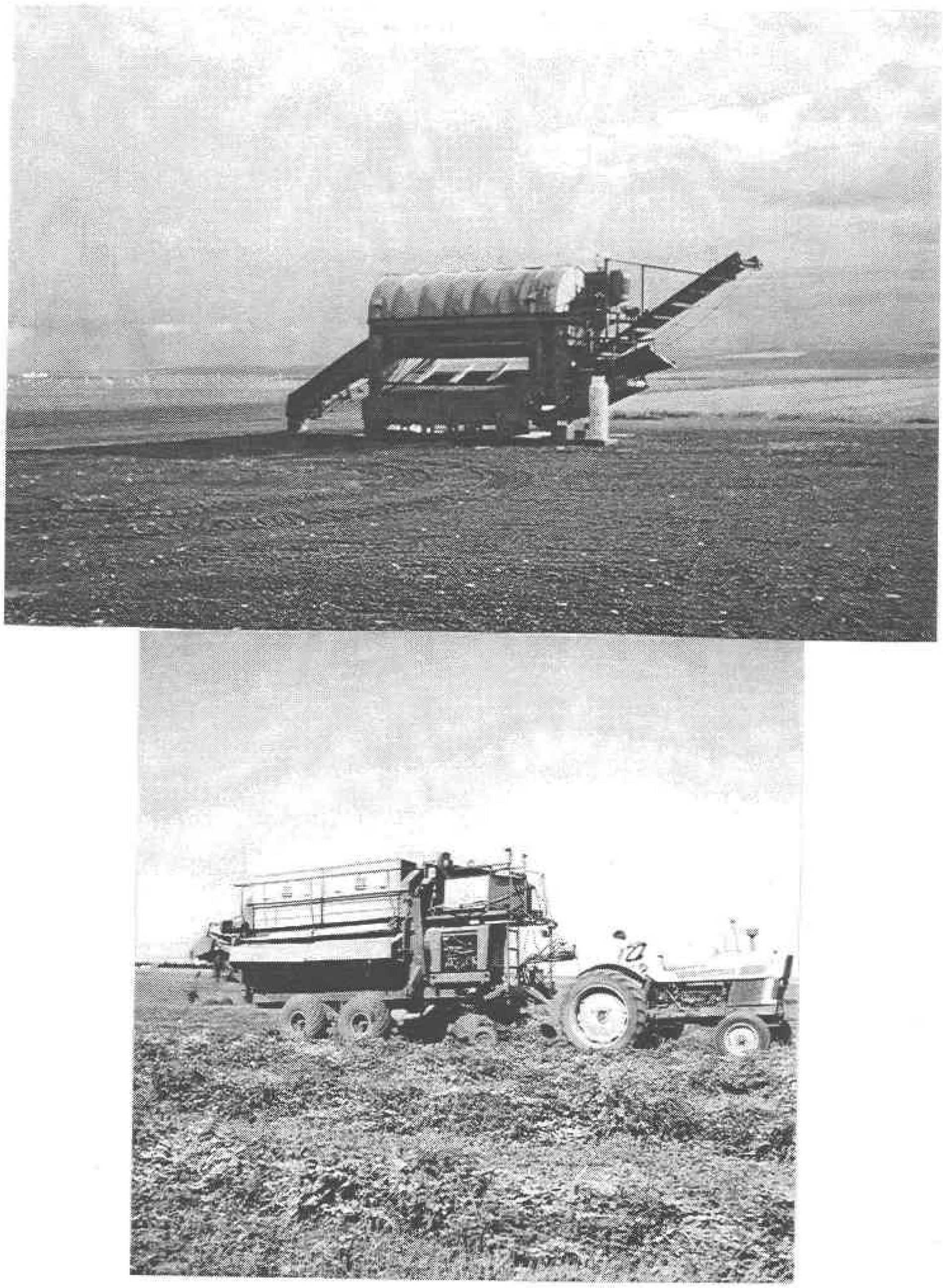

Figure 9. Pea vining changed from the stationary viner (top) to mobile field viners (bottom, an early model). Stationary pea viners became obsolete.

attributed to year-to-year variations in temperature and precipitation.

The relationship between the tenderness of fresh peas of the cultivar "Dark Skinned Perfection" and fresh pea yield was established. This information provided growers and processors broader knowledge of yield-tenderometer changes as the peas matured. Also, research workers had firmer guidelines for comparing yields with different tenderometer readings.

Plant and root development of four legumes--peas, garbanzo beans, lentils, and fababean--were examined. Leaf and root development was heat driven. For example, germination and emergence of peas required 125 to 150 growing degree days (GDD); 5 leaves were grown with 215 to 230 GDD; 10 leaves were grown with 400 to 500 GDD. Nodules appeared with lateral roots and were active a week after appearance. Maximum daily water use occurred during blooming and pod filling.

## Other Crops

Most field crops and vegetables tested for alternate-crop potential were not adapted to a winter-type rainfall. Yield and quality of full-season crops were very erratic from year to year. The Pendleton Center averaged less than 2.5 inches of rainfall during the summer growing season (June, July, and August), which was inadequate to sustain summer growth of warm-season crops.

Edible rapeseed (rapeseed low in erucic acid and meal low in glucosinolate content) was named canola in Canada. This name was accepted in the United States. Winter canola was indicated as a potential crop when tested at the Center in the 1960's. Improved cultivars of winter canola had several advantages over spring canola such as higher yield, greater suppression of weed competition, greater over-winter ground cover to reduce soil erosion, and a more convenient time of harvest for producers. Establishing a stand from a fall planting was a major production problem. Modifying hoe drills improved the success of fall seeding. Late-season damage from seed pod weevil occurred. Observations indicated canola reduced the incidence of soilborne diseases on cereals which followed the canola crop.

The potential of garbanzo production was limited by a seedborne pathogen (causing Ascochyta Blight) which may increase with successive garbanzo crops. International agreement on production of certain drugs in the United States ended any further growing of Big Red poppy, *Papver bracteatum*, as a source of codeine. Rhizoctonia, a soilborne disease, eliminated the possibility of growing pyrethum, which is used as an insecticide.

Research supported previous results which indicated that winter-type rainfall and warm, dry summers were more favorable for early maturing crops than for full-season crops. Examples of adapted crops were winter cereals, winter canola, peas, and lentils. Perennial crops, such as grasses, needed to have a growth habit of rapid spring growth and near dormancy after mid-summer.

## Irrigation

An irrigation project was initiated in 1969; arrangements were made with producers at Adams and Weston for land and water.

Numerous field and vegetable crops were grown successfully, and seed production of vegetables was sufficient to encourage commercial production. Fresh pea yields were increased the most per inch of water applied when irrigated during flowering and pod filling. Irrigating had an adverse effect on fresh pea quality; peas were less uniform in size and tenderness, had a less desirable green color, and had more "blond" peas. Silt loam soils were not favorable for potato production because of soil aeration and water infiltration problems. The irrigation project was transferred to the Hermiston Research and Extension Center in 1973.

Occasionally irrigation water was applied to experiments located at the Center to supplement other irrigation research or when water stress was not wanted as a limiting factor to seedling emergence. An example of the latter was wetting the seedbed used in cereal smut disease research to insure stand establishment.

Appendix Table 1. Professional personnel, their area of expertise, and years at the Center, 1967-1992.

| Name | Area of Expertise | Years |
|---|---|---|
| Charles R. Rohde | Agronomist--Cereal Breeder OSU | 1952-1987 |
| | Superintendent OSU | 1966-1975 |
| Robert E. Ramig | Soil Scientist ARS-USDA | 1961-1990 |
| | Location Leader ARS-USDA | 1970-1981 |
| Donald J. Rydrych | Agronomist--Weed Control OSU | 1965-1990 |
| Roland K. Schwanke | Agronomist OSU | 1968-1969 |
| Ronald W. Rickman | Soil Scientist ARS-USDA | 1969-Present |
| F. Vance Pumphrey | Agronomist OSU | 1970-1987 |
| Mathias F. Kolding | Agronomist--Cereal Breeder OSU | 1971-1993 |
| | Acting Superintendent | 1985 |
| Paul E. Rasmussen | Soil Scientist ARS-USDA | 1971-Present |
| Raymond R. Allmaras | Supervisory Soil Scientist ARS-USDA | 1971-1984 |
| | Research Leader ARS-USDA | 1972-1984 |
| | Technical Advisor ARS -USDA | 1972-1981 |
| Fred Hagelstein | Area Supervisor, Extension Service OSU | 1973-1974 |
| Bruce Mackey | Area Community Development, Extension Service OSU | 1974 |
| Steve Lund | Superintendent OSU | 1975-1985 |
| | Agronomist OSU | 1975-1985 |
| Clyde L. Douglas, Jr. | Soil Scientist ARS-USDA | 1975-Present |
| Betty L. Klepper | Supervisory Plant Physiologist ARS-USDA | 1976-Present |
| | Research Leader ARS-USDA | 1985-Present |
| Joseph L. Pikul, Jr. | Soil Scientist ARS-USDA | 1976-1991 |
| Clarence E. Johnson | Agricultural Engineer ARS-USDA | 1977-1979 |
| Gerald O. George | Agricultural Engineer SCS-USDA | 1977-1980 |
| John F. Zuzel | Hydrologist ARS-USDA | 1979-Present |
| Dale E. Wilkins | Agricultural Engineer ARS-USDA | 1979-Present |
| Darrell C. Maxwell | STEEP Extension Agronomist, Extension Service OSU | 1982-1985 |

| | | |
|---|---|---|
| Donald J. Wysocki | Area Soil Scientist,<br>Extension Service OSU | 1985-Present |
| Richard W. Smiley | Plant Pathologist OSU<br>Superintendent OSU | 1985-Present<br>1985-Present |
| Harold P. Collins | Soil Microbiologist ARS-USDA | 1987-1991 |
| Pamela K. Zwer | Cereal Genetist--Cereal Breeder OSU | 1988-Present |
| Thomas G. Chastain | Agronomist OSU | 1989-1992 |
| Daniel A. Ball | Agronomist--Weed Scientist OSU | 1991-Present |
| Stephan L. Albrecht | Soil Microbiologist ARS-USDA | 1992-Present |

Scientist not located at the Pendleton location who made major contributions:

John M. Kraft Plant Pathologist, USDA, Prosser, WA
Pea diseases and genetics

Warren E. Kronstad Plant Breeding and Genetics, OSU, Corvallis
Wheat breeding and variety releases

Robert J. Metzger Cereal Genetist, USDA, Corvallis
Smut resistance in cereals, especially wheat; triticale

Support staff who made outstanding contributions to the Center and have retired or resigned:

Roger S. Atkinson
Franklin Ball
Leslie G. Ekin
Marion L. Hibbard
Wesley B. Locke
Sandra L. Nuxall

Appendix Table 2. Publications.

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