

Summary of Selected Major Research Projects in the Agricultural Experiment Station

CRUSTING STUDIES

A large percentage of the sugarbeet crop grown in North Dakota is on fine textured soils with massive structure (poor aggregation). Some of the typical problems encountered in production of beets on these soils relate to tillage, emergence, stand establishment, and aeration. Field and greenhouse studies are currently underway to assess the effects of a range of soil physical conditions upon sugarbeet response.

Field studies have included comparison of emergence and stand establishment in seedbeds ranging

from "loose" to "firm", assessment of a variety of anti-crusting chemicals in sugar beet production, and observation of the effects of compaction upon a sugarbeet, potato, small grain rotation. Initial evaluation of the '77 field data indicates sugarbeet emergence may have been enhanced in the firmer seedbeds where seed was placed to moisture. In addition, tendency to crust with heavy rainfall may be less when a loose seedbed is avoided. Farmers should remember, however, that last spring was quite dry, and that in a wet year response could easily be reversed due to aeration and crusting in a firm seedbed.

The problem of aeration is being studied also, comparing the response of various beet varieties to reduced oxygen availability in the root zone. Early results indicate there may be some varietal response differences, and that potassium nutrition may be related to aeration response.

SOIL WATER STUDIES WITH LYSIMETERS

The Department of Soils is in the process of installing four, precision-weighting lysimeters near Absaraka, North Dakota. These lysimeters are being installed with several objectives in mind, namely:

- measurement of evapotranspiration;
- evaluation of the contribution of irrigated cropping practices to soil water and related fertilizer movement;
- determination of the impact of irrigated cropping practiced on the quality of soil water and ground water;
- development of a total salt and nitrogen balance under irrigated crop management, and
- evaluate the effects of a "normal" tillage system and a "conservation or minimum" tillage system.

The four lysimeters have surface dimensions of 5 feet by 5 feet and will be 5 feet deep. This depth



Compare the stunted, chlorotic, sprangled sugarbeet on the left, which came from a flooded field, with a healthy one. The beets are held by Frank B. Arnold, Research Assistant on the project directed by Dr. R. E. Sojka, Assistant Professor of Soils. Sprangling and other related problems are associated with soil compaction and soil aeration. See pictures of greenhouse experiments.



Enclosing the undisturbed soil monolith within the lysimeter box, LeRoy Zimmerman, NDSU Soils Department, Agricultural Experiment Station, located at Mandan, is carefully applying just enough pressure with the backhoe to force the lysimeter box over the trimmed monolith. The detached lysimeter bottom was placed on the top of the box to ensure an even distribution of pressure. In the far background is the new UPA-CPA power plant under construction near Underwood, North Dakota.

will accommodate the rooting habit of most crops and provide enough area to be representative of the surface environment. Researchers plan to reconstruct within two lysimeters a relatively coarse-textured soil profile and within the other two a medium-textured soil profile. The coarse-textured soil would have a low cation exchange capacity and be low in nutrients, have a low water-holding capacity and not be subject to salinization. The second soil would be higher in nutrients and could be subject to salinization under some situations. Optimum level of management based on experience and research, will be employed on both soils.

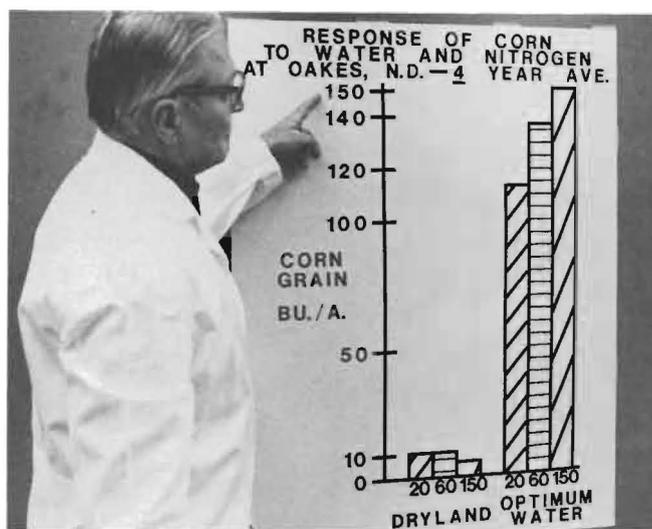
Studies of this type are needed to provide quantitative information as to the effects of irrigation agriculture on soil and water quality. The inclusion of a tillage related treatment is valuable from several aspects. Many coarse-textured soils that are well suited for irrigation are also very subject to wind erosion. Higher residue amounts associated with reduced tillage may be useful in reducing wind erosion. Also, possible effects of conservation tillage on nutrient utilization and movement have not been evaluated.

Each lysimeter will be equipped to monitor water and nutrient movement to accomplish objectives 2, 3, and 4. Porous ceramic filter cups and candles and perforated plastic tile drain will be used to continuously obtain leachate samples and soil water samples. Tensiometers and neutron attenuation will be used to evaluate soil water status. A complete nitrogen balance will be done with the use of ^{15}N tagged nitrogen fertilizer techniques.

FERTILIZER AND WATER MANAGEMENT OF IRRIGATED CROPS

Efficient management of fertilizers and water in producing agricultural crops is important because these resources are limited in quantity and because they are vital components of food and fiber production. These resources should be used as efficiently as possible to minimize production costs, conserve fertilizers and water and to conserve energy utilized in manufacture of fertilizers and in application of irrigation water. Production of agricultural crops should also prevent surface and ground waters from being contaminated with fertilizer elements or pesticides and should maintain or improve the productivity of the soil.

Efficient water use depends on factors that control crop yields and losses of water from the soil. Under good management the main loss of water from soils is by evapotranspiration and this loss is essentially dependent on energy available from net radiation and advection. Crop yields are largely determined by many soil and crop management practices. The principal soil and crop management practices that affect crop yields include use of appropriate fertilizer, providing adequate water, proper timing of irrigation water, planting early, good weed control, good control of insects and diseases, appropriate tillage practices, proper planting patterns for row crops, planting adapted varieties, and using appropriate cropping sequences. Common ways of increasing efficiency of fertilizers are to apply fertilizers so that losses by leaching and erosion are minimized, apply nitrogen fertilizers by methods causing least denitrification, placing fertilizer in moist soil containing plant roots, establishing appropriate plant population, and applying the correct



Dr. Joseph C. Zubriski, Professor of Soils at NDSU, points to a chart showing that both irrigation water and nitrogen fertilizer are required to produce about 150 bushels of corn grain per acre on the sandy soils of the Oakes, North Dakota area. The numbers below each bar represent the pounds per acre of fertilizer nitrogen applied.

amount of irrigation water at appropriate times to minimize water shortages and excesses.

A research project in the Department of Soils was approved in 1977 to include all research on fertilizer and water management for irrigated crops in one project. The specific objectives of this project are: (1) to evaluate the effects of rate and time of application of fertilizers on yield and on concentration of elements in tissues of crops grown under varying irrigation levels, (2) to determine the internal nitrogen requirement of irrigated crops, (3) to evaluate the effect of rate and time of application of nitrogen fertilizer on nitrogen distribution and movement in soil profiles under varying irrigation levels and (4) to evaluate water use efficiency of irrigated crops as affected by fertilizer and water management. This research is conducted at the Oakes Field Trials location.

The data obtained so far indicate that irrigation water is necessary to maximize crop yields on coarse textured soil and that the amount of irrigation water required depends upon the crop grown and on growing season precipitation. Nitrogen fertilizers are also required to achieve the production potential of irrigated non-leguminous crops. The amounts of nitrogen fertilizer required varied with seasons and with crop grown. Water use efficiency has been increased by irrigation water. Effects of fertilizer on water use efficiency of irrigated crops remain to be determined. Losses of nitrogen fertilizer below rooting depth have been minimal when the rate of application did not exceed the amount required to produce near maximum yield of the crop.

Continued research in this area should provide information on the production potential of irrigated crops grown on different soils, the water requirement of crops, the fertilizer requirement of crops and management techniques to maximize efficiency of water and fertilizers use by irrigated crops without causing pollution of surface or ground waters and return flows with soluble constituents from fertilizers or pesticides.

RESTORATION OF COAL STRIP MINED LAND

The restoration of coal strip mined land to its approximate original agricultural productivity is a research area receiving considerable attention by the North Dakota State University Department of Soils staff. With the large increase in power development now in progress in Western North Dakota, the restoration of the disturbed lands assumes great importance to the farmers of the area.

Research by Soils staff in past years was reported in the last two issues of 1976 and the first two of 1977 of North Dakota Farm Research. This included use of soil surveys to help predict results of reclamation, evaluation of potential problems related to climatic and meteorological factors. Other research was to physically, chemically and biologically characterize the coal overburden and evaluate its properties in terms of suitable material for the support of plant growth. Some of the parameters

measured included bulk density, particle size fractions e.g. sand, silt and clay, water infiltration rates, the presence of sodium salts and the supply of essential plant growth nutrients. Most overburden is made up of layers, varying in thickness and in physical and chemical properties.

The North Dakota legislature meeting in 1977 appropriated funds for an expanded program of mined land reclamation research by the Soils department. Several experiments of a long time including N and P fertilization, and various topsoil depths are ongoing from earlier work and others are being added. Also, a neutron probe access tube network has been maintained to monitor soil water movement and recharge at five mine sites. Close cooperation with ARS-USDA researchers at the Northern Plains Center in planning and conducting experiments is a major "plus" factor in solving problems.

Research conducted during 1977 included an evaluation of run-off and erosion characteristics of spoil materials reshaped at various slopes and stabilized with straw mulch. This work was conducted by using a rain simulator to apply various rainfall amounts and intensities. This work has major importance as related to the potential losses of spoil and "topsoil" material by erosion. Also, water infiltration and recharge of disturbed areas is related conversely with runoff.

The two most important factors in re-establishing crop growth on these disturbed lands are plant available soil water plus precipitation and the presence or absence of sodium. Through chemical analysis it is possible to evaluate some of the qualities of the overburden but further research is needed to test, under field conditions, whether it may be located within the surface plant root zone. Research under way, and being planned for the coming years, should provide answers to these questions and provide management techniques for reclaiming disturbed lands which maximize the possible success of the reclamation effort.

North Dakota reclamation laws require that the surface soil be removed in two lifts or layers. The first lift usually consists of the A and B soil horizons and may be 12 to 20 inches thick followed by a second lift, or layer, consisting of the next 5 feet of surface that may be suitable as plant growth material. The materials are set aside in separate stockpiles during the mining operation and returned as the surface when the coal cut is refilled. Management research contemplated for this summer is directed at determining whether, if the overburden is nonsodic and of a silty texture, it is necessary to return the 5-foot second lift material as a buffer between the overburden and the surface soil. If the second lift material is not necessary to establish plant growth, a considerable saving in time and money would result for the mining operation.

The amount of water available to plants that a soil material can hold is a function of its texture, bulk density and compaction. Therefore, by varying the nature of the overburden material and the way

it is replaced, it may be possible to change the amount of plant available water in the surface soil of the reclaimed land. A research project funded cooperatively by NDSU and coal mining and power generating industries is being contemplated to study the effects of various management factors on the need to maintain the second lift buffer zone between the nonsodic overburden and the returned original surface soil to establish good plant growth.

Treatments include varying texture, compaction, and thickness of various materials. Plots will be instrumented with access tubes for neutron probe moisture measurements, pycnometers and tensiometers to fully monitor all water parameters such as infiltration, diffusion and absorption. Rainfall and evapotranspiration measurements also will be made. The crops grown will be analyzed for their essential nutrient contents and the undesirable elements like cadmium, mercury, molybdenum, arsenic, selenium and zinc to assure the quality of the grain and fiber is suitable for food and feed. The experiments will be located on a Falkirk mining site just south of Underwood, N.D. and will be conducted by NDSU Soils researchers from the Northern Great Plains Soil and Water Research Center, Mandan, and NDSU, Fargo.

The North Dakota State University laboratory facilities at the Mandan station are being upgraded to accommodate the expansion of coal mine reclamation research.

Research support and cooperation by the mining companies in the area has been outstanding and deserves recognition. These are the North American Coal Corporation, Falkirk Mining Company, Baukol-Noonan Coal Company, Consolidation Coal Company, Knife River Coal Company. Research of this nature could not be accomplished without their support.

MINELAND RECLAMATION IN MCLEAN COUNTY

Research conducted during 1977 on mine spoil reclamation projects were funded primarily by EPA Grant No. R-803727-01-1, "A (3-state) Cooperative Program to Evaluate Surface and Groundwater Problems Associated with Potential Strip Mine Sites". A research assistant is conducting the research from the NDSU Soils location at the USDA, Agricultural Research Service, Northern Great Plains Research Center, Mandan. Assisting and advising on this project are Soils researchers at NDSU.

The Department of Soils has been working on this project jointly with the Department of Chemistry of NDSU, the N.D. Geological Survey, and with universities of Montana and Wyoming. The first three-year phase of the project will be completed in June, 1978. This phase has been primarily one of characterization of overburden and water status at various sites prior to mining, including the installation of lysimeters to evaluate evapotranspiration. The next phase will involve an evaluation of soil and

water problems related to the "during mining" period of stockpiling of materials and their replacement at the same sites. Lysimeter and related research will also be continued.

Overburden and soil samples have been analyzed for several problem-indicators pertaining to plant growth, water movement, and potential root growth including pH, EC, SAR, CEC, soluble ions, and exchangeable cations. Physical analyses have been for water holding capacities at various soil water potentials, saturated and unsaturated conductivities, bulk densities, plastic limits and particle densities. These data will be used in conjunction with data collected at other stages in the mining and reclamation process to develop and test predictive models of the effects from mining.

Greenhouse and field studies have been conducted to evaluate the effects of various combinations of overburden and soil material on the germination and yield of spring wheat. Results from the greenhouse studies point to the importance of returned topsoil material to root development as well as to dry matter yields. Initial results from field experiments indicate that kernel weights and plant heights on undisturbed soil may be greater than on a site which has been disturbed by simulated reclamation, but total dry matter yields may be unchanged.

Two 125-cubic foot weighing lysimeters have been installed at the mine site near Underwood to evaluate the consumptive use of water in both an undisturbed soil monolith and in a soil profile disturbed to simulate a reclaimed site (see accompanying pictures). Small grain will be grown in these lysimeters and in adjacent field plots to evaluate the differences in water use and plant water stress under pre-mined and post-mined conditions.

SOIL SURVEYS OF POTENTIALLY IRRIGABLE LANDS

The primary thrust of the detailed soil surveys of potentially irrigable soils is the mapping of soils in the Middle Souris and Mouse River irrigation districts in McHenry county. Due to the lack of precipitation in the area the past two years the water table is lower than normal and mapping was confined to low lying areas that are normally wet around lakes and a broad ancient outwash channel. Approximately 20,000 acres were mapped and several soil descriptions and samplings were taken for purposes of correlation into the standard State-Federal Soil Survey.

Two graduate student research projects were initiated. One deals with water movement in soils having a barrier that restricts the downward movement of water. The other project deals with chemical and physical changes within selected soils which have been irrigated for a period of years. Potential changes in soil and water quality are being monitored at several locations having irrigation systems. The area extension irrigation agent stationed at the

Garrison Conservancy District Office in Carrington works directly with many irrigators and is alert for potential problems developing within soils.

REGIONAL SOIL SUITABILITY MAPS AND LAND USE INFORMATION

In many states a large acreage of farmland is transferred to nonagricultural uses each year. Housing and commercial developments and highway construction continue to absorb land suitable for the production of food and fiber. Many agriculturalists are disturbed by these irreversible changes in land use which further reduce our supply of farmland.

Since present land use trends probably will continue, soil scientists in 12 states of the North Central Region (N.D., S.D., Nebraska, Kansas, Missouri, Iowa, Minnesota, Wisconsin, Michigan, Illinois, Indiana and Ohio) are developing a series of interpretive maps showing the relative suitability of the major soil associations in the region for wheat, corn, alfalfa, native range and woodland. The information for North Dakota was assembled by the Department of Soils. The maps will provide a general basis for planning the use of our soil resources at the regional level. More detailed maps, however, are required for decision making at state and local levels.

In addition to the five interpretive maps, a table of selected characteristics of the soil associations is being developed. The table will provide an estimate of the percentage of each soil association in the region, the current names of the dominant soils in each association and an estimate of the percentage of each association used for cropland, rowcrops, small grains, permanent pasture or native range, and woodland or forest.

The soil associations considered are those shown on the "Major Soils of the North Central Region, U.S.A.", a general soil map published with "Soils of the North Central Region of the United States," North Central Regional Publication No. 76. The scale of the original soil map and interpretive maps is 1:2,500,000 (40 miles = approximately 1 inch).

RESIDUE MANAGEMENT AND N SOURCES FOR SMALL GRAINS

Continued interest in saline-seep management in western North Dakota has created new interest in residue management. In 1977, residue management studies were initiated in four counties in western North Dakota. This work was conducted by NDSU Soils researchers, cooperating farmers, area agents and Branch Station personnel.

Spring wheat was used as an indicator crop in order to determine soil water use, water use efficiency, N source efficiency and yields of small grains as influenced by N sources and N rates. The objective of

the study was to quantify the effect of residue on fall and spring applied N when the N was left on the soil surface or incorporated with the residue. If residue can be left standing to entrap snow, the possibility of recropping, to reduce soil water recharge, can be increased. We have previously shown that N applications on recrop not only increase yields but increase the water use efficiency of the crops, when N deficiencies limit crop production.

Nitrogen applications using two sources, and at several rates of N, ammonium nitrate (35-0-0) and urea (46-0-0), were broadcast in the fall in standing residue or broadcast and incorporated in the fall. Spring applications of the same materials and rates were applied to the remaining residue and incorporated. Initial results show positive yield responses at three locations and a negative response at the fourth location. Some source differences appear to be emerging, but the data is not conclusive at this time.



Residue management includes seed placement after the residue has retained winter snow. This research at the Williston Experiment Station conducted by Dr. Russ Schneider, E. French, N. Riveland and F. Sobolik applies the principles of no-till planting to minimize water loss and tillage costs early in the growing season. Notice the large coultter directly in front of the double disk opener.

Per cent protein and test weight showed positive N responses at all locations. The lack of adequate precipitation negated the water use efficiency data to a large degree but water use efficiency was increased with N additions. These efforts are being conducted again in 1977 - 1978 at four locations.

A second residue study conducted at the Williston station using three residue heights (0, 7, 14 inches) showed a three-fold increase in available soil water to a depth of 4 feet in early spring when no residue was compared to 14-inch residue. No-till planting, and adequate weed control showed a \$20.00 per acre difference between no residue and 14-inch residue when compared at the best yield level for any one N treatment. The difference appeared to be a function

of stored soil water. A similar study has been initiated at the Williston station.

GREENHOUSE INVESTIGATIONS OF NITROGEN FERTILIZER MOVEMENT

The element nitrogen is probably the single plant growth requirement that has received the most attention as an environmental contaminant or pollutant in recent years. Nitrogen, in one of its many forms and from some of its many sources, has been directly related to metabolic upset in both animals and humans. In some instances N has even been detrimental to plants. As a plant requirement, nitrogen most commonly finds its way into the soil through inorganic fertilizers, although some other common avenues such as rainfall, plant assimilation, and organic residues play a significant role. In North Dakota progressive farming has made way to such inorganic N fertilizers as anhydrous ammonia, urea, and ammonium nitrate and sulfate. Additionally, management has introduced split applications during the crop season, fall applications, and fertigation, the addition of fertilizer to irrigation water.

Emphasis on soil nitrogen research has remained high because 1) the amount naturally in the soil is often small while crop requirements are high, 2) inorganic fertilizer N sources are often very soluble and readily moved through the soil profile, and 3) once incorporated into ground water, nitrogen may warrant such water supplies unsuitable for human or livestock consumption. In addition, the recent increase in acreage of irrigated land has been the cause for much concern.

During the recent past and currently extensive research has been undertaken to evaluate plant uptake of nitrogen. Fellow researchers are evaluating many aspects of nitrogen fertilization, including application timing and method, nitrogen form, and amount of nitrogen applied. However, only limited attention has been focused on nitrogen movement in the soil. Consequently, a greenhouse study was initiated by the Department of Soils to evaluate and characterize some of these nitrogen movement problems. Three nitrogen sources (urea, ammonium sulfate, and calcium nitrate) are being compared, in terms of their resultant nitrogen movement under different irrigation practices. A total of 24 undisturbed soil columns have been cropped to Era variety wheat and instrumented so that drainage water can be collected. The water draining from the bottom of the columns is being analyzed principally for nitrogen.

Growing concern for environmental quality has caused much attention to be focused on agriculture as a major contributor to deteriorating water quality. Findings from the type of research being conducted here will hopefully aid farm managers. Recommendations in terms of both irrigation scheduling and nitrogen fertilization will be forthcoming. This work complements on-going field research being conducted at the Oakes Irrigation Field Trials site.



Two varieties of hard red spring wheat were grown with different levels of fertility to obtain grain for evaluation of its nutritional value. This research is being conducted by Paul Syltie, Soils graduate student, under supervision of Dr. W. C. Dahnke. The taller, darker strips are Waldron, an "older" variety, and the shorter, lighter strips are Era, a new dwarf variety which produces higher yields but is lower in protein content.

WHEAT COMPOSITION AND NUTRITIONAL VALUE

Both genetic and fertilization differences have been known for some time to influence the composition of plants, especially foliar portions. However, since many humans and the animals they raise depend on cereal grains as a source of food, the possible effects of fertility variables and genetic makeup on the nutritional value of grain has far reaching implications. The Department of Soils, in cooperation with the Department of Animal Science and the Department of Agronomy, is studying the influence of the factors on hard red spring wheat. After partial completion of the study, which involves field fertility treatments, rat feeding trials, and laboratory analyses, significant results have been shown regarding both genetic and fertility variables.

The study was initiated in the spring of 1977 on land owned by Sherwood Johnson, a farmer near Page, North Dakota. The objectives are to (1) determine the effect of various fertilization treatments on the composition and nutritional value of hard red spring wheat grain, and (2) determine the influence of varietal differences on composition and nutritive value of wheat. Two wheat cultivars of unlike genetic backgrounds (Waldron and Era) were grown in a split-plot, complete-factorial arrangement using nitrogen, phosphorus, potassium, and certain other minor element amendments. Following harvest wheat samples from 11 of the fertility treatments were ground, supplemented with vitamins and minerals, and fed to laboratory rats. In this manner, differences in nutritional value of the protein could

be determined as measured by such factors as rate of gain and protein efficiency ratios. Preliminary statistical analysis of growth rate data from the rats indicates significant differences in many cases among the different fertility treatments, and especially between the two wheat varieties grown. While continuing studies will help ascertain differences in growth rate due to fertilization variables, it is obvious that the higher protein Waldron wheat exceeds Era in its ability to produce somewhat faster, more efficient weight gains.

Chemical and spectrophotometric analyses of grain and feed samples are continuing in order to establish the relationship between the two variables investigated (genetics and soil fertility) and wheat grain composition. Both major and minor elements will be analyzed as well as certain organic fractions of the seed such as protein, total energy, and possibly several vitamins.

The evidence assembled so far indicates that seed composition can be changed enough through fertility treatments to produce significant growth differences when fed to test animals. Protein content and nutritional quality of different wheat varieties may vary enough so that grain producers and the food industry might want to consider nutritional quality factors when deciding what variety to use or buy and how much fertilizer to apply.

ANHYDROUS AMMONIA AND N-SERVE FOR IRRIGATED CORN

Although anhydrous ammonia is now the dominant nitrogen fertilizer used in North Dakota, little local research has been done with this material. The influence of N-Serve on efficiency of anhydrous ammonia use by irrigated corn was studied for a second year by The Department of Soils at Oakes during 1977. N-Serve, a proprietary compound manufactured by Dow Chemical USA and licensed for use with nitrogen fertilizers added to wheat, corn, sorghum and cotton, slows down the conversion of ammonium-N to nitrate-N. If soil conditions favor leaching of nitrate or denitrification, use of N-Serve may greatly increase fertilizer use efficiency.

Difficulties involving the calibration of application equipment complicate anhydrous ammonia research. The researchers found considerable diversity in the quantities of ammonia originating from selected outlets of a commercially available manifold. It was only after a great deal of checking that four outlets dispensing approximately equal quantities, within $\pm 10\%$, of ammonia, were found.

In both 1976 and 1977, application of 120 pounds ammonia-N per acre increased yields by about 75 bushels per acre and decreased grain moisture content. The soils in both years contained at planting approximately 30 to 40 pounds of nitrate-N in the upper acre-2 feet of soil. Application of 60 instead of 120 pounds of nitrogen per acre resulted in yield decreases of 18 and 20 bushels per acre in 1976 and

1977, respectively. Top yields in 1977 exceeded 190 bushels per acre.

N-Serve tended to increase yields by 3 to 5 bushels per acre in the two years. Conditions were not favorable for extensive leaching of nitrate in either year. Soil studies indicated that N-Serve decreased the rate of nitrification, almost completely eliminated nitrite accumulation and prevented the usual mid-season drop in soil pH in the center of the injection zones. Limited data to date suggest that N-Serve may be a useful management tool for reducing the quantity of nitrate in return flow water originating from sandy irrigated soils in North Dakota.

There was no difference in the efficacy of late fall-applied and spring-applied anhydrous ammonia in 1977. This aspect of the research and the role of N-Serve in preventing or reducing losses of fall-applied ammonia will be studied more intensively in future years.

WHEAT FOLIAR SPRAY

Interest has been regenerated in foliar applications of plant nutrients to increase crop yields. Significant yield increases in the applications of NPKS to soybeans sparked this new interest. The NPKS foliar sprays were not intended to supply the total plant nutrient requirements, but applied late in the season, after flower initiation. The aim of the foliar applications was to supplement good soil fertility management programs and obtain yields in addition to those normally harvested. The success of the foliar sprays depended on increased seed set attributed to the correct combination of NPKS along with adequate moisture and carbohydrate production to fill the additional seeds subsequently formed.

Foliar applications of NPKS to soybeans has shown only limited success, but application of the principle to other crops such as wheat are now drawing attention. A foliar spray project was initiated in 1977 with Waldron spring wheat. Foliar spray solution containing NPKS and a surfactant (X-77) at 0.1% was applied with a pressurized sprayer at three separate applications times (7 days apart) following flower initiation. The nutrients were supplied in the form of urea, potassium polyphosphate and potassium sulfate. The total pounds per acre applied as foliar nutrients was 60 N + 15 P + 30 K + 6 S. The foliar spray treatment was compared with a no fertilizer treatment, 60 pounds of N top-dressed as urea and a combined topdress treatment with a foliar application. A moderate amount of leaf burn occurred with the foliar application.

Based on one year's data, wheat yields were highest (42 bu/A) with topdressed nitrogen. The foliar spray and control yielded 36 bu/A. Both test weight (lb/bu) and kernel weight (grams/1000 kernels) decreased with foliar applications while percent N in the grain increased. Both total number of florets and fertile florets produced under the foliar applica-

tions increased, which gave a two and three percent increase in floret fill (seed set) above the control and topdress N treatment, respectively.

These data suggest that increased seed set and grain N (protein) can be increased by foliar spray, however, the decrease in yield along with seed weight or size indicates that soil moisture and/or carbohydrate production were insufficient for maximum development of the increased seed set. Thus yield reduction was obtained at the expense of increased seed set. Thus yield reduction was obtained at the expense of increased seed set. The wheat plants were exposed to moisture stress during the time of filling which was a key factor in the results obtained. Additional information is needed on varietal difference and/or under reduced moisture stress to fully evaluate foliar spray on wheat and its subsequent benefits.

WINTER WHEAT RESEARCH

The variety Roughrider was increased under contract in 1977 and was reallocated to counties which had not obtained an initial allotment. Approximately 15,000 acres were seeded for the 1978 crop, which should provide an adequate seed supply for seeding next fall.

The winter wheat breeding program has both short- and long-range goals. Current emphasis is being placed on improving agronomic and quality traits, while maintaining a winterhardiness level similar to that of Roughrider and Froid. A longer-range emphasis is to develop winter wheats with higher winterhardiness levels.

Some of the specific improvements being sought include the following. Resistance to both stem and leaf rust have been obtained by crossing with spring wheats. Leaf spot resistance is being transferred from some unadapted winter wheats. Higher protein content is being obtained from both spring wheat and winter wheats. Shorter plant height is being achieved, although no semidwarfs with good winterhardiness are yet available. High yielding European winter wheats are being used for improving this important characteristic.

Improved winterhardiness is a difficult objective. Some old Russian winter wheats are more winterhardy than Roughrider and Froid and crosses have been made with them. Progeny are being evaluated to determine if higher winterhardiness has been combined with satisfactory agronomic characteristics. Another attempt to improve winterhardiness was started recently in which wild wheat relatives were used for making hybrids to determine if they can contribute additional winterhardiness.

Another factor which may help to improve winter survival is to combine cold resistance with deep crown formation. The deep crown trait was found to be quite simply inherited and is being combined with high cold resistance to see if this will help winter survival.

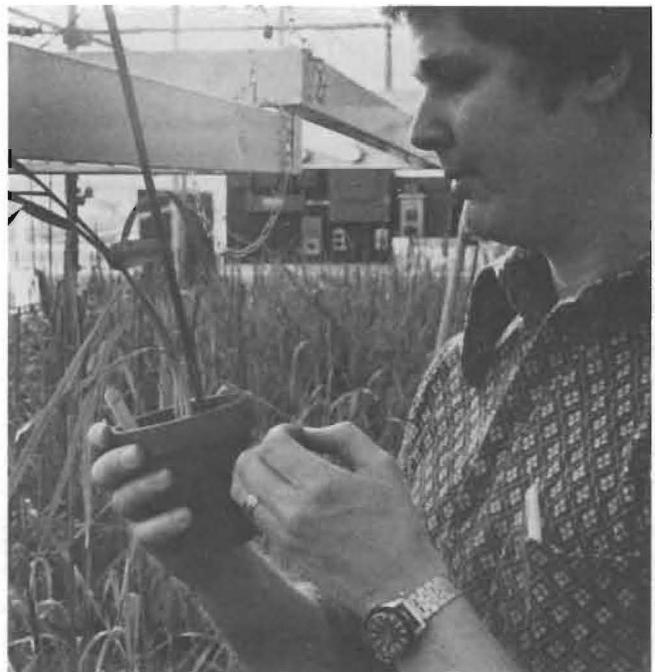
A graduate student is investigating management

practices, such as stubble seeding and depth of tillage in seedbed preparation to determine which practices will give improved winter survival.

OAT RESEARCH IN NORTH DAKOTA

Rust diseases of oats have been a chronic problem for oat producers in North Dakota. None of the commercial varieties have adequate resistance to the most prevalent race of oat stem rust which predisposes the oat crop to serious losses from stem rust infection. Severe stem rust infection occurred in some later oat fields in 1977. Excellent stem rust resistance is available in oat germplasm which is not well-adapted to North Dakota. This resistance is being incorporated into breeding lines which are agronomically acceptable for North Dakota production. Improved crown rust resistance is simultaneously being incorporated into these lines.

In addition to improved disease resistance, increased yield, straw strength, test weight and protein percentage remain major objectives of oat research in North Dakota.



Researcher Mike McMullen is engaged in developing disease resistant and profitable oats varieties.

CORN RESEARCH IN NORTH DAKOTA

The corn improvement program at North Dakota State Agricultural Experiment Station has produced over 35 parental inbred lines for use in producing hybrids for North Dakota. However, deve-

lopment of even better inbreds depends upon knowledge of what characters are desirable in these inbreds and which breeding methods are most efficient in producing these lines. Recently, research was conducted to find more efficient methods of developing inbreds which will perform well over a range of different environmental conditions. Results indicated that inbreds which can produce two ears per stalk with many rows of deep kernels on each ear should produce such hybrids. The study indicated which types of breeding procedures should be effective in producing this type of inbred.

Annual tests of commercial corn hybrids are conducted to provide growers and seedsmen with information about performance of current hybrids available for various growing areas. A recent study was conducted to determine how to best utilize this test data in selecting hybrids for a particular area. Results favored selecting the two or three highest yielding hybrids from the nearest yield test. Surprisingly, selecting from hybrids tested two years was found to produce higher yields than selecting on the basis of three year averages. Hybrid selection on this basis would have produced an average 4.4 bushel per year yield advantage for the 10-year period studied at nine locations.

Research to evaluate the potential of corn under irrigation produced spectacular plot yields in 1977. Using narrow rows, high fertility and experimental single cross hybrids at the Oakes Research site, yields averaged 193 bushels per acre for 64 hybrids tested with individual hybrids yielding as high as 260 bushels per acre. Most of these hybrids, including the highest yielder, included North Dakota inbred lines as parents.

HRSW RESEARCH BENEFITS

Testing hard red spring wheats which have alien cytoplasm was continued with five new alien cytoplasms added. Wheats with three alien cytoplasms have yielded and performed similarly as the same wheats with normal cytoplasm. Little effect of the alien cytoplasms on grain protein have been found. Several other alien cytoplasms have deleterious effects on wheat growth, yield, and germination. Although no enhancement of agronomic or quality performance has been found using alien cytoplasms, the possibility of diversifying the cytoplasm pathogens which may attack normal wheat cytoplasm.

Choice of parents used for hybridization to produce promising new varieties is a major problem in plant breeding. By using a dominant male sterile gene, progeny testing to identify useful parents may become feasible in wheat such as being used in corn. Increased efficiency of knowing the expected performance level of progenies from certain parents would be of great assistance in producing new varieties.

The newly released triticale variety 'Welsh' from the University of Manitoba has been tested in North Dakota for two years. Welsh has not performed as well as several older triticale varieties

although test and kernel plumpness are improved. Because of limited marketing opportunities and triticale's susceptibility to ergot, which provides hazards for feed grain use, triticale remains a crop which would require a favorable contract before consideration should be given for production. Better triticale varieties have yielded about the same as wheat in North Dakota. However, barley and oats have outyielded triticale consistently in trials conducted since 1969. New triticale varieties will continue to be tested as the crop continues to be improved.

DRY EDIBLE BEAN RESEARCH

The agronomic evaluations of different bean types, named and experimental lines are continuing. The majority of the studies are conducted in the eastern third of North Dakota where the majority of the acreage is found. Limited evaluations are also being made at the branch stations in central and western North Dakota.

Efforts are being made to evaluate the potential for dry bean seed production in western North Dakota. The majority of the seed sown by North Dakota dry bean producers each year is produced in one of several western states where drier climatic conditions are more conducive to the production of disease-free seed. Possibly the drier portions of North Dakota, where commercial dry bean production is non-existent, may have this same potential for seed production. Evaluations for yield potential and adaptability are being completed. In cooperation with the Department of Plant Pathology, evaluations of disease potential in this area are also being studied.

Other research being conducted with dry beans include studies involving various row widths, seeding rate, the use of various chemicals for defoliation, and date of planting.

Money from a grant given NDSU by the National Crop Insurance Agency and the Crop Insurance Research Bureau is being used to evaluate pinto and navy losses due to hail damages. Dry bean producers and the hail insurance companies often have difficulty in reaching a mutually fair agreement where hail has occurred. The amount of information relative to losses due to hail damage is limited and conflicting. Information obtained from this study will hopefully shed new light in this area.

SUNFLOWER PRODUCTION AND PHYSIOLOGY RESEARCH

Several areas are being researched including date of planting studies as they interact with plant population. Should a producer change his plant population as the seeding date changes from year to year? How early or how late can sunflowers be sown? What effect will these factors have on water usage? Hopefully some of these questions will be answered by this study.

Because of the expense in hybrid seed production,

several sizes of sunflower seed are being marketed. Studies are being conducted at several locations to evaluate emergence of the various seed sizes from different planting depths. In addition to emergence, yield factors as influenced by seed size are also being studied.

The role of leaf size and leaf number in sunflower yield is also being studied.

RESEARCH IN MINOR AND NEW CROPS

Research continues in several crops of limited acreage in North Dakota. Varietal evaluations of winter rye are conducted at the branch stations. Varietal evaluations of millet at normal and delayed seedings also are being made. Data on the delayed seeding is of particular importance since millet is often sown late following hail or other damage to an earlier-sown crop. Research in mustard includes date of planting and varietal evaluations. Other minor crops evaluated includes canarygrass and dry peas.

New crops evaluated includes lentils, crambe and azuki beans. Crops evaluated in the past include plantago, sesbania, horsebeans, and tickbeans.

OATS STRAW QUALITY

Crop residues are the largest, basically untapped carbohydrate reservoir for livestock production. Crop residues, especially small grain straws, are typically quite low in energy, intake potential, and protein content. They can be used most efficiently in maintenance rations such as overwintering of gestating beef cows. Little information is available on varietal differences in small grain straw quality characteristics, yet such differences could affect markedly the cost of a maintenance ration.

Cooperative research in the Departments of Agronomy and Animal Science is evaluating several oat varieties and experimental lines for potential differences in straw quality characteristics. Each variety is evaluated chemically for percent in vitro dry matter disappearance (% IVDMD), percent acid detergent fiber (% ADF), and percent acid detergent lignin (% ADL) to indicate the energy fraction; percent cell wall constituents (% CWC) or total cell walls as an indication of potential intake; percent crude protein; and percent phosphorus. Percent acid detergent fiber nitrogen determined on representative varieties will indicate the potential digestible protein in the oat straw.

Preliminary observations from Fargo trials indicate significant oat varietal differences in the quality characteristics % ADF, % ADL, percent crude protein and % CWC. Random oat had the highest quality straw of 25 varieties tested and OA 313 (an experimental line with Random parentage) had the highest straw quality of 36 genotypes tested from the Regional Mid-Season Oat Nursery. These data need to be further substantiated, but difference in oat straw quality among varieties detected to

date were sufficiently large to be of practical importance in ration formulation. In addition, spring wheat, durum wheat, and barley straws are being evaluated preliminarily for varietal differences in straw quality.

BARLEY RELEASES

Two experimental barley lines, ND231 (Park) and ND718 (Glenn), were released January 12, 1977 by the North Dakota Agricultural Experiment Station in cooperation with the United States Department of Agriculture. ND231 has much better resistance than Larker to the leaf spotting diseases, spot blotch, net blotch, and Septoria leaf blotch. ND231 appears to be best adapted to northeastern North Dakota, where leaf spotting diseases occur most frequently. Lodging resistance of ND231 is better than Larker. Kernel plumpness of ND231 is between that of Larker and Bonanza. The Malting Barley Improvement Association has classed ND231 as an acceptable variety for malting and brewing.

ND718 has consistently yielded more than Larker, particularly in the eastern areas of the state. While ND718 has better resistance than Larker to leaf spotting diseases, the resistance is not as good as that of ND231. ND718 is resistant to prevalent races of loose and covered smut while Larker is



NDSU barley researchers Earl Foster and Melvern Anderson examine experimental barley lines in the Agronomy greenhouse.

susceptible to both. ND718 matures about two days ahead of Larker and is considerably better in resistance to lodging. Kernel plumpness of ND718 is equal to Larker but is lighter in test weight. The Malting Barley Improvement Association will not classify ND718 for malting and brewing until the 1978 crop is evaluated but they have indicated that tests to date have been generally favorable.

TWO-ROWED BARLEY BREEDING

Two-rowed barley breeding efforts began at NDSU in 1968. There is an increasing annual demand for two-rowed malting barleys. Initial plant breeding efforts in the program were to develop adapted two-rowed varieties with the earliness, disease resistance, and straw strength to be competitive with other cereal grains. Variety trials in the late 1960's showed two-rowed varieties had yield advantages over six-rowed varieties in the drier western part of the state. This yield advantage disappeared and actually reversed itself in the eastern areas of North Dakota presumably because of the greater disease resistance of adapted six-rowed varieties. We have now developed adapted two-rowed breeding lines which are competitive in yield and other agronomic and disease characteristics. Three two-rowed breeding lines from NDSU entered pilot scale malting and brewing tests by industry for the first time this year. At the present time all of the two-rowed barley utilized for malting is imported from Canada or brought in from the Western United States.

In the near future when malting quality standards are met, North Dakota producers can become significant suppliers of two-rowed barley as well as six-rowed barley. Two-rowed barleys produce a very uniform, plump kernel which is extremely desirable from both a malting and feed standpoint.

DURUM BREEDING

The durum breeding program at NDSU continues as a very productive crop improvement program. The program has been enlarged with funds supplied by industry and the North Dakota State Wheat Commission and now is evaluating thousands of new experimental lines of durum wheat each year. The program is improving the following characteristics of durum wheat: maturity, straw height, disease reaction, resistance to lodging or falling over, better kernel characteristics, yield, and all the known quality characteristics. The program also is adding higher gluten strength to newer durum lines to produce better pasta quality for domestic and export customers. The consumer should notice the improved gluten characteristics soon in firmer spaghetti and improved resistance to cooking, although pasta products must be handled and cooked correctly for optimum results. The improved gluten strength will make North Dakota durum wheat

much more desired by foreign customers and compete with any durum available around the world.

Two new varieties will be released and named from our durum breeding project at NDSU in 1978. One of these is a semidwarf durum with yield ability equal to Cando and having much better kernel characteristics, that is, larger kernels and slightly higher test weight along with all other characters equal to Cando. Like Cando, this new durum called Calvin probably will perform best in the eastern and northeastern areas of North Dakota with high production potential although Calvin has performed well in western and central North Dakota also. Cando and Calvin may be adapted especially for straight combining without swathing. Edmore durum is a new durum of normal height straw similar to Ward in most characteristics but having white glumes and slightly different head type or conformation. Edmore durum has high gluten strength and the first high gluten durum released by NDSU. Edmore durum will be of great interest to domestic and export customers and also popular with consumers.

INTRODUCING LEGUMES INTO UNPLOWED TAMEGRASS PASTURES

Introducing legumes into tamegrass pasture or haylands can improve the quantity and quality of forage produced without relying on expensive, annual applications of nitrogen fertilizer. Legume-grass mixtures can be established initially on tillable soils, but frequently the soils are erosion prone or too rocky to use conventional establishment. Sodseeding, seeding a forage crop into an undistributed sod, has shown some potential on such soils in trials conducted in 1977.

Our research, partially supported by a two-year grant from the Old West Regional Commission, is directed at determining the optimum technique to introduce alfalfa into existing tamegrass sods. Several experiments were seeded in 1977 into an old brome grass sod at Absaraka, ND and into a 25-year-old, deteriorating crested wheatgrass pasture at Sawyer, ND utilizing the John Deere 1500 Power-Till drill. These trials evaluated the grazing intensity permissible the establishment year, sod control via herbicides or clipping to decrease the sod's competition with the establishing legume, optimum plant density (various seeding rates and row spacings), nitrogen and phosphorus fertilization effects, two alfalfa types, and several miscellaneous legumes.

Preliminary results indicate adequate alfalfa stands can be established in brome grass and crested wheatgrass under good environmental conditions if adequate sod control via herbicides or judicious grazing is available. Several treatments appear to provide adequate sod control. Glyphosate (Roundup) at 2 to 3 lbs a.i./acre broadcast sprayed in a 6-inch band over alfalfa rows seeded 16 inches apart gave adequate sod control in both brome grass and crested wheatgrass pastures; maybe too much con-

trol since some weed invasion was noted. Paraquat at ½ lb a.i./acre gave less sod control, but possibly adequate.

Early close grazing preliminarily appears to be the best economical sod control method. Close grazing for seven days about June 1 when the sod-seeded alfalfa seedlings were about 1½ inches tall produced good, healthy-appearing alfalfa stands in bromegrass at Absaraka. Likewise, continuous light grazing allowed apparently good alfalfa stands to develop in the crested wheatgrass pasture at Sawyer. Early grazing in combination with a herbicide for sod control produced the healthiest-appearing and highest number per unit area of alfalfa plants during the 1977 fall. Winter survival of these sod seeded stands will be determined in the spring of 1978.

WEED CONTROL RESEARCH

Extensive experiments to evaluate various treatments for annual and perennial weed control in annual crops, fallow, pastures, and non-crop areas are conducted throughout North Dakota. The wild oats research is in cooperation with the Agricultural Research Service, USDA, and all research in cooperation with the State Experiment Stations. Many experiments are conducted in cooperation with farmers. Weed control research in flax is supported by the Business and Industrial Development Department with flaxseed levy funds. Sugarbeet weed control research is in cooperation with the University of Minnesota.

Research on wild oats control involves investigation of seed germination, plant biology, chemical control, and an integration of agronomic practices with herbicides for maximum control. Extensive research was conducted on chemical stimulation of wild oats seed germination with the objective of depleting the soil seed reserve. Germination of seed was incurred by sodium azide, but the germination stimulation was not complete as chemical distribution in the soil was variable and all wild oats seeds did not respond to the treatment. Research is in progress on the variation among wild selections as to differences in herbicide tolerance, growth habit, and seed dormancy. A better understanding



John Nalewaja explains NDSU weed research to a group of campus visitors.

of the biology of wild oats may give insights into the development of long term control systems.

Green and yellow foxtail (Pigeon grass) have been important weed problems in recent years. Research is in progress to develop preemergence and post-emergence herbicides for foxtail control in small grains and flax in North Dakota. Foxtail control research is closely coordinated with research on wild oats and broadleaf weed control. The objective is to develop a treatment or a series of treatments which would give broadspectrum weed control. One approach to broadspectrum weed control in small grains has been to evaluate mixtures of various herbicides each specific for a different weed species. However, some of these mixtures are antagonistic, i.e., the individual herbicide may be ineffective in combination with another herbicide.

Weeds are the most important deterrent to flax production in North Dakota. Various fall applied, preplant incorporated spring applied, preemergence surface, and postemergence herbicides treatment combinations are being evaluated throughout the state.

Weed control as related to reduced tillage is being researched with the objective of evaluating weed control and the effect of reduced tillage on crop yields. The primary objective of tillage over the years has been for weed control.

Research on the control of leafy spurge and field bindweed is in progress to develop effective chemical control measures.

Weed control research in sugarbeets is aimed at developing a system of treatments to give broad-spectrum weed control and possibly eliminating the need for hand labor.

WATERMELON VARIETIES

A three-year search for watermelon varieties suitable to the northernmost counties of North Dakota has culminated in the finding of a Japanese hybrid which appears to meet the requirements of earliness, quality and reliability. NDSU horticulturists grew and tested the melon called Sugar Delicata in cooperation with the manager of the SCS Forest Nursery at Towner. They describe it as oblong, dark green to nearly black, weighing 20 to 28 pounds. Flavor and sweetness were excellent even under adverse growing conditions and the melons mature before August 20 in the Towner area with yields running over 20 tons per acre.

ASH SELECTION AND EVALUATION

Dutch Elm disease is taking a serious toll of American elm (*Ulmus americana*) trees in areas adjacent to North Dakota. Minnesota as well as Manitoba have lost thousands of trees due to the devastation of this disease. North Dakota has still only lost minor numbers of trees, but the incidence of the disease is expected to increase in the next few years.

In 1977, Dutch elm disease was found for the first time in a native stand of American elm in eastern North Dakota, which is not an encouraging development. Prior to 1977, trees lost represented only planted specimens growing on city boulevards or in parks. Prompt removal of these diseased trees has undoubtedly helped to lessen the spread of Dutch elm disease to date in North Dakota.

In addition to elms, insect and/or disease problems are limiting the planting of our popular white-barked birches (*Betula*), poplars (*Populus*), a number of cultivars of ornamental crabapples (*Malus*) and also other trees. It is indeed unfortunate that man is one of the worst enemies of shelter and ornamental tree plantings in the Northern Plains due to careless application of 2, 4-D, particularly high volatile ester formulations.

In 1971-72, a tree selection and evaluation study was initiated by the Department of Horticulture. Since green ash (*Fraxinus pennsylvanica*) is one of our most widely adapted native trees efforts have been concentrated in this genus, but not to the exclusion of other trees. This study now represents a 3.6 acre planting at the Absaraka Horticulture Research Farm.

Data collection will continue for a number of years to determine the potential value of the respective ash selections. Evaluations will be based on tree form or growth habit, growth rate, foliage density and quality, fall color, pest resistance and other factors.

The need for introducing improved ash selections is clear. The goal of this study is to potentially release one or more new ash cultivars with superior hardiness, adaptability and form for planting in North Dakota.

NEW APPLE VARIETY IN TWO YEARS

A new variety of apple will be named, released and available in 1980 as a joint introduction by the Agricultural Research Service of the United States Department of Agriculture and the Department of Horticulture, North Dakota Agricultural Experiment Station. A name has not yet been selected for the new variety (Apple Selection Mandan 41-27).

Mandan 41-27 is from a cross of Duchess and Starking Delicious. The cross and initial selection was made under the fruit breeding program at the Great Plains Field Station, Mandan, ND. Upon termination of the fruit breeding program at the Great Plains Field Station, continued evaluations were done by the Department of Horticulture.

The tree of 41-27 is a natural semi-dwarf. By the age of 15 years it should reach 7 to 10 feet in height and about 15 feet in spread. It is precocious and frequently starts fruiting at the age of three to four years. The tree has been hardy under North Dakota conditions and has been quite free of fire-blight. Its fireblight rating would be similar to the Haralson apple. It has been an annual cropping variety.

The fruit is large, up to three inches and about three fruits per pound. The color is an attractive dark red with about 80 per cent of the surface fully colored. The flesh is greenish-yellow, medium firm, juicy and slightly coarse. The flavor is mild, subacid and pleasant for eating. It rates good as a desert apple and also for culinary purposes. The fruit ripens in late August and has a short storage life. This new variety should be considered as a replacement for Beacon apple under North Dakota conditions. It should find its major use as a home orchard variety and for local sales of fruit.

The present status of 41-27 is increasing propagation material for distribution to propagation nurseries so trees will be available to the general public for planting in the spring of 1980.

MALE/FEMALE FLOWER RATIOS IN SQUASH

Squash plants produce separate male (pollen producing) and female (pistillate-resulting in the squash fruit) flowers. Both flower types occur on the same plant and both types are needed to produce the crop. Completely gynecious (all female - no male flowers) plants have been found in cucumbers and has resulted in superior producing varieties when planted with a small percentage of male flower producing plants.

In the squash breeding program in the Department of Horticulture, several plants were found with extremely high numbers of fruit produced. The progeny from these plants have a low male/female ratio enabling increased fruit set. Flower counts during 1977 showed Buttercup squash had an average of 4.4 male flowers to each female flower. A selection produced 2.7 male flowers to each female flower. One plant in these breeding lines produced 56 fruits during 1977, compared with 5 to 8 fruits per plant for the average squash variety.

These selection lines are strictly for breeding purposes at the present time since they lack many desirable horticultural characteristics. Inheritance of the male/female flower ratios is now being studied and hopefully can be incorporated into desirable varieties. It may be possible to greatly increase production through the use of this genetic characteristic.

HORTICULTURE AND FORESTRY RESEARCH FARM ABSARAKA, NORTH DAKOTA

On January 31, 1974, final papers were signed for the purchase of 80 acres of land one and one-half miles east and one mile north of Absaraka, North Dakota. This land was purchased basically for a horticultural and forestry research site. The site is bounded on the north, west and south sides by excellent windbreaks.

The land was surveyed by the Department of Agricultural Engineering. A continuous roadway completed in 1976, entering from the north was placed about 330 feet in from the outer boundaries. Placing

the road in this manner allowed for the same depth for all plots, with the extreme distance no more than 330 feet.

A well, 50 feet deep, was dug in the fall of 1976. This supplied adequate water for the multi-purpose storage building and allowed for some drip irrigation research.

Electricity was also brought into the area where the storage building was proposed.

During the winter and spring of 1977 a multi-purpose storage building was constructed. This frame building 30 x 40 feet in area is divided into several areas: a work-storage area 30 x 28 feet, a work-laboratory area of 12 x 20 feet and two rest rooms. All areas except the work-storage area can be heated electrically.

The center area of some 35 acres that is surrounded by the plot road is devoted to an arboretum for hardiness studies. The areas on the outside of the plot road have been divided so that they will contain certain types of horticultural research or may be designated to other departments for short term or permanent usage. The areas not specifically set up for perennial plants are being placed on a permanent type of rotation system.

Demand for usage of land on this site has been increasing. Since establishment in 1974 the Departments of Entomology, Soils, Agronomy-Weeds and Plant Pathology and the Agronomy Seed Farm have used the area for research. Permanent research areas have been delegated to Plant Pathology, Soils and Agronomy-Weeds.

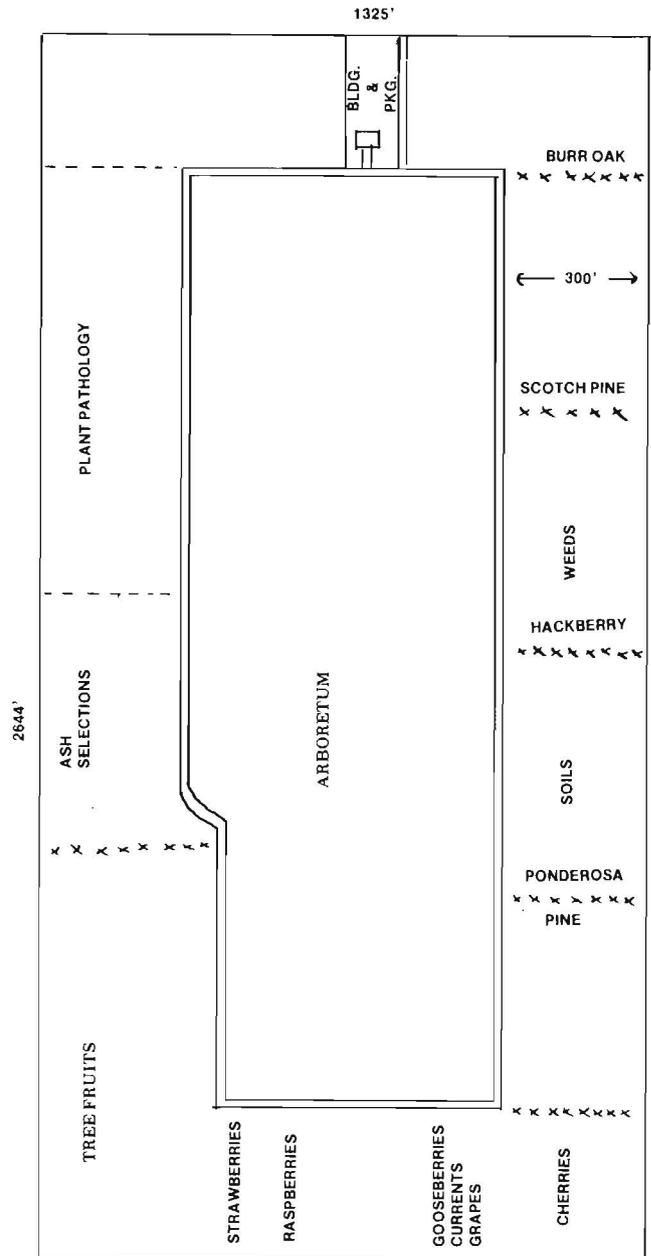
This area has allowed the Department of Horticulture to develop research in a soil area that is more typical for horticultural production. The soil type is Spottswood sandy loam underlain by a water-bearing gravel layer. It is a relatively early soil and is relatively easy to till.

It is reasonable to assume that other areas such as this should be evaluated because of the probable land stress situation at the Fargo Main Station.



Horticulturist Dale Herman examines plant material at the Horticulture and Forestry Research Farm near Absaraka.

ABSARAKA FARM



SUNFLOWER WATER USE EFFICIENCY

In the past 20 years, sunflower production acreage in North Dakota alone has increased a hundred-fold. From 1957 to 1977 acreage increased from approximately 10,000 to 1.2 million acres. At the same time yields have increased almost three-fold, from approximately 700 to 2000 lbs of seed/acre. Needless to say, production advancements have been outstanding.

As the acreage and emphasis on sunflower production has increased, the need for proper management has become increasingly apparent. Maximum yields and optimum resource utilization are two objectives of farm management that are constantly demanding research attention. One production resource that significantly affects crop yields in North Dakota is

crop-available moisture. Although farm managers have some limited control over crop-available moisture, they are more often at the mercy of Mother Nature.

In an attempt to circumvent Mother Nature, or at least to find out how to use natural rainfall to its best advantage, research was initiated in 1977 in the Department of Soils to determine water up-take patterns of several sunflower varieties. Additional studies of sunflowers were initiated to determine yield response to various amounts of water use. Water use efficiency, or seed yield per inch of water used, is being compared for several crops, including sunflowers, corn, small grains, forage crops, sugarbeets, and beans. Crops are being studied on sites located in both eastern North Dakota and western Minnesota. In addition, both dryland and irrigated sites are being studied.

Yields per amount of water used by the crop are the basis for comparison of 8 sunflower varieties, including such superstars as Peredovik, Cargill 204, and Interstate 894. In the coming year research will be expanded to include the effects of variable nitrogen fertilizer rates on sunflower yield and water use.

BACTERIAL BLIGHT AND CERTIFIED DRY EDIBLE BEAN SEED PRODUCTION IN NORTH DAKOTA

Initial attempts at growing certified dry edible bean seed in North Dakota have been unsuccessful. The primary reason for failure has been the presence of bacterial diseases. Diseased plants detected during field inspection or infested seed determined by a laboratory test cause the total yield from any field to be rejected for certification. Acreage planted for certification in 1976 totaled 2,631, but only 1,565 passed both field and laboratory inspection. In 1977, 943 acres of beans were planted for certification. Of these, 35 acres passed field inspection.

Research at NDSU has emphasized improvement of bean seed testing to detect blight bacteria. A new test utilizing enrichment culture and vacuum infiltration of seedlings has been developed and is undergoing critical evaluation. Should this test continue to prove satisfactory, testing of breeder, foundation, and certified seed before it is released to certified bean growers may aid growers in producing acceptable seed.

Clean seed will be of little value if alternate sources of inoculum exist within the state. Weed and native legumes are being evaluated for their capability to maintain bean bacteria as pathogens or as epiphytes. A bacterium taken from native vetch was pathogenic on bean. This bacterium (*Pseudomonas syringae*) causes bean brown spot, has a wide range and is most likely the one existing on alternate vegetation.

Airborne bacteria also provide an alternate source of the pathogens. Rainsplash or sprinkler irrigation can cause bacteria to become airborne and spread to clean fields. NDSU plant pathologists have

shown that airborne bacteria can survive in air currents over three hours and that airborne bacteria landing on susceptible plants initiate infections. To assess the availability of bacteria for spread during the course of a rainstorm, NDSU plant pathologists have shown that bacteria are exuded onto the surface of a wet bean leaf from a bacterial lesion for over 24 hours. This indicates that bacteria are available for dispersal throughout most rainstorms.

FLAX RUST STUDIES

A substantial acreage of North Dakota is devoted to the culture of flax which annually produces about 50 per cent of the oilseed crop in the United States. The flax rust pathogen, *Melampsora lini*, endemic to all areas where flax is commercially grown, provides a constant threat to the crop.

The fungus, *M. lini*, overwinters as black, crusty telia on flax straw left in fields after harvest. These telial pustules contain spores which produce the sexual reproductive structures of the fungus in the spring; the latter being responsible for the primary infection of young flax seedlings.

Studies of the flax rust organism are being conducted in The Department of Plant Pathology, using both light and electron microscopy. The goal of this research to document the disease cycle of the host-parasite interaction which will provide detailed information on the production of sexual structures and fertilization process, mode of infection, ramification of the fungus in host tissues and spread of



Plant Pathologist Randall Gold prepares flax plants for inoculation with flax rust fungus.

the disease organism. This information is critical for the development of effective control measures and resistant varieties.

FUNGICIDE SPRAY TRIALS

Fungicide spray trials are planted each year to determine the effectiveness of fungicides on the market for controlling wheat leaf rust. The percentage of control of new compounds is also evaluated, often before they are on the market. Plots are planted with a small drill, randomized and replicated several times for leaf rust evaluations and yield determinations.

Factors important in controlling leaf rust with fungicides such as when the compounds are applied, application rate, amount of water and coverage are also evaluated.

Since leaf rust development varies with years and varieties, rust is controlled on several varieties to determine the potential destructiveness of leaf rust. Yield loss is the average yield of the plots sprayed with fungicide minus the average yield of unsprayed plots.

Rust is evaluated several times throughout the season to determine the rate of rust development for the season and the variety. Several varieties have been identified as slow rusters; that is varieties on which rust does not develop as rapidly and whose yield is not significantly reduced by leaf rust.

SHELTERBELT DISEASES BEING STUDIED

During 1977, the pathology portion of the shelterbelt decline cooperative project was expanded to include a full-time forest pathologist to work on disease problems of shelterbelt trees. To enable researchers to determine what role diseases play in the shelterbelt decline problem and eventually develop recommendations to reduce or avoid such disease problems, one of the first steps is to find out what diseases are involved and how extensive they are. A statewide survey of disease problems in shelterbelts is planned for 1978.

Previous surveys have concentrated on a single disease or a single tree species, ignoring others. This survey will avoid this pitfall by looking at many different species and their problems. Most surveys will be made with particular problems in mind, but we will watch for and record new or potentially damaging diseases.

Some older shelterbelts have lost so many trees that they are being removed. These will be studied to determine what the problems are and what can be done with newer plantings to prevent the same problems. Of particular concern are problems on conifers. Also of concern is interaction between pathogens and problems caused by farm practices such as herbicide, livestock, and mechanical damage, which result in weakened or wounded trees. Shelterbelts could have longer lifetimes if farm practices caused less injury.



Plant pathologists Robert Stack and James Walla use an electronic instrument to detect decay inside of a tree trunk, part of the department's research on shelterbelt diseases.

Frequently statewide surveys are limited to sites along main highways; the reliability of such a method is questionable. Shelterbelts will be randomly preselected from each county using maps with shelterbelts plotted on them. This planning is being done now.

A preliminary survey of shelterbelts in Ransom County was done this summer. The objective of the survey was to test procedures for doing the statewide surveys, that is determining most reliable and/or fastest disease detection methods and finding a reliable method of recording information. This preliminary survey will also help determine the significance of different disease levels between groups of trees and will point researchers in the right direction in determining the number of trees needed for statistical analysis.

Cooperative research has been set up with the SCD Lincoln-Oakes Nursery in Bismarck to reduce disease problems which are presently limiting the nursery's production of cottonwoods and poplars. Healthier stock produced in the nursery should result in higher field survival rates and therefore in more uniform and effective shelterbelts.

NDSU pathologists are also working with U.S. Forest Service entomologists in Bottineau to begin research on interaction of borers and heartrot in green ash and willow. The shelterbelt surveys necessary in this program, with pathologists and entomologists together in the field, could help determine the cause of other problems where symptoms of insect and disease damage is similar.

STORAGE ROT IN SUGARBEET PILES

Most of the sugar loss from sugarbeets caused by disease occurs as decay in storage piles in the Red River Valley of North Dakota and Minnesota. Over 3½ million tons of sugarbeets are placed in storage. Sampling roots as they entered a factory during the

1974-75 processing season showed that 1.22 per cent by weight of the roots were rotted. This small amount translated into a sugar loss of 2.9 million pounds for all factories in the valley. During the 1975-76 processing season the sugar loss was much less, being only 24 per cent of the previous years loss. The three pathogens that caused most of this decay were *Phoma betae*, *Penicillium claviforme* and *Botrytis cinerea*.



William Bugbee, plant pathologist, is working on reducing storage rot in sugarbeet piles.

Phoma betae is the most important of these three pathogens because it is associated with all phases of the sugarbeet's life cycle. This fungus infects the seed, causes seedling disease, leaf spots, or remains inactive within the sugarbeet until the root is harvested. After the root has been stored for several weeks, the pathogen becomes active and decays the root. Research by the Department of Plant Pathology has shown that the fungus will remain alive in our soils for at least 27 months after seed has been planted. Therefore, a four-year rotation is required to prevent planting into phoma-infested soil. The fungus is present all year around in the soil of storage yards where there is an annual renewal of root tissue to support the survival of the fungus.

The fungus *B. cinerea* is recognized in other parts of the world as the most destructive pathogen of stored sugarbeets. This might well be the case in the U.S. also if it were not for *P. claviforme*, another less effective pathogen, found by NDSU investigations

to be antagonistic towards *B. cinerea*. This is an unusual situation where a less virulent pathogen inhibits the growth of a more virulent pathogen.

The research effort on this project also has shown that bacteria, yeast, and occasionally fungi inhabit healthy roots. Since these microorganisms increase in number during the storage period, it is possible that their metabolic activity contributes towards a lowering of the juice quality of the root. Proving this has been difficult, but efforts continue.

Our efforts to reduce storage rot losses has centered on the identification and development of genetic resistance to the disease causing fungi. In 1977, two breeding lines with resistance to *P. betae*, *B. cinerea* and *P. claviforme* were released to private sugarbeet breeders. It is anticipated these lines will serve as sources of resistance in the development of storage rot resistant hybrids.

SWINE IN UTERO LIVABILITY

Research was initiated by the Department of Animal Science to investigate feasibility of progesterone injections at various times early in gestation to increase swine litter size. Swinemen have long been aware that a major loss of the potential pig crop (30 per cent) occurs before 30 days of gestation. Progesterone injections of three days duration given either at 8-10 days or 16-18 days post-breeding were given to test this compound's potential saving effect on embryos lost. Final criteria will be pigs born per sow and pigs born alive. Sows are due to farrow beginning January 1 and results collected then should provide answers as to the advisability of using hormone treatments in such a manner to stimulate livability or are there other physiological mechanisms eliminating these embryos such that uterine capacity is not overloaded.

FASTING AND SWINE REPRODUCTION

A project has been conducted at the NDSU Hog Farm to determine the effects of fasting, imposed at weaning, on the reproductive performance of sows. This project was developed in response to the management practice of withholding feed for several days from newly weaned sows.

Producers from several states have indicated that fasting hastens the "drying off" process and allows for a more rapid return to estrus. To study this procedure, 70 sows have been used thus far to observe time to return to estrus, ovulation rate and percent embryonic mortality.

Results from several trials at NDSU have indicated that fasting does not shorten the interval from weaning to estrus and as the lactation period increases, fasting delays return to heat. Results also indicate that fasting for a period of four days has a detrimental effect on ovulation rate.

During the coming year, data will be obtained that will indicate whether or not fasting improves litter size at birth.

CAFFEINE INFLUENCES ON REPRODUCTION

Another study at NDSU is studying the effect of caffeine intake on reproduction. Caffeine is a compound which Americans daily consume in the form of coffee, tea and soft drinks.

Preliminary trials with rats indicate that low levels of caffeine may improve the number of animals that conceive and may also increase the number of fetuses in pregnant animals.

ADRENAL CORTICAL LEVELS IN SHEEP

Previous research conducted at NDSU has implicated the secretions of the adrenal gland as one factor responsible for early embryonic death losses in ewes. More recently, studies have been made into the normal, rhythmic pattern of adrenal corticoid concentrations in the plasma of ewes in a confinement situation.

Studies have been initiated by the Department of Animal Science to ascertain the influence of acute and chronic high temperatures on adrenal corticoid concentrations. Following exposure to elevated temperatures, corticoid levels tend to rise rapidly indicating a maximal response to the initial onset of acute stress. Data from long term high temperature exposure indicates a rapid adaptation as signified by decreasing corticoid concentrations following the initial day of exposure. These results identify the immediate onset of high temperatures as being the stimulus for increased adrenal corticoid secretion and possibly a cause of embryonic mortality in ewes.

MILK PROGESTERONE AND OVARIAN ACTIVITY

During the past 8-10 years scientists have collected blood samples to monitor the level of hormone being produced and thus drew conclusions regarding endocrine activity within the body. Recently analysis of milk samples have indicated they would also allow for monitoring ovarian activity and provide for diagnosis of pregnancy as early as 21 days post-breeding.

Work has been initiated by the Animal Science department to evaluate these procedures as possible pregnancy indicators with samples collected from cows in various stages of their reproductive cycle. These samples are being analyzed to develop patterns such that later samples may be plotted against known standards to determine the actual stage of reproduction.

OUT-OF-SEASON LAMBING

A project has been initiated to determine the practical value of using progesterone pessaries in the induction of early estrus in sheep. The use of hormones to induce estrus out-of-season may be a

means of increasing production by providing the producer with a fall lamb crop.

The hormones used were progesterone soaked sponges (pessaries) and gonadotropins. The progesterone acts to stimulate estrus after removal of the pessary. Gonadotropins are then injected IM to stimulate follicular development so mature ovum may be present at the time of mating.

The hormones used on anestrus ewes stimulated a significant level of estrus response. The hormone stimulated a significant increase in estrous response in the out-of-season breeding. Lambing performance of the treated ewes bred produced a viable fall lamb crop that was increased significantly over the untreated ewes. The response to progesterone pessaries and gonadotropin injections produced significant results suggesting that hormones used for inducing out-of-season lambing may be feasible to the producer.



Researchers in the Department of Animal Science surgically collect blood from sheep to determine blood hormone levels.

IMPACTS OF ENERGY DEVELOPMENT

A project in the Department of Agricultural Economics to evaluate the effects of alternative patterns of coal-based energy development in North Dakota, Montana, and Wyoming is nearing completion. The emphasis of the project is on the effects of alternative development patterns on economic activity, land and water resources, and the costs and revenues of state and local governments.

Surveys of construction and operating work forces at seven coal mines and seven power plants in the study area have been conducted. The purpose of the surveys was to obtain information on the socioeconomic characteristics of the work forces associated with coal-based energy development.

The North Dakota input-output model has been used to estimate the economic impacts of energy development. Estimates have been made of gross business volume, personal income, and employment associated with different levels of development. The results indicate substantial growth in the various

economic sectors in the western coal development areas.

The costs associated with the reclamation of strip-mined land in North Dakota have been estimated using an engineering approach. The reclamation process was divided into stages, with reshaping and the application of topsoil accounting for most of the cost of reclamation.

A linear programming model is being used to analyze water usage under alternative levels of coal energy demand, water cost, and other factors. The model selects those coal conversion technologies which result in the lowest total energy production and transportation cost while satisfying energy demands.

Analysis of the effects of energy development on governmental costs and revenues indicates that the substantial population growth accompanying an energy related project can cause fiscal difficulties for some local units of government during construction activities. During the operation phase, however, financial problems are reduced and, for some communities, revenue surpluses may exist.

The project is scheduled for completion in the coming year. Work remaining includes refinement of the linear programming model and analysis of reclamation costs under alternative reclamation goals.

DEVILS LAKE BASIN STUDY/ ALTERNATIVE USES OF WETLANDS

A study to analyze the economy of the Devils Lake Basin and assess the economic impact of alternative plans for water and land management in the basin is nearing completion in the Department of Agricultural Economics.

Data related to a number of economic dimensions have been collected and assembled to provide an overview of economic trends in the basin. Projections of the future economic structure of the basin will be made and the overall economic impact of changes in selected economic sectors due to land and water management plans will be analyzed. The economic impact on agriculture and recreation as it relates to the overall basin economy will be emphasized.

Information gathered in two surveys of farm operators was used to develop a composite acre for use in estimating flood damages. The estimated annual average loss on land that may be affected by flooding in the basin was \$8.71 per acre using long-run price relationships. The total annual average dollar loss due to flooding in the entire basin was estimated to be \$1.9 million using long-run price relationships. A methodology for determining composite flood losses in the basin was developed.

The value of wetlands both to the recreationist and the farm operator plays a key role in an analysis of alternative land and water management plans. Therefore, a literature review was conducted on the economic value of fish and wildlife and their habi-

tats. A bibliography, which included a section on wetland economics, was completed.

A survey of nonresident hunters was conducted to assess the significance of their expenditures in the basin and the state. Results of the survey indicated that expenditures of nonresident hunters in the basin in 1976 were approximately \$865,000 — which resulted in an induced gross business volume of \$2.2 million and employment of 47 individuals.

SHEYENNE RIVER BASIN

Research completed under the Sheyenne River Basin project has ranged from detection methods for salmonella to attitudes of residents and public officials. The project objective is to evaluate methods of improving water quality. Achievement of this objective has involved measurement of current water quality, identification of pollutant sources, simulation of methods to reduce sediment entering the river, and documentation of perceptions of water quality and attitudes toward improving water quality.

Chemical and bacteriological analysis revealed frequent cases of pollutants exceeding state and/or federal standards. Major contributors to pollutant loadings were soil loss and sediment, and livestock and human wastes. Simulations of cropping patterns and conservation practices in the basin yielded estimates that soil loss and sediment could be reduced by about 50 percent if summer fallow were eliminated. An additional reduction in sediment could be achieved by adopting contour strip-cropping as a conservation practice. There was no economic loss estimated in terms of net return to the farmer. In fact, the simulation model estimated that net farm income would increase with the adoption of these changes.

Water pollution and destruction of natural resources, such as soil erosion, consistently were ranked as the first or second most important pollution problem in North Dakota by public decision makers with jurisdiction in the Lower Sheyenne River Basin (LSRB). Eighty-eight percent of public decision makers and about two-thirds of farm and nonfarm rural residents in the LSRB indicated concern about the water quality in the Sheyenne River. One might expect strong public support for adoption of cropping practices and other means to improve the water quality given such a high level of concern and low cost methods of achieving improved water quality.

Major activity during 1978, the final year of the project, will be to publish and disseminate the findings of the project.

RESEARCH-EXTENSION RURAL DEVELOPMENT

Over 80 percent of the communities in North Dakota are experiencing a population decline as farm numbers decrease and the rural to urban mi-

gration continues in the state. This situation poses problems for businessmen who provide the goods and services needed in a viable community and problems for the urban and rural people dependent upon the community for public services, such as schools, medical care, police and fire protection.

The rural development project in North Dakota involves a joint research and extension program aimed at increasing the capability of people in rural areas to identify and solve community development problems and to successfully pursue viable community development opportunities.

Several feasibility studies have been completed under this project, including the feasibility of: an alfalfa pelleting plant; flax fiber processing plant; portable seed cleaning unit; large-scale hog slaughtering plant; large-scale cooperatively owned hog farrowing system; and small livestock slaughtering and meat processing plants in rural communities.

Other activities completed or initiated include: leadership and community development workshops; in-depth group interviews to determine the strong and weak points of individual businesses and the total community retail services provided; the economic impact of irrigation on communities; and a study regarding attitudes and problems associated with land use planning.

One of the major activities conducted under this project has been a five-week educational course aimed at rural business and industrial development. Departments and agencies cooperating in presenting the course include: the North Dakota Cooperative Extension Service; Agricultural Economics Department; North Dakota Business and Development Department; Otter Tail Power Company; Montana Dakota Utilities; Small Business Administration and the Regional Planning Councils. The course has been presented in seven communities to date.

SUGARBEET INSECT REARING

Cutworms cause extensive localized damage in sugarbeets throughout the Red River Valley. Advanced prediction of areas of infestation is very difficult, which hinders researchers in establishing chemical control trials. In addition, the biology of these insects in the valley has not been clearly established. Two species, the dark-sided cutworm (*Euxoa messoria*) and the red-backed cutworm (*Euxoa ochrogaster*) are commonly found in sugarbeets in the Valley. Research is presently underway to establish laboratory colonies of these cutworms.

Laboratory cultures provide sufficient insect material for basic biological studies essential for a better understanding of field populations in sugarbeets. Of a more immediate nature, however, laboratory reared cutworms are available on a year around basis for testing presently used and experimental chemicals for control. Laboratory reared cutworms can be artificially infested into sugarbeet plots in the field to further screen chemicals under controlled conditions and with a known population

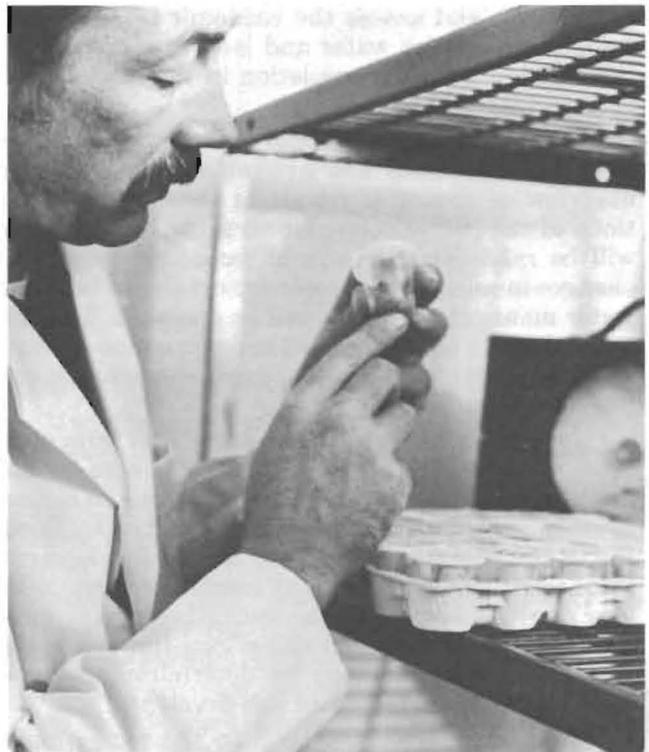
of insects. The principle goal of this research is to provide the sugarbeet grower with effective cultural and chemical control recommendations to reduce or eliminate losses due to cutworms in beets.

RIMS/RIMAS PROGRESS REPORT

Three major activities are currently under way in the RIMS/RIMAS project. The activities are: 1) composite mapping of the economic value of coal fields, agricultural land, and wildlife habitat in Mercer County to identify a continuum of avoidance to preference locations for coal mining; 2) computer assisted mapping overlays of soils and land cover to identify conflict areas and optimum land uses; and 3) an environmental-economic simulation model of coal and other land use impacts.

Composite Mapping System-II (CMS-II) was used to exhibit the value of each 160-acre unit (quarter sections) in Mercer County in various uses. Livestock grazing, crop production, wildlife support, and coal mining were the uses considered. Avoidance and exclusion areas identified by the North Dakota Public Service Commission and currently irrigated land were also identified on the CMS-II generated maps.

Agricultural uses and wildlife habitat were not competitive in economic value with areas of identified coal fields. The economic value of wildlife was competitive with agricultural values on the lower productivity soils. Reclamation procedures taken after coal mining will achieve higher valued results if aimed at multiple use (rangeland and wildlife habitat) or complementary uses (cropland inter-



Albin Anderson, Department of Entomology, is working to establish laboratory colonies of sugarbeet insects.

dispersed with wildlife habitat) than a single use of the reclaimed land.

Computer-generated maps of general soil associations for each county in North Dakota are within the current capabilities of RIMS/RIMAS. These maps can be produced at varying scales and include all or selected soil associations. Transparent overlay maps of either soil associations or land cover generated by the computer are expected to be available in early 1978. Land cover maps, interpreted from the Bureau of Land Management high-altitude photos, will be available only for Oliver County and parts of Mercer, McLean, Morton, and Burleigh counties. These overlay composite maps will be useful to persons evaluating current and potential land uses.

A simulation model is operating which includes the following modules: detailed agriculture, water quality, economic, coal development, demographic, and government. This computer model is currently being evaluated and will be expanded in 1978 to include a detailed module on coal mining-reclamation alternatives and their future impacts. The model is being tested on a 4,900-square mile area in the coal mining area of western North Dakota.

PREDATOR ON MOSQUITO LARVAE STUDIED

Mosquitoes are not only annoying but are a source of disease for man and livestock. Their control is expensive and can pollute the environment with insecticides. Many chemicals are becoming less effective as mosquitoes develop resistance to them. Staff of the Department of Entomology are working on an alternative to chemical control of mosquitoes by using the planarian (a free living flatworm) *Dugesia tigrina* as a predator on mosquito larvae.

Accidental contamination with these worms has decimated experimental mosquito colonies. This led workers in California to study the feasibility of using another species of *Dugesia* to control mosquito and midge larvae. They found that these worms



An NDSU entomologist samples a pool of water for the planarian, a flatworm that feeds on mosquito larvae.

can significantly reduce the number of larvae at experimental sites. *Dugesia tigrina* is abundant in Red River of the North. The planaria catch their prey either by physical contact or by entangling the prey in a slime trail which the worms secrete as they move. More mosquito larvae may be killed than are eaten.

Planarians have some features which other organisms used as biological controls lack. When prey mosquitoes are scarce, the *Dugesia* population does not necessarily decrease. Planarians can eat a variety of organisms and usually do not resort to cannibalism. They can also go without food for relatively long periods. Migration is a problem encountered with many predators. Planarians cannot move from one body of water to another on their own. This allows a dense population in one area without unwanted contamination in other area.

Field work shows *D. tigrina* can reproduce in small artificial ponds. In the laboratory, 25 *D. tigrina* can destroy 50 mosquito larvae in 2-5 days. Water depth, size of planarians and size of mosquito larvae influence the number of larvae destroyed.

Several problems remain to be solved if *D. tigrina* is to be considered as a biological control. An economical method for mass rearing and dissemination must be found. The effect of predators of *D. tigrina* on mosquito control as well as the effect of alternative prey on the number of larvae destroyed must be evaluated.

INSECT REARING FACILITY

The research staff of the Department of Entomology is working with natural populations of insects as they affect man and his environment. However, not all work can be conducted in the field under natural conditions. Much information can be gained during the winter with laboratory experiments so that summer field work can be more productive. A complete understanding of insect control, economic importance, ecology, behavior, etc., often requires laboratory experiments with insects of known age and condition. For this purpose an insect rearing facility was included in the department space in Hultz Hall, the new agricultural science building at NDSU.

In the rearing facility are 15 small (5' x 5') rooms with controlled temperature, relative humidity and light that may be programmed to provide suitable conditions for the insect and type of experiment. In addition there are two low temperature rooms for maintaining insects in dormant or overwintering stages. A preparation room with equipment for making and sterilizing insect diets, cages, etc., is joined to the rearing rooms. The whole facility is designed with double doors and limited access to prevent insects from escaping.

Several types of experiments are conducted with insects maintained in the rearing rooms. Many different species, each with particular requirements for rearing are used by the entomologists. In most

cases, several types of research are conducted at the same time with each insect species. Some of the types of experiments include:

Screening of chemical and biological control agents. Before field tests can be made, the effectiveness and dosage rates of the agents must be determined by laboratory experiments. Only those agents that show promise at this stage will be further tested.

Life cycle and development. The developmental stages of insects are examined to determine if there is a vulnerable stage or condition in which they may be more effectively controlled. The overwintering or dormancy capabilities of insects and the length of time required for development under different conditions can be found out. The tolerance to temperature and humidity ranges can be discovered.

Nutrition and feeding behavior. Experiments can determine what actually enables an insect to locate the plant or animal upon which they feed. The role of various nutrients in insect development can be established to help in understanding the relationship between an insect and its principle host. Attractant baits or traps can be developed.

Physiology and ecology. Investigations of the physiology and ecology require rearing insects under strictly defined conditions. These experiments are essential for a complete understanding of the insects and how they survive and prosper.

Insect identification. Many insect species are most damaging in the immature stages. Often the first sign of the insects and the potential damage is the finding of immature forms, eggs, larvae or pupae. Frequently the immature forms are so tiny or poorly known that identification is extremely difficult. These forms may be reared to the adult stage which is more readily identified. Specimens can be reared and samples of all of the stages preserved for future reference.

Insect systematics. Research can be conducted to determine if populations of insects represent distinct species or strains of the same species. It is



Entomologist Greg Mulkern checks controls in the insect rearing facility.

important to learn if the different strains are equally damaging or are susceptible to the same control programs. Sometimes insect species adapt to new hosts or conditions and become more serious problems than before. It is important to understand how this comes about. Rearing and breeding different populations is essential for this research.

Training programs. The availability of insect cultures is useful in training research and survey people, and for familiarizing growers, cooperators and students with the life cycle and habits of various insect pests. All stages may be shown at the same time during the winter season when the insects are not present in the natural habitat.

LARGE ROUND HAY BALE STORAGE AND HANDLING LOSSES

A project has been initiated by the Agricultural Engineering Department to evaluate short and long term storage losses in large round hay bales resulting from various outdoor storage methods. Research to date has indicated that storage losses in large round bales may not be significant if the bales are stored on a well drained area with 12-18 inches of air space on all sides of each bale. However, in North Dakota it is a common practice to stack large round bales two, three, and four bales high. This method of storage does present several advantages; less land area is required for storage and the bales do not become completely covered with snow during the winter, so less snow has to be moved for access to the bales. What is not known is how significantly storage losses are increased, if at all, by stacking bales on top of each other.

Initial plans called for hay to be harvested using a large round baler at Hettinger, Carrington, and Fargo. These sites would represent somewhat of a climatic cross section of the state. However, due to the severe drought in the southwestern part of the state, hay was not available for this project at Hettinger. Hay was harvested at both Carrington and Fargo using the same baler and baler operator at both locations. Before the bales at Fargo could be weighed and placed into storage, a 3½ inch rain-



Storage losses in large round hay bales are under investigation by NDSU agricultural engineers.

fall flooded the storage site and resulted in the termination of data collection due to severe bale deterioration.

At Carrington, samples of hay were taken at the time of harvest. Each bale was individually weighed and randomly selected for placement into various storage arrangements. Each storage arrangement was replicated to permit the study of both short term (6-7 months) and long term (18-19 months) storage losses. The bales will be weighed again at the end of the storage periods and weights corrected for moisture to determine dry matter loss. Laboratory analysis will be used to determine additional parameters necessary to indicate any changes in nutritional quality.

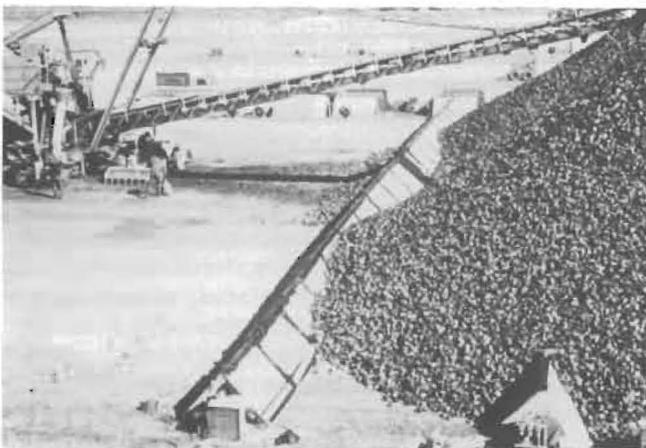
Physical observation of hay quality will also be made at the end of the storage periods to note hay color change, odor, and depth and location of weathering.

Results of the sample analysis will be used to determine the short and long term storage losses farmers could expect if large round bales are stacked in various ways compared to current recommendations based on research in other states and baler manufacturer recommendations.

DEEP FREEZING PILED SUGARBEETS WITH FORCED AIR VENTILATION

A research project was initiated in 1976 to determine the design parameters for ventilation and freezing sugarbeet piles at sugar processing plants in the Red River Valley and to evaluate the performance of air flow systems for ventilation of sugarbeet piles. This project is a cooperative effort involving American Crystal Sugar Company and the Agricultural Engineering Department.

The primary purpose of ventilating and freezing a sugarbeet pile is to reduce the loss of sugar due to respiration and microbial activity. The estimated loss of sugar from stored sugarbeets is 0.5 pounds per ton per day. For a plant processing 5000 tons of beets per day, such as the Moorhead plant, the average daily sugar loss from stored sugarbeets



Reduction of sugar losses from piled sugarbeets is the objective of a ventilation study by the Agricultural Engineering Department.

would be 137,500 pounds. These losses are primarily dependent on the temperature of beets in storage and the level of bruising the sugarbeets have sustained.

Since the cells of the stored sugarbeet are living, they respire in order to maintain life. This results in the reduction of sugar and the production of heat. Daily sugar losses have been found to be temperature dependent. While daily sugar losses at 32°F are about 0.2 pound per ton, the losses at 95°F are about 2.6 pounds per ton. If no ventilation is used, the heat from respiration causes a rise in temperature which results in an increase in rate of respiration. Mechanical ventilation with natural air can be used to reduce and maintain the beet pile temperature.

Research in the Soviet Union has indicated that sugar losses are greatly reduced by mechanical ventilation of beet piles to reduce pile temperature to 32°F, although some sugar loss is apparent even at that temperature. Sugar loss can be reduced to zero by freezing the beets at about 19°F. However, extreme care must be taken to prevent the beets from thawing due to the extremely rapid deterioration that would result.

During the time of harvest and stockpiling season of 1976, triangular wooden duct sections, each 8 feet long and made primarily of 2 x 6 lumber and 3/8" plywood, were placed on the ground ahead of the piling operation in two piles. Twenty duct sections were used to form a "run" perpendicular to the pile length. Temperature monitoring equipment was positioned at various positions, vertically and horizontally, in both piles as well as in an unventilated control pile. The runs were spaced 20 feet on center. Fans were placed on each end of the run to provide approximately 20 cubic feet per minute of ventilation air per ton of sugarbeets. One of the ventilated piles contained approximately 16,000 tons of beets and the other contained approximately 18,000 tons. Beet samples were taken from both ventilated piles and the control pile at the time of piling to determine a reference sugar content.

Ambient air was used to cool the two ventilated piles to maintain a pile temperature of 37°-39°F. This was accomplished by ventilating anytime the ambient air temperature was less than the pile temperature but above freezing.

In December 1976, fans were operated continuously to freeze the beet piles. Fans were operated anytime the ambient air temperature was less than the pile temperature. Using this procedure it was possible to lower the pile temperature to -10°F.

Although evaluation of sugar sample data is not complete, temperature data for the ventilated piles and control pile, plus visual observation, indicates that ventilation and freezing were highly successful in reducing sugar losses. Actual physical and economic effectiveness will become known after further data evaluation.

IRRIGATION SCHEDULING FOR MECHANIZED SPRINKLER SYSTEMS

A first step in achieving energy and water conservation in irrigated agriculture is to eliminate needless applications of water. This goal is presently best achieved by using water balance scheduling techniques. Studies are being conducted by the Agricultural Engineering Department to develop needed input data for these methods of scheduling. Crops being studied are small grains, corn, alfalfa, potatoes, sugar beets, soybeans, dry edible beans, sunflowers, and grain sorghum. Data summaries are being produced in the areas of (1) seasonal distributions of water use for sizing of pumping capacities, (2) crop coefficient curves for scheduling methods, (3) plant water stress criteria for determining when to irrigate, (4) root zone depth advance with time after crop emergence, and (5) yield responses to seasonal water use.

Computer simulation studies have been conducted to compare the relative efficiency of water balance scheduling with simpler, less accurate methods. When comparisons are made at equivalent yield attainment levels, the results show water balance scheduling can achieve a 20-25 percent water savings. By adding plant water stress criteria for determining when to irrigate, an additional 15 percent savings appears likely.

A simplified water balance method (called check-book method) has been developed for farmers that are unable to obtain or utilize a commercial irrigation scheduling service. This method is being user tested with good results.

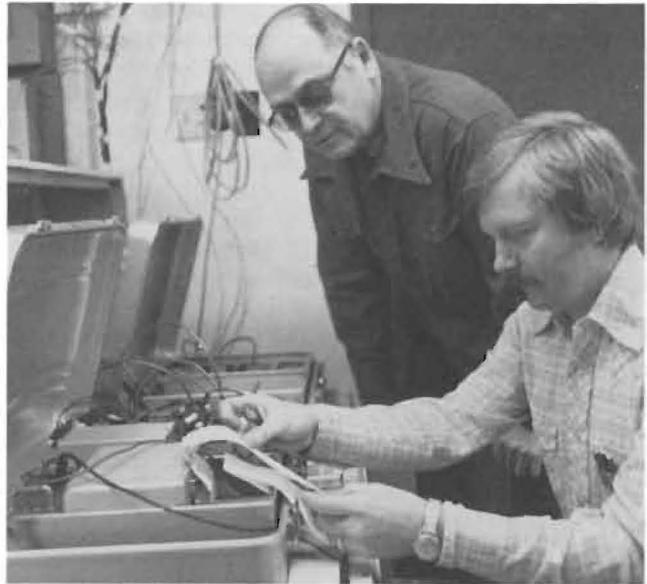
LIVESTOCK VENTILATION

The Agricultural Engineering Department is investigating the use of solar energy for livestock ventilation. The project is centered around a 40-animal beef confinement barn on one of NDSU's research farms. The problem in a cold confinement barn is one of removing moisture to avoid high relative humidity. It is expected that a solar collector installed on the intake side of the ventilation system will increase moisture removal by heating the air and thereby lowering the relative humidity to acceptable levels.

The solar heating system will be operated without heat storage, so moisture accumulations will need to be removed during periods when solar energy is available. This system will be compared with a rock heat exchanger recovery system which conserves heat during periods of low temperature and high chill factors.

The barn is approximately 30 x 50 feet and is divided lengthwise into two sections. One section will have a single glazed solar collector installed on the roof. The size of the collector will be 16 x 48 feet. The other section will serve as a control.

The collector will be built on site. Black painted sheet steel will serve as the absorber plate and



Robert Woell, graduate research assistant, and Richard Witz, Department of Agricultural Engineering, check data collected in a livestock housing ventilation study.

"Kalwal" transparent resin panel will be used as the glazing material.

Another installation in the hog farrowing barn uses an aluminum sheet metal heat exchanger to salvage heat from the exhaust air. This is a commercially manufactured unit. It will be compared to the rock system as well as the solar heating system.

FARM WATER QUALITY

Farm water quality is often very poor. Many farmers haul water for drinking, cooking, bathing and washing clothes. In addition to mineral contamination other waters are sometimes highly colored.

A study was initiated to help farmers with the problems of colored waters in southwestern North Dakota. It was soon determined that water in this area was not only high in color but also high in minerals. These minerals were other than the type removed by the common water softener. There was also considerable variation and one universal treatment probably would not be feasible.

Initial studies tried reverse osmosis, coagulations and chlorination for treating water in this area. Of the three methods, reverse osmosis was the most successful. Color was reduced from as high as 4200 down to 15 color units on the platinum cobalt scale. Other minerals were also reduced on a comparable basis. Coagulation and chlorination did not perform satisfactorily. In many cases individual minerals such as sulphates were increased when treated by coagulation. Chlorination obviously increased chlorine levels in the water.

Further studies with reverse osmosis has further substantiated this method as a successful way to treat water on a home basis. Water quality is excellent, far exceeding standards. Original costs are high and filter modules are lasting much longer than anticipated. Operating costs are nominal when water use is limited to washing clothes and domestic needs. Three test units were installed to determine the operating costs and expected life of the reverse osmosis modules. One unit is approaching five years and another four years. Both are still performing well.

HRS WHEAT QUALITY

A good share of the work of the Department of Cereal Chemistry and Technology is the evaluation of plant breeders' samples. A large number of HRS wheat cultivars are tested to assist the breeder to develop high quality hard red spring and winter wheats for North Dakota. This past year the department determined the quality attributes of 3028 samples in several test series. The various tests and the number of samples are grouped as follows: macro milling and baking tests accounted for 528 samples, the micro test series for nursery wheat samples, a total of 1800 were tested, while early generation tests were performed on 700 new selections.

A hard red spring wheat quality survey showed that, in general, the average quality of the 1977 crop is surprisingly good, particularly when one considers the adverse weather conditions that prevailed during harvest. It has been estimated that about 15-20 million bushels of this crop has been subjected to some sprouting. The results of the survey show that, on the average, the test weight is 59.7 pounds per bushel, the protein content is 14.5 per cent and the moisture content 11.9 per cent. Although the average grade is U.S. No. 1 Dark Northern Spring the percentage of vitreous kernels is down sharply and damaged kernels are up considerably from the preceding two years. The wheat mills satisfactorily and produces a flour of high extraction and good color. The falling number, however, is 147 units lower than the 1976 year's crop. With the exception of loaf volume and crumb grain and texture, which show values slightly lower than last year, the baking properties are very good.

During the past year a new hard red spring wheat variety for North Dakota was released for commercial production. The department assisted in the work involved in its development. The name selected was "Butte" and has been tested since 1973 as ND 519. Butte is higher than Chris, Waldron, Era, Olaf or Kitt in test weight and baking absorption. It is lower in wheat protein content and higher in flour extraction than all of these varieties except Era. In general, the baking properties of Butte are not equal to Chris, Waldron or Kitt. However, because of its outstanding agronomic characteristics



Cliff Watson, Cereal Chemistry, uses a new method for measuring protein content of grain.

and certain desirable quality factors it was released.

Studies continue on the quality aspects of new winter wheat varieties and sawfly resistant cultivars for commercial growth in North Dakota.

Further studies relative to the quality of export cargos of hard red spring wheat being loaded at the ports of Duluth-Superior were conducted. In addition, a study was initiated to determine the quality of HRS wheat exported from the gulf port of New Orleans.

Continued research on near infrared reflectance shows that this is a fast and accurate method for determining protein content in cereal grains. Also, research shows that the method is reliable as a quality control instrument for flour mills and bakeries for controlling the level of protein, ash and moisture in flour. It is anticipated that further research will improve upon the accuracy of the instruments for this purpose.

The role of the largest size proteins in wheat flour on milling and bread baking quality is being investigated. Glutenin (the highest molecular weight fraction) is being studied by chemical and physical methods on eight hard red spring wheat cultivars that differ widely from low to high in quality.

The detection of farina (granular material made from HRS and HRW wheats) in semolina (granular material made from durum wheat and used for pasta) is a quality control problem; especially in those countries that prohibit by law the mixing of farina

with semolina unless it is so labeled. Present methods for the detection of farina in semolina require several hours to days to complete and are not very quantitative. A method was developed this past year using gas liquid chromatography for detecting farina in semolina. The method takes less than one hour and is quantitative.

BAKING STUDIES

Several composite flour baking studies have been conducted and are being continued in the department of Cereal Chemistry and Technology. Composite flours referred to in these studies are flours in which various amounts of hard red spring wheat flour are replaced with non-wheat flour. The purpose of such studies is to produce a higher protein or fiber type product as well as utilization of particular additives. Because of its high quality and greater strength the use of hard red spring wheat flour is advantageous and would possibly result in greater usage of this particular type of wheat if composite flour products become a popular consumer item.

In one study the effect of using flour obtained from untreated and roasted navy beans on dough and baking properties was examined. Bread containing the roasted navy bean flour had a higher volume than the bread containing the untreated flour at the same level of incorporation. In general, the physical dough studies and conventional baking data would indicate that if navy bean flour were to be utilized it would be beneficial to roast the navy beans prior to milling. The only bread quality factor which would be adversely affected would be the crumb color. Recently, research was completed in which a high fiber bread was produced utilizing brewers spent grains (BSG). The spent grains, the residue left after the brewing process, are high in protein as well as fiber content. Results indicate a potential use for the brewery by-product which may be beneficial in view of current data regarding nutritional benefits of high fiber foods.

Effects were studied on bran and protein concentrate from oats on dough properties and on bread. Bran from dry milled commercial oatmeal increased farinograph absorption and maintained dough stability to a greater degree than bran from dry milled oat groats of a pure cultivar. At equal levels of addition loaf volume was lower for oat than for wheat bran but panelists preferred oat bran bread over wheat bran bread. Addition of protein concentrate from oats also increased absorption and decreased loaf volume and defatting the concentrate increased the detrimental effect. Bread containing 10 or 20% oat bran was better accepted than bread containing the corresponding level of wheat bran.

During the past year, several studies on bread staling were conducted. The bread staling problem is not something new and considerable information has been reported on this topic. It is generally accepted that changes in the starch component play a major role in causing bread firmness. However, the exact mechanism involved, the role of other bio-

chemical components and the mechanism involved in its retardation are not fully understood.

A study was conducted to compare the relative retentions of thiamine, riboflavin and niacin during the dough processing stages and during baking using the conventional and continuous bread system.

An increase in thiamine, riboflavin and niacin occurred after mixing the flour into a dough with the remaining bread ingredients. With the continuous bread system, the extrusion process caused a reduction in thiamine and riboflavin retention; however, after proofing, these two vitamins showed a marked increase in retention.

Retention of thiamine decreased as a function of baking time with the greatest loss occurring in the crust. Thiamine retention was higher for the continuous produced bread than the conventional bread. Riboflavin showed a small decrease in content with baking.

The fermentation time in bread baking is time consuming. Studies are being conducted in attempts to eliminate or shorten the fermentation period. Such a baking procedure would be of benefit in a quality evaluation program in that the number of samples baked in one day could be increased. The effect of such a procedure on various wheat types such as long, intermediate and short mixing will be studied.

GRAIN CONSTITUENTS

A method for predicting spaghetti color from the color and enzyme activity of ground wheat has been developed. The color can be measured chemically or by light reflected from the ground grain. Linoleic acid oxidizing or B-carotene bleaching enzyme activities can be used with equal accuracy for predicting spaghetti color. The method appears promising for use with small samples on early generations in a durum breeding program for predicting the spaghetti color before there is enough wheat to actually make spaghetti.

Wheat samples containing various degrees of sprouting are being investigated. Various methods will be attempted to measure sprouting. Attempts to determine where sprouting in the kernel is greatest as well as in what flour streams will be conducted. Scanning electron microscopy also will be used as a tool to detect sprouting. The effect of different levels of sprouting on dough and baking properties will be studied.

A study is being conducted to investigate the carbohydrates present in three oat cultivars of different protein content with the results compared to a hard red spring wheat flour.

More crude non-starchy polysaccharide (CNSP) material was isolated from the oat flour than wheat flour. Analysis of the CNSP of oats revealed high percentages of B-glucans in comparison to wheat non-starchy polysaccharides which are predominantly pentosans. The oat flours and brans showed higher and lower reducing and non-reducing sugar



Lynn MacArthur and Bert D'Appalonia, Department of Cereal Chemistry, examine the internal characteristics of an experimental loaf of bread.

values, respectively, than the HRS wheat. Total sugar content was found to be highest in the wheat cultivar. Of the individual free sugars present in oats, sucrose was predominant followed by raffinose. Stachyose was found in oat flour and bran but was not observed in wheat flour. Only minor differences were noted in maltose, fructose and glucose between oats and wheat. Small amounts of an unknown sugar believed to be verbascose was detected in oat bran.

Oat starch exhibited a higher peak height than the Waldron wheat starch but appeared to have less stability and a faster rate of retrogradation.

Small differences were noted in absolute density, water binding capacity and percent amylose content in the oat and wheat starches. The oat cultivars contained higher amounts of lipid material than the wheat in the flour, bran and starch.

Work has continued in the area of pentosans and their role in bread. In the most recent work pentosans were isolated from both wheat and rye flour utilizing various methods of extraction. The effect of pentosans on bread produced from composite flours was studied. Also, the gelatin reaction of pentosans was investigated.

BARLEY QUALITY STUDIES

In 1977, for the first time, a barley quality survey was conducted in the primary malting barley areas of North Dakota, South Dakota and Minnesota. The more than 800 samples collected were analyzed for protein content, color, test weight and grade. Samples were collected during harvest from farm trucks as they were being hauled to the elevator or from the farmer's combine. A few samples were picked from the swath and hand threshed. The survey showed that the 1977 North Dakota barley crop had an average protein content of 13.5 per cent and was, in general, moderately stained. Authorization has been received to repeat the survey on the 1978

crop and planning for this project is currently underway.

A project has been initiated to determine the phosphorous content and distribution in barley and to study the changes which phosphorous undergoes during the malting and brewing processes. Phosphorous is a key mineral in all plants due to its role in the energy transformations which are associated with the life of the plant. It is of further interest because of its role in yeast metabolism during fermentation.

Constant efforts are made to upgrade and improve the analytical techniques used to evaluate experimental barley lines, to either improve the ability to recognize and select superior selections or to speed the analytical process so that a greater number of experimental lines can be evaluated. Current work is being concentrated on developing a more rapid means of assaying the enzyme activity of early generation barley lines and on the development of an automated procedure for the evaluation of malt wort nitrogen levels. Both of these procedures would allow us to speed these assays and to evaluate a greater number of experimental lines.

An instrumental method is currently being evaluated for the determination of barley and malt protein levels. Preliminary data suggest that use of the procedure would not affect the accuracy of these determinations and would be quite a bit faster.

During the past year, over 2400 experimental barley lines were evaluated for malting quality, including 1444 early generation lines which were evaluated by means of barley prediction tests and 972 more advanced lines which were evaluated after malting.

DURUM WHEAT QUALITY

The overall quality of the 1977 North Dakota durum crop is considered more variable and of lower quality than the 1976 crop. This can be attributed primarily to the problems of sprouting at harvest. The sprouting resulted in 20 to 25 per cent of the 62 million bushel crop being sprout damaged. Average grade was 2 HAD compared with 1 HAD for the 1976 crop. Milling on an experimental mill resulted in slightly lower semolina yield. Spaghetti color is excellent but cooking data showed, on the average, slightly higher cooking loss and slightly lower cooked firmness.

The number of samples tested for quality in the durum wheat variety development program this past year were as follows: macro-milling and processing (field plots), 165; micro-milling and processing (nursery samples), 644; micro-mixograms, 483; micro-color, 1198. This gives a total of 2490 samples evaluated.

An additional quality factor receiving emphasis in the durum wheat variety development program is protein quality. Protein quality with respect to its rheological properties or gluten strength characteristics is normally determined by either the Farino-



Technician Rachel Nelson tests small-scale samples of wheat for baking quality.

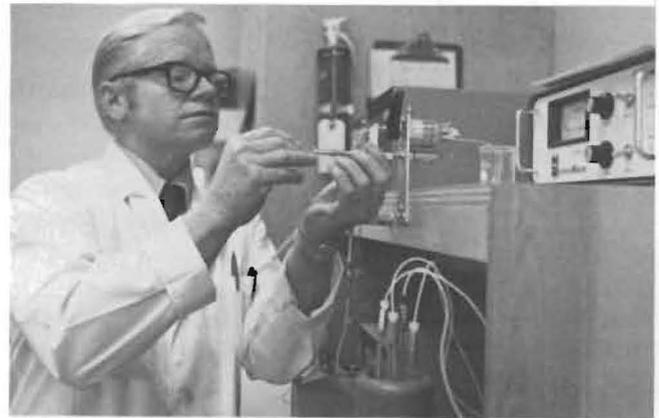
graph or Mixograph. Recent experimental data indicate that strong gluten durum wheats provide pasta with improved cooked firmness and cooking tolerance. Durum varieties currently being grown in North Dakota have weak gluten. Because of demands in some areas of the export market for strong gluten durum wheat and the improved cooking quality of pasta processed from this wheat, emphasis is now being placed on the development of stronger gluten durums. A number of experimental durums in the variety development program have quite strong gluten characteristics. These wheats have been developed without sacrificing any other quality factor.

Phytic acid is a nutritionally undesirable component of wheat since it chelates minerals and reduces their availability in the diet. Studies were completed this past year on the phytic acid content of six varieties of durum wheat grown at three different locations in the state of North Dakota. Results showed that durum wheat had relatively high levels of this compound present and that there were significant differences between varieties and locations. The milled fractions of the wheat, namely the bran, semolina, flour and dust, also had significant differences in phytic acid content with the bran containing the largest and the semolina the least amount of this compound. Because of the relatively

low levels of phytates in semolina and flour, consumption of pasta products should not cause any adverse nutritional problems with respect to mineral deficiencies.

The use of encapsulation as a technique to reduce cooking loss of vitamins, amino acids and mineral in food products is being investigated. If successful, this technique will improve the nutritional quality of food products to which these ingredients are added.

Studies are in progress on the effect of high temperature drying on the quality and biochemical composition of pasta products.



Cereal Chemist Clarence McDonald uses a high pressure liquid chromatograph for separation of biochemical components of grain samples.

SEM is being used as a tool to investigate the micro-structure of pasta products. This technique will be evaluated for its ability to differentiate between samples of uncooked and cooked pasta processed from high and low protein semolina and weak and strong gluten samples.

Sprouting of durum wheat reduces the marketing quality of the wheat and some of the milling and pasta quality factors. Wheat with different degrees of sprout damage will be examined to determine critical levels for adverse quality effects. Biochemical composition, pasta storage effects and SEM studies will also be conducted.

A harvesting study to determine the effect of maturity, harvesting and drying methods on durum wheat and pasta quality is being completed. The results of this study will indicate the relative merits on quality of straight combining versus swathing and air drying versus artificial drying of the wheat harvested at three levels of maturity.

The feasibility of using sunflower meal as a source of quality protein for fortifying food products such as bread, cookies, pasta, etc. is being studied. Efforts this past year were concentrated on removing chlorogenic acid from the meal prior to utilization. Chlorogenic acid is a natural component of the meal which produces undesirable color reactions in acidic or alkaline food products.