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MINNESOTA SCIENCE

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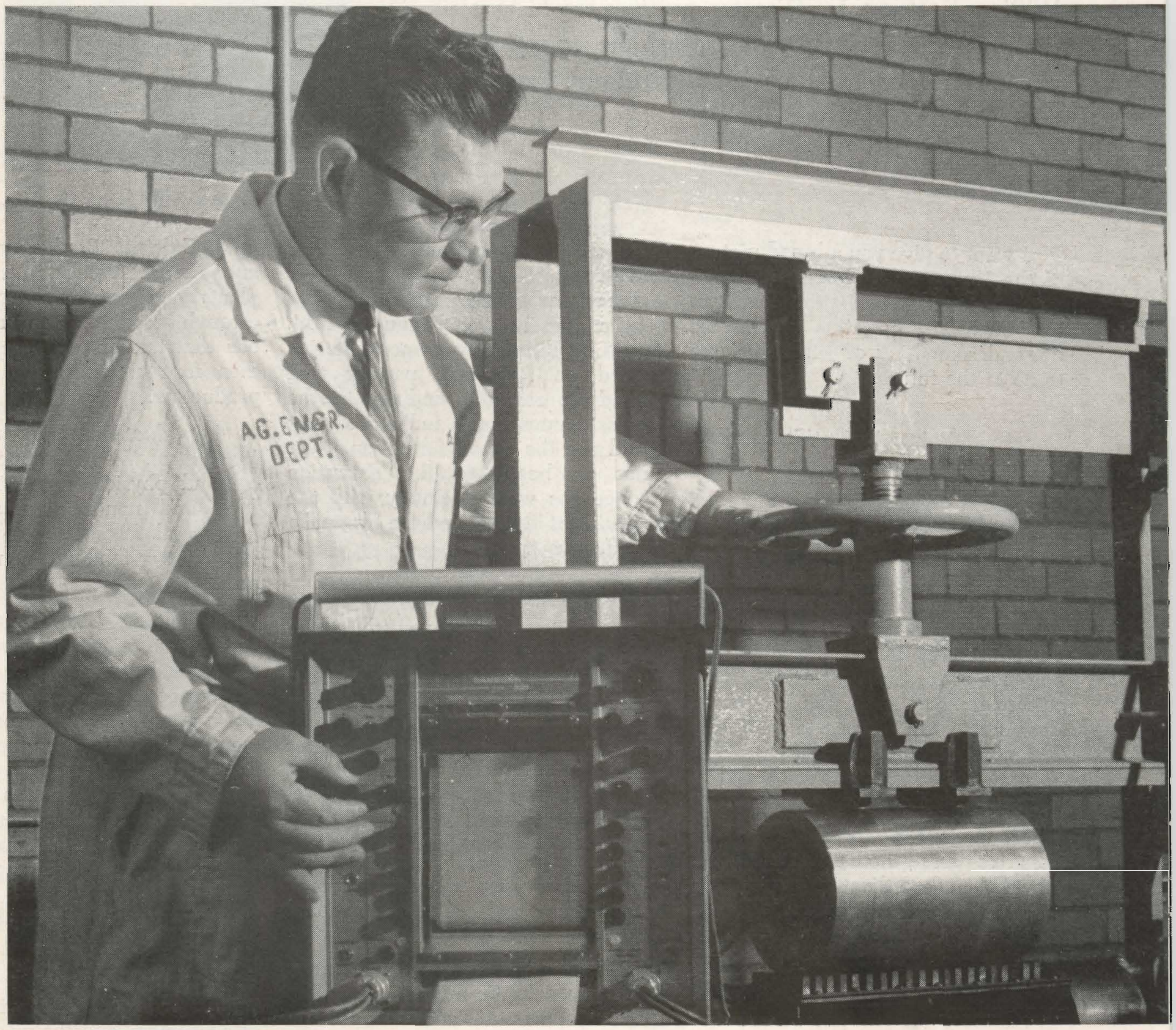
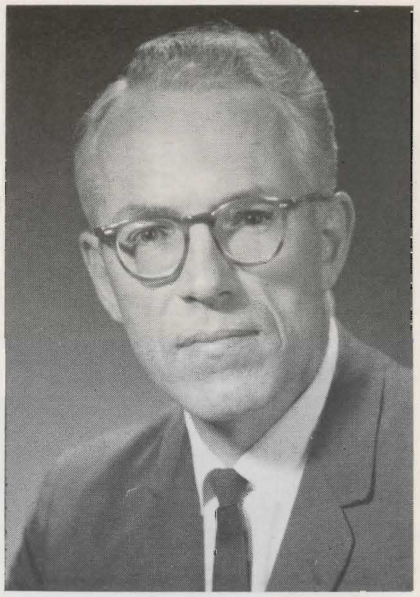


DRAIN TILE RESEARCH, page 16.

RESEARCH... in a Growing Minnesota



Dr. Hueg

William F. Hueg, Jr., Director, outlines the history the present research programs, and the objectives of the University of Minnesota Agricultural Experiment Station.

I want to give you a broad picture of the University of Minnesota Agricultural Experiment Station. I want to tell you what the Station is, what we do, and something of what we hope to do in the future.

Important Points in Station History

Four events in our history are especially worth remembering. First, the members of the Minnesota Legislature and the Regents of the University of Minnesota established this Agricultural Experiment Station back in 1885. At that early date those men showed great foresight, for they saw the importance of research in scientific agriculture, forestry, and home economics. Even today the Minnesota Station is the only state unit that does research in those three important fields and in veterinary medicine as well.

Second, in 1887 the United States Congress passed the Hatch Act, which provided a coordinated nationwide program of state and federal research in sciences related to agriculture. That program continues to this day, giving valuable support to this station and many others.

Third, as time went on the Experiment Stations took on an important auxiliary role by training new scientists for academic positions and for state, federal, and industrial research work. Students were able to earn and learn while carrying out research for the Station.

Fourth, when the Agricultural Extension Service was begun in 1914, the Agricultural Experiment Station gained an important partner that spread its research findings to the farms, homes, and industries that could use the new information. Ever since its beginning the Extension Service has worked closely with the Experiment Station, and the two make an effective team.

Minnesota Station Research

Now I want to tell you about the main research we are working on today at the Minnesota Station. These research topics can be listed under seven headings as follows.

1. *Resource Conservation and Use.* We strive to bring about multiple use of lands and waters without depleting any natural resources. To do this we take stock of natural resources, suggest methods to improve resource management, and evaluate additional ways to use these resources.

2. *Protection of Forests, Crops, and Livestock.* We investigate weeds, diseases, parasites, and harmful insects of plants and animals; and we devise ways to fight them with chemicals, cultural practices, and biological controls. We also work out ways to protect against fire and other hazards to natural resources.

3. *Efficient Production by Farm and Forest.* We learn more about plants and animals, improve them through breeding, and work out methods that farmers can use to manage them for most efficient and profitable production.

4. *Product Development and Quality Control.* We determine the chemical and physical properties of both food and non-food products from farms and forests. And we also develop better food and non-food products.

5. *Efficient Marketing.* This includes wise pricing, improved quality, and consideration of the needs and preferences of consumers. Here we find ways to identify, measure, and maintain quality of products. We analyze supplies, demands, prices, and the structure and function of markets. Then we take into account interregional competition, international competition, and developing domestic markets. And in the end we suggest better ways of marketing.

6. *Better Nutrition for Satisfied Consumers.* We study the nutritional quality of foods, the buying patterns of consumers, and the quality of family living—including the management of time, money, and other resources available to families.

7. *Development of Human Resources.* This includes study of com-

munities, regions, and nations. We note important trends and possibilities for economic development. This research is hopefully improving the well-being of people, showing the way for social services, and helping people adjust to social and economic changes.

Experiment Station Staff

All the work listed above would be impossible without a staff of well-trained men and women. The staff at the Minnesota Agricultural Experiment Station includes professional scientists who teach and also conduct research.

Some 300 students working toward advanced college degrees are supported by Experiment Station funds. They contribute to research as they pursue either the Master's or the Ph.D. degree.

Another important group is the Civil Service staff, who work as herdsmen, plot supervisors, assistant scientists, laboratory technicians, secretaries, clerks, and so on.

Financial Support

The financing of the Minnesota Agricultural Experiment Station comes from three major sources: The State of Minnesota, the federal government, and private organizations and firms.

About 60 percent of our money is provided by the State of Minnesota. The Minnesota Legislature appropriates much of this money directly to the University. The remainder comes indirectly from other agencies of the State government through contracts. What sort of contracts? With the Minnesota Highway Department we evaluate plantings to beautify and stabilize roadsides. With the Minnesota Conservation Department we carry out certain research on the management of fish and game.

About 30 percent more of our money comes from the federal government. About 12 percent comes through federal grants as prescribed by the Hatch Act and the McIntire-Stennis Cooperative Forestry Research Act. The other 18 percent from federal sources comes through research grants and contracts with the United States Department of Agriculture, the National Institutes of Health, the National Science Foundation, the Atomic Energy Commission, and other agencies.

The final 10 percent is provided by industry, by private foundations, and by farm and forestry groups as gifts or contracts.

Headquarters and Outlying Stations

The major research effort occurs at the St. Paul campus of the University of Minnesota, and our headquarters is also there. But the Minnesota Experiment Station also has a group of outlying stations where specific regional state problems can be studied.

The stations at Rosemount, Waseca, Morris, Crookston, and Grand Rapids solve problems of crops and farm animals. Research at Lamberton emphasizes crops and soils. The Duluth station concentrates on horticulture. The Forestry Research Center at Cloquet studies both forests and wildlife problems. An extensive forestry program also is conducted at Grand Rapids.

At Excelsior the Fruit Breeding Farm develops new fruits that are valuable in Minnesota and works out management practices for a small but growing Minnesota fruit industry.

The Landscape Arboretum, also at Excelsior, evaluates ornamental plants introduced into Minnesota as well as those developed or improved through Minnesota research.

At each of these locations professional staff members conduct research in cooperation with department members at St. Paul. We are especially fortunate that these outlying stations are permanent. Continuity in research is necessary. Research at Crookston has been uninterrupted since 1895. The newest station, Lamberton, began in 1960.

Coordination With Other Agencies

The Minnesota Station is one of 53 state experiment stations tied together through cooperative research programs. In addition, the United States Department of Agriculture has many research stations and laboratories that deal with specific problems. Cooperative research programs are possible because of the frequent opportunities state station and federal agency scientists have to meet and plan together. More recently the involvement of industry scientists assures a three-pronged attack on the critical problems of farming, foods, forestry, and fibers. The state experiment stations, the USDA, and private industry make an effective research team.

Benefits of Research

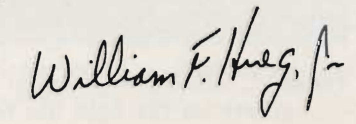
All mankind benefits from the scientific information that we gain from research, but undoubtedly the American consumer is the main beneficiary. Consider the facts. American scientists have helped American farmers develop the most efficient agriculture in the world. As a result, the American consumer eats well at relatively low cost.

In some developing countries as much as 80 percent of the income of a family goes to buy food. For a Russian family the figure is 51 percent. But an American family spends on the average only 18 percent of its income after taxes on food!

Minnesota now has an agricultural industry that grosses more than 4 billion dollars annually. The Minnesota Agricultural Experiment Station is providing a strong scientific base on which that agricultural industry can build. This base is important to the half-billion-dollar annual forestry industry also. We are alert to the needs and interests of three million Minnesota consumers.

We believe that we have the confidence of the people of Minnesota. This is reflected in present support from the State Legislature. Our program continues to seek solutions to those problems of today as well as those that are ahead.

One means of telling you about your Agricultural Experiment Station is through *Minnesota Science*. In its pages our scientists tell you about some of their research, and in each issue I will direct your attention to special topics. I hope that you will find this magazine both interesting and of practical benefit.



Sulfur Deficiency In Some Minnesota Soils

Three Experiment Station soil scientists have found a big area in Minnesota where much of the soil is low in sulfur, an important nutrient of plants. If you live in that area, applications of sulfur fertilizer to your land may double the yield of some of your crops.

By A. C. Caldwell, E. C. Seim, and G. W. Rehm

Sulfur is an essential element for plant growth. It is a necessary part of some proteins and other substances that are important for the growth of human beings and animals. In some areas sulfur may be one of the major factors limiting plant growth, particularly the growth of legumes.

We recognized a sulfur-deficient area in Minnesota more than 30 years ago, and some research on sulfur was done at that time. Recently we decided to do some further field experiments with sulfur, and in 1962 we began work at a field near Park Rapids.

One of the reasons for our doing this was to get some new information on sulfur response by various crops. Also, the higher-analysis fertilizers in use today are made from increasingly purer chemicals, and they contain less than they once did of other plant nutrients such as sulfur; therefore sulfur deficiencies might have developed recently in some soils. Additional reasons for starting sulfur work again were to get some recent information on different sulfur fertilizers and to establish more accurately the boundaries of the sulfur-deficient areas.

Figure 1. Alfalfa in a sulfur-deficient region. The good growth on the right has received sulfur fertilizer.

Crop Response to Sulfur

At the sulfur experimental field, we conducted trials with alfalfa, red clover, corn, soybeans, small grains, sunflowers, and potatoes. Of these, alfalfa showed the greatest response to sulfur fertilization (figure 1). This is not surprising, because sulfur is a component of the protein in which alfalfa is very rich. On land where sulfur is in short supply, we found that applications of sulfur-bearing fertilizers will increase yields, reduce death of young plants in severe winters, and increase sulfur content in plant tissues.

Yields of alfalfa at Park Rapids averaged 0.53 ton per acre per cutting when all nutrients except sulfur were supplied. But as table 1 shows, yearly applications of elemental sulfur or of gypsum (a sulfur compound) increased the yields to 1.27 tons per acre—more than double. These increases were obtained in dry years as well as in years when supplemental irrigation was prac-

Table 1. Effect of sulfur on the yield of alfalfa

Fertilizer applied	Rate lb S/acre	Average tons/acre/cutting (5 years—11 cuttings)	1965 yield tons/acre (3 cuttings)
None	0	.53	2.19
Elemental sulfur	50	1.11	4.30
Elemental sulfur	100	1.27	4.92
Gypsum	50	1.06	4.08
Elemental sulfur (annual applications)	50	1.24	4.94
Gypsum (annual applications)	50	1.26	5.09

A. C. Caldwell, is a professor, E. C. Seim is a research assistant, and G. W. Rehm is a teaching assistant, Department of Soil Science.

ticed. Residual applications of sulfur were as effective as annual applications when adequate amounts of sulfur were applied prior to planting in 1962.

In the spring of 1963 a stand count revealed that sulfur had significantly reduced the mortality of young alfalfa during the previous winter. On plots that had received sulfur, the stand averaged from 14 to 19 alfalfa plants per square foot; but on untreated plots the stand had been reduced to 7 plants per square foot as shown in table 2.

Table 2. Effect of sulfur on the stand of alfalfa

Fertilizer applied	Rate lb S/acre	Stand plants/sq ft
None	0	7
Elemental sulfur	25	15
Elemental sulfur	50	15
Elemental sulfur	100	18
Gypsum	50	19
Gypsum	1000	14

Besides increasing yields and decreasing winter kill, addition of sulfur also led to significantly higher sulfur content in the alfalfa. Sulfur analyses of the plants are in table 3. Although a part of this increased sulfur content may have been sulfate, other research men have shown that significant increases also occur in the sulfur-containing amino acids—cysteine, cystine, and methionine —which help make up proteins. Sulfur fertilization, therefore, increases quality as well as yield.

Table 3. Effect of annual sulfur applications on the sulfur content of alfalfa

Fertilizer applied	Rate lb S/acre/year	% S 1st cutting 1963	1964	1965	1966
None	0	.220	.167	.175	.158
Elemental sulfur	50	.360	.274	.304	.344
Gypsum	50	.457	.323	.271	.351

Both gypsum and elemental sulfur are effective in supplying sulfur to plants. We added 50 pounds of sulfur per acre to two of our experimental plots. One plot received elemental sulfur, and the other received an equal amount of sulfur in the form of gypsum. The gypsum supplied slightly more sulfur to the plants for the first 2 years, but (table 4) its effect did not last as long as the effect of the elemental sulfur.

Table 4. Residual effect of sulfur on the sulfur-content of alfalfa

Fertilizer applied	Rate lb S/acre/year	% S 1st cutting 1963	1964	1965	1966
None	0	.221	.167	.151	.146
Elemental sulfur	50	.308	.226	.216	.189
Gypsum	50	.332	.243	.179	.169

Table 5. Sulfur yield per ton of alfalfa harvested

Fertilizer applied	Rate lb S/acre/ year	Total S yield lb S/acre	Total hay yield (11 cuttings) tons/acre	lb S/ton alfalfa
None	0	16.4	6.29	2.6
Sulfur	50	77.8	13.64	5.7
Sulfur	100	86.5	13.38	6.5
Gypsum	50	80.5	13.84	5.8

In 11 cuttings of alfalfa harvested over a 5-year period, the sulfur that was recovered by plants ranged from 18.4 pounds per acre on the unsulfured check plots to 96.9 pounds per acre on experimental plots that received 100 pounds of elemental sulfur per acre per year. The data, table 5, show that on the average a ton of alfalfa that receives adequate sulfur removes about 6 pounds of sulfur from the soil.

Yield responses in other crops have not been as striking as in alfalfa. Corn, however, often shows severe deficiency symptoms early in a growing season. Sulfur-deficient corn is light yellowish-green, the areas between

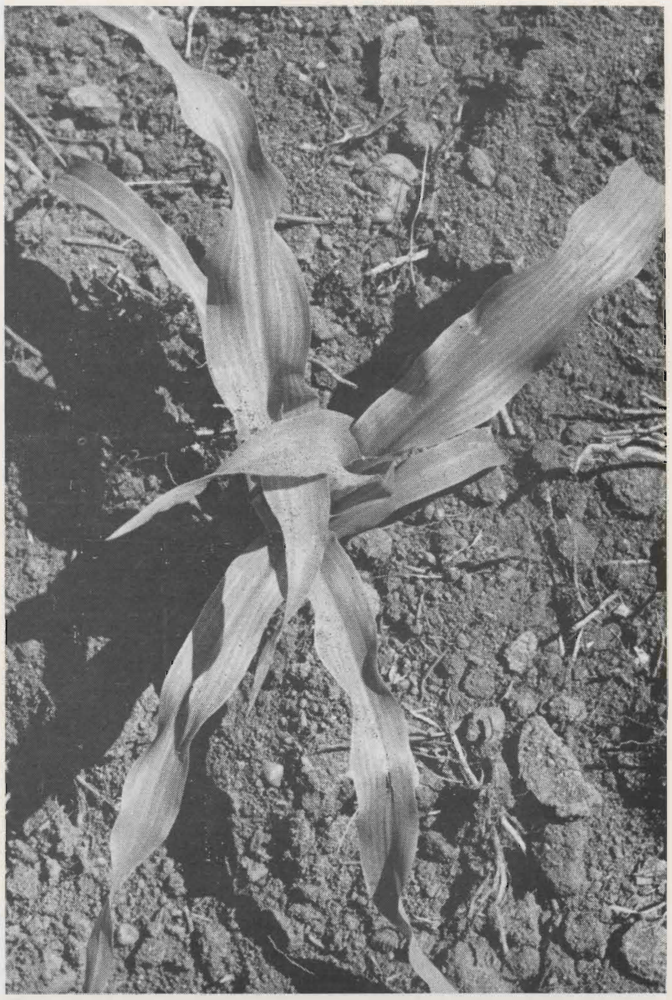


Figure 2. Light green striped leaves of young corn plant indicates sulfur deficiency.

the veins being still lighter green so as to give a striped appearance (figure 2). This striping is more severe on the younger leaves and in the whorl. Deficient plants are shorter and are delayed in maturity. With the coming of warmer weather and cultivation, the symptoms usually disappear and the corn develops normally. If the season permits the corn to ripen, yields may be normal. Our sulfur fertilizing in 1965 increased corn yields by 9 bushels per acre. Small grains and soybeans also had small increases in yield some years.

Sources of Sulfur

In sulfur-deficient areas, application of sulfur to the soil will improve crops. You can use any one of a number of fertilizers that contain considerable sulfur. At present gypsum is the chief form of sulfur used by Minnesota farmers, but other important sources are elemental sulfur, commercial fertilizers such as ammonimum sulfate and potassium sulfate, and certain mixed fertilizers made with low-analysis phosphate.

Sulfur occurs in the air in particle form and as gases. When rain or snow falls, airborne sulfur is washed out of the air and carried to earth. This sulfur fallout is an important source of sulfur for plants in certain areas where sulfur is abundant in the air.

For some years we have been getting an estimate of how much sulfur the air contains at four Minnesota locations: St. Paul, Park Rapids, Duluth, and Lamberton. We find that airborne sulfur is least at Park Rapids, where we have our sulfur-deficient experimental field. Air and rain and snow contain about five times as much sulfur in St. Paul as in Park Rapids.

Sulfur-Deficient Areas in Minnesota

The studies that we began at Park Rapids in 1962 showed definitely that a sulfur deficiency exists in Minnesota. However, no one knew the extent of the sulfur-deficient area. To learn its extent we collected soil samples throughout Minnesota and determined their capacity for supplying sulfur.

In this study, sulfur uptake by grain sorghum plants was measured in an atmosphere free of sulfur dioxide. These uptake values then were compared to the sulfur uptake from the Dorset sandy loam at Park Rapids—a soil we knew to be deficient in sulfur.

Results showed that the large majority of the soils that have low sulfur-supplying capacity are in north central Minnesota. The soils of western, southwestern, southern, and southeastern Minnesota have high sulfur-supplying capacity. The map, figure 3, shows the sulfur-deficient areas of Minnesota as determined by our work.

Within the shaded area of the map the soil series that have a low sulfur-supplying capacity are: Dorset, Rockwood, Brainerd, Onamia, Chetek, Hiwood, Menahga, and Redby. Other soil series within this area may also be sulfur-deficient, but some soils there such as Adolph and Grygla have a high sulfur-supplying capacity. The majority of the soils in this area contain less than 500 pounds of sulfur per acre plow depth. On the other hand, the soils of the remainder of the state contain 600 to 1400 pounds of sulfur per acre.

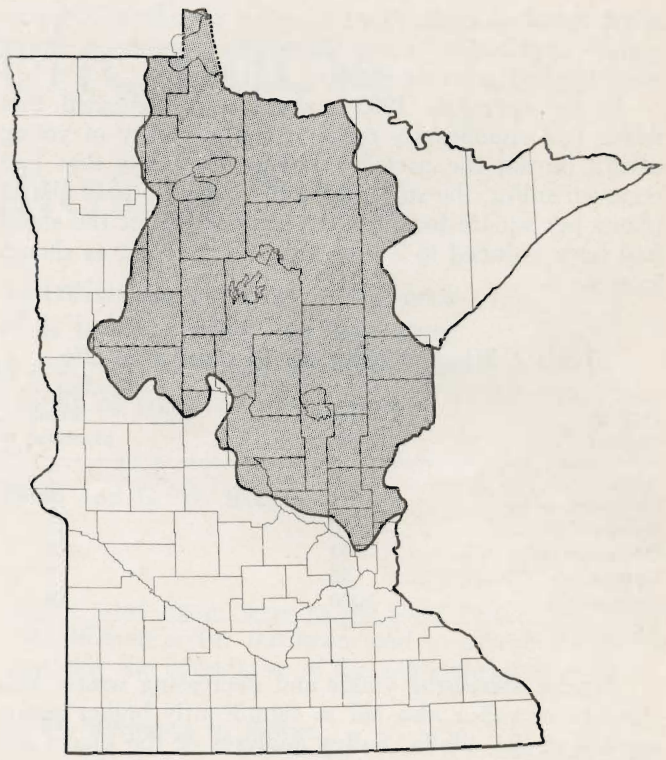


Figure 3. The shaded area shows where some soils are deficient in sulfur.

The soils that are low or deficient in sulfur usually have a loamy sand to sandy loam texture, a moderate acidity (pH 5.5 to 6.2), and a low content of organic matter. When in addition a soil with a low sulfur-supplying capacity also happens to be in an area where the sulfur fallout from rainfall is low, sulfur deficiency in plants is common.

Recognizing Sulfur Deficiency

How can we determine whether a field is sulfur-deficient?

1. A soil test for sulfur will reveal a deficiency.
2. In Minnesota our sulfur deficiency is in an area of low to moderately low rainfall. This means that in many years not enough sulfur is brought down in precipitation to nourish high-sulfur-requiring crops such as alfalfa.
3. Fields near industrial or large-population areas are not likely to need a sulfur application.
4. We find also that sulfur deficiencies are more common on sandy soils low in organic matter.
5. We look for and try to recognize sulfur deficiency symptoms of crops, particularly in legumes such as alfalfa and the clovers.
6. Plant analysis for sulfur will give us a clue to possible need for this nutrient.
7. Poor stands of crops and low yields in an area suspected of being sulfur-deficient may call for a sulfur application.

Laundering White Nylon Slips

This research, which is still in progress, has already revealed some valuable facts that homemakers can use.

By S. Davison, L. O. Lund, and B. C. Nelson

"Why do our white nylon slips become gray after several washings? And why do they develop yellowish stains where they touch our skins? What can we do to keep slips really white?"

Many women have been asking these questions lately. To find definite and accurate answers, we began a research project. Though the work is still in progress, women may want to begin making use of some of our early findings.

At the outset of our nylon slip laundering research we chose two hard-water areas—Nobles County, Minnesota, and Moody County, South Dakota. Then we had the Home Agents of those counties ask a number of typical homemakers about their laundering methods. What was the source of their laundering water? Did they presoak clothes? Did they wash clothes by hand? What sort of washing machines did they use, if any? What detergents did they use? Was their laundry water artificially softened?

The women's answers revealed that no two laundered alike. Some used soft rainwater. Many used well water. A few had water softeners, but almost none regularly added water-softening products to the wash. Some presoaked, but most didn't. A very few washed by hand, but most used automatic washing machines. One used home-made soap, but most used commercial detergents. Some used amounts of detergent recommended on the package, but others added extra detergent "for good measure." Some used two or even three commercial detergents together!

Besides asking questions, the Home Economics Agents also picked up a sample of the water used in laundering by each homemaker. These water samples then were sent to our laboratories for analyses. Chemical tests showed that most water used by these homemakers was hard to very hard—up to 33 and 47 grains hardness in two instances. Much of the water also contained considerable quantities of iron compounds.

Next the Home Agents gave each woman a new white nylon slip for this study. These slips, which were identical except for size, were a common type of a knitted white fabric called nylon tricot.

In accordance with instructions, each woman wore her slip at least 8 hours, then washed it. After five washings she returned the slip for examination at our laboratories. Later she got the same slip back for additional wear and laundering. She submitted the slip to the laboratory again after the tenth laundering and finally after the fifteenth laundering.

Miss Davison is a professor and Mrs. Nelson a research assistant, Department of Home Economics, Agricultural Experiment Station, University of Minnesota. Miss Lund is a professor, Department of Home Economics, Agricultural Experiment Station, South Dakota State University, Brookings, S.D.

Scientists at the laboratory rated each slip for discoloration after the fifth, tenth, and fifteenth launderings. Judgments of discoloration were made both by eye and with the aid of sensitive, unbiased instruments.

Here's what we found. In general, the more often a slip goes through the laundering process, the grayer it becomes. Also, the harder the water, the grayer the slip becomes. It seems that each washing in hard water adds a little gray over the basic white of the nylon fiber.

Our work also showed that the stronger the detergent, the whiter the nylon remains. Among the nylon slips studied, the only one that remained white-as-new through the 15 washings belonged to a woman who used home-made soap. Such soap usually contains considerable excess lye. This harsh alkali removes dirt and stains very well, but it may shorten the life of fabrics.

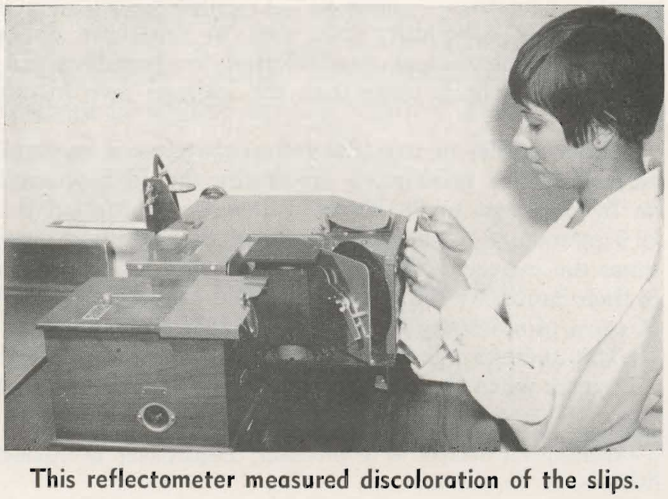
Yellow stains appeared on the slips where they touched bare skin. Oddly, the amount of iron compounds in the laundry water had nothing to do with this yellowish discoloration. It seemed to originate with skin oils or other skin secretions. The staining developed to a noticeable degree only in slips washed in mild detergents that apparently could not remove these skin secretions. The worst yellowing occurred in a slip that had been washed regularly by hand in a mild dishwashing detergent that is advertised as easy on the hands.

Though our investigation is still in progress, we feel that we can now offer two practical recommendations to women who want their slips to stay white.

First, use soft water. Either use naturally soft water such as rainwater, or soften your water. You can soften water either by installing a water softener in your plumbing system or by pouring some water-softener product directly into your washing machine.

Second, use a laundry detergent of the "built" type—a product which the manufacturer recommends for getting out stubborn dirt.

Our investigation is part of the cooperative research at the Home Economics Departments of the Agricultural Experiment Stations at the University of Minnesota and South Dakota State University.



This reflectometer measured discoloration of the slips.

Breeding Better Sheep

Research men at the University have been improving their sheep flocks for 30 years. Any breeder can upgrade his flocks by using the same breeding methods.

By William E. Rempel

The Agricultural Experiment Station at the University of Minnesota has had a research program in sheep breeding since 1937. When we analyzed the accumulated sheep-breeding records recently, we found information that should be useful both to producers of purebreds and to producers of market lambs.

Better Purebreds

A breeder of purebred sheep is really a seed stock producer, primarily a grower of rams for sale to growers of market lambs. Therefore the purebred breeder needs a system of selection and breeding that will increase the breeding performance of his flock. To reach this goal he must choose the highest-performing animals in his flock as parents for the next generation. Flock improvement will depend on the amount of superior productivity the selected animals have and the degree to which they pass this superiority on to their offspring.

This study is based on the 30-year records of purebred flocks at three branch Experiment Stations: Grand Rapids, Crookston, and Rosemount. All three were closed flocks kept at about 100 sheep each.

For these three experimental flocks, herd managers selected ewes that had superior productivity. A ewe was considered superior in productivity if for every 100 pounds of her weight she produced lambs and wool having a total value above average in our flocks. This superior value, though it included both lambs and wool, was combined and expressed in a single figure as extra weight of lambs.

Counting superiority this way, in the three flocks mentioned the typical ewe selected for breeding produced 13.9 pounds more than the average ewe in our flocks.

Other studies of ours showed us that in our flocks 23 percent of this productive superiority should be passed on by a parent to its lambs. When we multiplied the 13.9 pounds of extra productivity of the breeding ewes times the expected 23 percent that should be passed on to their lambs, we found that we could expect 3.2 pounds of extra productivity in the lambs.

The average age of parent sheep in our flocks was 2.72 years when their lambs were born. This means that the average generation interval was 2.72 years, or that a complete generation was turned every 2.72 years.

Since the expected improvement per generation was 3.2 pounds, and since a generation was 2.72 years, we can expect an improvement of 1.18 pounds *per year* in the sheep in our flocks.

Checking what actually happened in our flocks, we find that the actual improvement was 0.82 pounds per year. In some kinds of work you would consider 1.18 and 0.82 far apart, but in the breeding of animals this is considered close agreement between expected and actual results.

The important thing is that real improvement occurred every generation in our three flocks as a whole. Our breeding plan met its objectives.

You will notice that *progress per year* can be increased by shortening the generation interval. Since females have to be kept in a flock for several years as an economic necessity, the easiest way to shorten the generation interval is to replace flock sires with their young sons frequently.

It is well known that inbreeding generally causes a decline in performance. One of the problems of running closed flocks is to avoid a rapid rise in inbreeding.

In our three experimental flocks, inbreeding increased only about 0.6 percent per year, a low figure. Herd managers kept the rate of inbreeding down by using from 2 to 10 rams per year in a flock of about 100 ewes. These rams were chosen from among the offspring of superior ewes.

Any breeder can increase the number of sires in his flock by himself, or he and several other breeders can cooperate and manage their several flocks as if they were one breeding flock.

Although the results cited here are based on ewe productivity, selection also could have been based on daily gain. Both characteristics are heritable to about the same extent, and either can be used for selecting superior parents. The important thing is that the breeder must keep records of his own flocks so that he can compare one sheep with another in a meaningful way and choose the best for breeding. Breeders can obtain help with their record-keeping from: Animal Science Extension, 101 Peters Hall, University of Minnesota, St. Paul, Minnesota 55101.

To end this discussion of purebred breeding let me point out a bonus. If a breeder selects for better perform-

William E. Rempel is a professor, Department of Animal Science.

> *Recommendations to breeders of purebred sheep:*
> - *Test the performance of your entire flock.*
> - *Select replacements on the basis of performance.*
> - *Replace flock sires rapidly to shorten generation interval.*
> - *Use more sires to avoid inbreeding.*

ance in his purebreds, we know that the animals resulting from crosses of those purebreds will on the average be better in performance also.

Better Market Lambs

We have recently completed several studies on crossbreeding. Our results show that on the average the crossing of breeds increases the weight of lambs at weaning about 8 percent. At birth the crossbred lambs weigh about 5 percent more than purebred lambs. From these results it is obvious that the producer of market lambs should be crossbreeding.

Two studies here at the Minnesota Agricultural Experiment Station indicate that rams from heavy breeds sire faster-growing lambs. Suffolk rams have shown up particularly well in these tests. Hampshire rams, Columbia rams, and rams from some of the Minnesota lines ranked just below Suffolk rams in this matter. Sires from the heavy breeds also produced lambs with the best carcasses.

Our experience tells us that a specific cross of either Suffolk or Hampshire rams bred to crossbred white-face ewes will make very good lambs for market. The heavy breed of ram contributes faster-growing lambs to such a cross, and the white-face ewes have good mothering ability and heavier fleece. If the ewes are themselves crossbreds, they will have the added advantage of superior mothering ability due to hybrid vigor.

So a commercial producer of lambs can market all his lambs if he crossbreeds rams of heavy breeds with white-face ewes. He should buy purebred rams out of performance-tested flocks. And as his ewes become old and lose productivity he will need to buy young white-face ewes to replace them as breeders.

Three Kinds of Sheep Business

Present knowledge indicates the need for three kinds of specialists in the sheep-breeding business, as follows:

1. The breeder of purebred heavy breeds. This breeder primarily sells rams that will be used to sire market lambs.

2. The producer of purebred and crossbred white-face ewes. This man provides ewe flocks to growers of market lambs.

3. The commercial producer of market lambs. This man buys purebred rams of heavy breeds, buys white-face ewes, and produces lambs for market.

Silage Made From Poplar Bark

Poplar bark silage may eventually provide part of the ration for wintering beef cows and ewes in northern Minnesota, according to University of Minnesota research.

Animal scientists J. W. Enzmann, R. D. Goodrich, and J. C. Meiske studied the chemical composition of poplar bark silage with and without barley and enzyme additives. They concluded these additives weren't necessary for proper fermentation, and that poplar bark with 25 to 50 percent moisture fermented properly.

Mechanically peeled poplar bark was ground in a hammer mill, then ensiled in laboratory test silos, each of which held 2 to 3 pounds of bark. The scientists are doing more testing of total digestible nutrients and palatability of the bark silage so that a recommendation can be made regarding commercial use.

Now That It Tastes Better . . .

Fish Flour in Calf Diets

By J. B. Williams and J. W. Rust

Human beings, pets, and fur-bearing animals eat fish with relish and thrive on it. Would calves thrive on fish too?

The question occurred to us because the fishing industry now markets a defatted whole-fish flour that seems likely to be useful in feeds. High in protein, this fish flour is now competitive with dried skim milk in price.

Early attempts by fish-processors to grind and dry whole fish produced a product with strong taste, so processors removed most of the fish oils. The resulting defatted whole-fish flour is bland in taste, contains a lot of protein, and keeps well. And thanks to new technology in the fishing industry, it may remain low in cost.

Could this new fish flour take the place of milk protein in the diets of calves? Might it even have some advantages? We knew these questions deserved to be answered, so we ran some experiments.

As you may know, a calf in its first 24 to 36 hours after birth does best on a diet of colostrum—the special milk produced by its mother during that period. After that day-and-a-half the mother's milk returns to normal. Then most farmers start selling the milk and feeding the calf a milk-like mixture called milk replacer.

A regular milk replacer contains vitamins, milk sugar (lactose), fat, and a lot of dried milk protein. The farmer buys milk replacer as a dry powder, then mixes it with water just before feeding it. The resulting mixture is so much like normal milk that calves prosper on it.

Dried skim milk is the main ingredient in milk replacer, and defatted fish flour is similar to dried milk in price and in protein content. Could defatted fish flour satisfactorily take the place of part of the dried skim milk in a milk replacer?

J. B. Williams is a professor on the St. Paul Campus. J. W. Rust is an associate professor at the North Central Experiment Station, Grand Rapids, Minnesota. Both are members of the Department of Animal Science.

To find the answer we prepared four experimental milk replacers, each containing some defatted fish flour in place of part of the dried milk protein. Table 1 shows what went into 100-pound baches of each of the four. Defatted fish flour provided from 14 to 42 percent of the total protein in these experimental milk replacers. Total protein, total fat, and total digestible nutrients were the same in all four experimental diets and the same as in standard milk replacers.

First we tried a preliminary experiment with calves that were two and three days old when the experiment began. These calves were in four groups, and each group was fed one or another of the experimental milk replacers. Before long most of these calves developed severe scours (diarrhea).

Did the fish flour in the experimental milk replacers cause the scours? We can't be certain; but because the scours occurred, we have to conclude that the fish flour may have been the cause. So for calves younger than two weeks of age we are not going to recommend rations that contain fish flour.

Then we ran our main experiment, using Holstein calves that were 10 to 27 days old when the experiment began. Each calf was alone in a pen, but again we considered the calves as four groups. In each group the calves consumed nothing but one or another of the milk replacers in table 1.

Once a week we weighed each calf and increased its ration as it grew. For every 100 pounds of its weight, every calf received twice each day one pound of dry experimental milk replacer mixed into 6 pounds of water. That is, at 90 pounds a calf received 1.8 pounds of dry replacer per day; when it reached 100 pounds it got 2 pounds; at 125 pounds it received 2.5 pounds; and so on.

Each day we rated every calf's manure as normal, soft, very soft, or watery. If a calf got severe scours, it received veterinary treatment and was fed 3 pounds of

Table 1. Composition of 100 lb. of each milk replacer

Ingredients	Ration 1	2	3	4
	pounds			
Dried whole cheddar cheese whey	24.8	0	0	0
Lactose (milk sugar)	0	12.3	14.8	23.3
Choice white pork grease	18.0	18.0	18.0	18.0
Dried skim milk powder	47.0	64.5	57.0	43.5
Fish flour, defatted	10.0	5.0	10.0	15.0
Vitamin mix*	0.2	0.2	0.2	0.2

* Vitamin mix supplied 10,000 I.U. Vitamin A and 3500 I.V. Vitamin D_3 per pound of dry milk replacer.

regular whole milk twice daily for three days. Except for this, no calf got any feed except the experimental milk replacer during the 42 days of the experiment.

Table 2 gives the results of the experiment. The calves on the four experimental milk replacers made similar gains in weight, and their gains were about what we expect in calves on ordinary milk replacers. In these calves the feed efficiencies—amount of gain for the amount of feed— were also normal. From this we conclude that some defatted fish flour can be used satisfactorily in the milk replacer diet of calves more than two weeks old.

Table 2. Performance results

Ration	No. calves	Age (days)	Body weight in pounds: Initial lb	21 D lb	42 D lb	ADG lb	Feed efficiency food/ADG	Diarrhea duration (days)
I	4	20	91	114	142	1.2	1.64	14
II	5	15	88	108	142	1.3	1.54	8
III	5	17	87	104	137	1.2	1.57	12
IV	4	19	94	111	149	1.3	1.59	10

Calves on diet 2 suffered scours least, and therefore it may be that diet 2 is better than the others. This does not mean that we recommend that farmers switch to diet 2. As we stated above, it probably should not be used on calves less than two weeks old, and it might not be worth using from two weeks to weaning unless dried skim milk becomes much more expensive than defatted fish flour.

Glacial Lake Discovered in Minnesota

A previously unrecognized glacial lake has been discovered in western Minnesota. The lake—called Glacial Lake Benson—was about 60 miles long and 40 miles wide. It covered an area of nearly one million acres.

Raymond Diedrick, soil scientist for the Soil Conservation Service in Benson, Minnesota, and R. H. Rust, professor of soil science at the University of Minnesota, described the evidence supporting the discovery of the lake at a recent meeting of the American Society of Agronomy in Washington.

Evidence for this glacial lake, which covers several counties in western Minnesota, was gathered from soil surveys. These surveys revealed a definite soil pattern which provided geomorphological evidence for a glacial lake.

Soils along the northern boundary of the lake basin developed in coarse-textured outwash material, while the central and southern portions of the basin have well-sorted silty soils similar to those in Glacial Lake Agassiz in the present Red River Valley. Small areas of buried soils occur along the northern boundary.

Diedrick and Rust say that the water for Glacial Lake Benson came from the north and outletted to the southeast. They postulate that two stages of flooding occurred. The interval between the two floodings was great enough to permit soil development.

Which Are Best . . .

Pure Varieties or Mixtures?

According to an appealing theory, several varieties of a crop, grown as a mixture, ought to yield better than a single variety. Here's what two crop scientists found when they tested the theory.

By D. C. Rasmusson and H. J. Otto

Does a mixture of several varieties of a crop do better than a single variety of that crop? Some people think that a mixture should offer higher yields and more stable performance, and their arguments can be rather convincing.

They argue that a mixture might send roots to different depths in the soil and in this way use soil nutrients and water more efficiently. And they say that, because of different resistances to disease in a mixture, the mixture could provide protection against diseases. Or because of differences in maturity, the mixture should escape part of the damage from drought or frost.

The question of the merits of mixtures is important in Minnesota, because if mixtures will give higher yields, our large acreages of soybeans, wheat, oats, barley, and flax—now planted to pure varieties—could be planted to mixtures. But are mixtures really better?

In 1961 we began to study this question with barley. We wanted to compare both the yield and the stability of yield of three things: single varieties, simple mixtures, and complex mixtures. Using six barley varieties adapted to Minnesota, we established two sets of entries for study.

Set 1 consisted of:

a. Three varieties—Liberty (V_1), N. D. B112 (V_2), and Iowa 5286 (V_3)

b. Simple mixtures of the varieties $V_1 + V_2$, $V_1 + V_3$, $V_2 + V_3$, and $V_1 + V_2 + V_3$

c. Three complex mixtures obtained by crossing $V_1 \times V_2$, $V_1 \times V_3$, and $V_2 \times V_3$

Set 2 was similar except that the varieties Fox (V_4), Vantage (V_5), and Traill (V_6)—and their simple and complex mixtures—were used in place of those listed for set 1.

The simple mixtures were made each year by mixing equal quantities of seed of the varieties. The complex mixtures were obtained by crossing the varieties and increasing the seed from each cross. For example, we crossed $V_1 \times V_2$. Then in successive generations we increased the seed without selection. When handled this way, every plant in the complex mixture is assumed to be genetically different from any other. The first tests were conducted with plants four generations from the cross (F_4).

Both sets, each consisting of the 10 populations listed above, were grown at both St. Paul and Crookston for 5 years in standard plots. So 10 environments (locations and years) were sampled with each set. Each trial contained four replications.

Yield Comparisons

In set 1, Liberty (V_1) and the simple mixture $V_1 + V_2$ were highest in yield. In set 2, Traill (V_6) was highest in yield (table 1). As might be expected, the highest-yielding simple mixtures were made up of the highest-yielding varieties.

Table 1. Average yield (bushel/acre) of varieties, simple mixtures and complex mixtures (10 trials)

Varieties			Simple Mixtures		Complex Mixtures	
Set 1						
Liberty	(V_1)	52.5	$V_1 + V_2$	52.3	$V_1 \times V_2$	48.4
N.D.B112	(V_2)	48.8	$V_1 + V_3$	48.4	$V_1 \times V_3$	46.5
Iowa 5286	(V_3)	43.8	$V_2 + V_3$	46.0	$V_2 \times V_3$	45.3
			$V_1 + V_2 + V_3$	49.6		
Average		48.4		49.0		46.8
Set 2						
Fox	(V_4)	46.3	$V_4 + V_5$	49.5	$V_4 \times V_5$	51.3
Vantage	(V_5)	49.5	$V_4 + V_6$	51.6	$V_4 \times V_6$	49.5
Traill	(V_6)	53.9	$V_5 + V_6$	52.1	$V_5 \times V_6$	50.9
			$V_4 + V_5 + V_6$	50.3		
Average		49.9		50.9		50.5

In the complex mixtures the pattern was not consistent. In set 1 the highest-yielding variety, Liberty (V_1), was a parent of the highest-yielding mixture; but in set 2 the cross of the two lowest-yielding varieties gave rise to the highest-yielding mixture.

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On the average, the three kinds of populations were similar in yield except that the varieties and simple mixtures exceeded the complex mixtures in set 1.

Stability of Yield

We evaluated stability of the three types of populations in terms of consistency of rank order and relative magnitude of variances. Rank order measures the yield position of one entry compared with the other nine entries in the set. The variances measure size of fluctuations above and below the average yield.

In the 10 trials the plants encountered extremes of moisture (from drought to flooding), of disease, of lodging, and of soil fertility. Such conditions favor wide fluctuations in relative yield of the entries. The range in rank was large for all entries in both set 1 and set 2 (table 2). The item of importance is that the three kinds of entries (varieties, simple mixtures, and complex mixtures) were about equally susceptible to change in rank. Judged on changes in rank, the mixtures did not appear to offer any advantage in stability of performance.

Table 2. Stability of yield as indicated by range in rank order in 10 trials

Set 1		Set 2	
Varieties	Range	Varieties	Range
V_1	1-9*	V_4	4-10
V_2	2-10	V_5	1-9
V_3	7-10	V_6	1-6
Simple Mixtures		Simple Mixtures	
$V_1 + V_2$	1-6	$V_4 + V_5$	3-9
$V_1 + V_3$	2-8	$V_4 + V_5$	1-10
$V_2 + V_3$	4-10	$V_5 + V_6$	1-10
$V_1 + V_2 + V_3$	1-8	$V_4 + V_5 + V_6$	2-9
Complex Mixtures		Complex Mixtures	
$V_1 \times V_2$	1-8	$V_4 \times V_5$	1-8
$V_1 \times V_3$	1-9	$V_4 \times V_6$	2-10
$V_2 \times V_3$	4-9	$V_5 \times V_6$	1-10

* This entry ranked as high as first and as low as ninth in at least one of the 10 trials. The maximum range was 1-10.

Based on the comparison of variances, both the simple and complex mixtures were more stable than the varieties in set 1. In set 2, however, the three kinds of populations were similar in stability.

Conclusions

We conclude from this study that mixtures, either simple or complex, are not inherently higher-yielding than pure varieties. In set 1 the highest-yielding entries were the variety Liberty and a simple mixture; and the highest in set 2 was the variety Traill. Therefore, growers should demand evidence of extra yielding abilities of mixtures before using them.

For many years plant breeders have selected varieties in pure stands for high yields, but very few mixtures have been evaluated. Accordingly, no one has enough information yet to draw definite conclusions about the opportunities for increased yields by using variety mixtures.

Here Professor Rasmusson removes the male flowers from barley plants of one variety. This is the first step in making a cross. Next he will sprinkle pollen from a second variety onto the female flowers of the plants shown here. The pollen-supplying second variety is the male parent of the seed that develops.

In this study, the mixtures, whether simple or complex, were not markedly superior to varieties in stability of yield. Claims for superior stability, like those for higher yielding ability, should be backed by experimental evidence.

In addition, the effects of variation in maturity, height, seed size, chemical composition, and other characters should be considered. Such variations might cause losses in harvesting or lowering of market value due to poorer quality. Furthermore, mixing two or more varieties does not eliminate the deficiencies of the individual varieties. So a mixture containing unknown varieties in unknown proportions is a poor substitute for a proved variety.

Beef Herds
In Northeastern Minnesota

Certain herds may be worth while even though they don't seem profitable. But careful feeding and marketing practices could make most herds show a profit.

By A. R. Wells and S. A. Engene

Many farmers in northeastern Minnesota have added beef breeding herds to their farming operations. Now as these farm operators look over their profits or losses they are seeking ways to make good profits consistently. Meanwhile some of their neighbors are wondering whether it would pay to add beef herds.

Can a beef breeding herd return a profit in northeastern Minnesota? To find the answer we studied the records for 1964 of 94 farmers in that region. Their herds ranged in size from 16 to 231 cows.

Costs and Returns for 1964

These 94 farms averaged a gross return of $78 per cow in 1964. This return was the value of feeder cattle and cull cows sold minus depreciation on herd bulls. Minor changes in inventory were taken into account.

As table 1 shows, this 1964 gross return did not cover the market value of all resources used on these farms. The estimated cost of these resources was $111 per cow—or $33 more than the gross return. Looked at this way, these herds certainly were not profitable.

Beef cattle prices were unusually low in 1964, however. The price of feeder calves in Kansas City averaged only $22.50, compared with an average price of $27 for the 8 years of 1959 through 1966. Cull cows were down in price about the same proportion in 1964. Over the 8 years, gross returns would have been about 20 percent above the 1964 return—or $94 per cow instead of $78.

But even this greater return would not have covered market prices for all resources. The loss still would have been about $17 per cow.

The figures in table 1 are based on 1964 market prices for all resources used. Contrary to what some people think, a beef herd does not always return market prices for resources used.

Table 1. Costs and returns, 94 beef cow herds, northeastern Minnesota, 1964

Item	Amount
Value of beef produced per cow*	$ 78
Costs per cow:	
Pasture	12
Other feed	57
Labor	14
Buildings and equipment	10
Other direct variable costs	18
Total costs	$111
Return over all costs	$—33

* (Sales + butchered + transfer to feedlot + closing inventory) minus (opening inventory + purchases + transfer from feedlot)

A. R. Wells was a research assistant, Department of Agricultural Economics, St. Paul campus, when this study was made. Now he is an associate professor, Department of Economics, Mankato State College. S. A. Engene is a professor, Department of Agricultural Economics, St. Paul campus.

The biggest item of cost—more than 60 percent of the total—was for feed. Three quarters of the 1964 feed cost was for 2.3 tons of hay per cow and 2 tons of silage per cow. Most of this harvested forage came from the herd-owner's land. Another 17 percent of the feed cost was for pasture.

Before we label these northeastern herds wholly unprofitable we must consider that many of these farmers had little or no chance to sell their hay, silage, and pasture feed except through their cattle. Their beef herds provided these farmers a market. Each farmer may have received less than usual market price, but a low price is better than nothing.

Similarly, the shelters for many of these beef herds were old dairy barns or other existing buildings. They would not have been used if the farms had not had beef herds. On such farms, adding a beef herd did not add building cost, and it did not contribute to building depreciation.

Table 2 shows that in our study many of the 94 farmers were part-time operators. This was especially true of farmers with small and medium herds. A good share of these men earn the big part of their incomes in nonfarm jobs. Some of them live in the country because they enjoy farm life, and they have found that beef herds can increase their incomes even though the herds do not pay normal rates of return.

Table 2. Type of operators, 94 beef cow herds, northeastern Minnesota farms, 1964

Size of herd	Part-time	Full-time	Total
	number of farms		
Small	19	13	32
Medium	18	14	32
Large	5	25	30
Total	42	52	94

Possible Returns

A beef herd in northeastern Minnesota can be made to return full market value for resources used. In fact, more than a third of the farmers in our study would have covered all costs if prices in 1964 had been up to the 8-year average.

Since feed is the biggest expense in raising beef, a farmer's efforts to increase his profits must start with feeds and feeding. First, he must harvest feeds carefully and economically. Second, he must not overfeed his animals. He must feed just enough to insure a large calf crop and fast gains in weight. By saving feed in this way, he can increase the number of cows that he can keep.

About 1.5 acres of tillable land in crops will produce the feed for one cow and her share of the younger animals. In addition, each cow will need about 2 acres of tillable pasture or 4 acres of nontillable pasture. Which is least costly? It depends on the price of tillable and nontillable pasture land.

So to make a profit the owner of a beef herd needs to harvest hay with minimum labor and minimum cash outlay, because high harvest costs can seriously cut profits. Then he must avoid overfeeding. And finally he must carefully adjust the type and quantity of land for each cow.

Farms in southern Minnesota wean about 90 calves for every 100 beef cows; but the northeastern Minnesota farms in our study weaned only 84 calves per 100 cows. Better management could bring larger calf crops. We did not measure the quality of these northeastern calves, but we know the prices they brought. The average prices indicate that the quality of calves may have been low on some farms.

Farmers in northeastern Minnesota also have difficulties in marketing. They are far from their markets. Besides that, many farmers in our study sold beef animals in small quantities. After we deduct replacement heifers, they had available for sale about 68 feeders for every 100 cows, or only 17 for a 25-cow herd.

About half of our farmers held calves on the farm either for later sale for slaughter or for sale as more mature feeders. The other half sold calves as feeders in the fall.

As table 3 shows, farmers with large herds were able to sell directly to other farmers who feed cattle; this type of sale probably brought higher prices. Farmers with small herds generally sold to buyers or to the central market in South Saint Paul; the buyers or the central market could then group the calves into uniform lots, but such extra handling usually lowers the price to the farmer.

Table 3. Market for calves sold as feeders, 46 northeastern Minnesota farms, 1964

Market	Size of herd			
	Small	Medium	Large	Total
	number of herds			
Cattle feeder	3	7	8	18
Cattle buyer	1	10	2	13
South St. Paul stockyards	7	6	2	15
Total	11	23	12	46

To improve their marketing, owners of beef herds in some communities are forming cooperatives. By grading and grouping their feeder animals the cooperatives can attract buyers more easily.

Our study shows that beef cows have been profitable for some farms in northeastern Minnesota, but not for all. To make a profit, each farmer must check carefully the returns he is getting and be alert for ways to improve his herd management. Doubtless some farmers will want to dispose of their beef herds, but others will want to add a herd or to increase the number of cows they now have.

From their studies in many laboratories over many years, scientists now generally agree on the following points:

- *Drainage does not remove from the soil the water that is useful to crops.*
- *Drainage does not affect the amounts of rain and snow that fall.*
- *Drainage does not measurably affect major floods.*
- *Drainage does not appreciably affect the amount of ground water—the reservoir of water in the earth.*
- *Drainage does not cause droughts.*

In the following article Professor Manson summarizes many important facts that he has learned about drain tile during his 40 years of investigations at the Drain Tile Research Laboratory, Minnesota Agricultural Experiment Station.

How to Choose and Install CONCRETE DRAIN TILE

By Philip W. Manson

Good agricultural drainage pays big dividends. It will benefit wet farm lands many ways, for drainage is an important soil and water conservation practice. Indeed, any operator of a wet farm will have trouble planning a good management program without draining his land. But since drainage alone does not make a complete conservation program, a farmer should design his drainage as part of his overall soil and water management plan.

Minnesota farmers know the importance of good drainage, and as a result they spend more than 10 million dollars each year buying and installing some 30 to 40 million linear feet of drain tile in our state. A properly designed, properly installed tile drainage system will give many years of satisfactory service, *provided durable tile is used.* Most drain tile sold in Minneosta is made of concrete. When properly manufactured, concrete tile proves to be very durable.

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Any concrete tile of reasonably good quality resists damage by frost. Certain improperly made concrete tile may fail in soil or water that is high in acid or high in sodium sulfate or magnesium sulfate. But properly made concrete drain tile will give satisfactory service under nearly all exposure conditions.

How to Choose Quality Concrete Tile

Forty years of research at the Minnesota Agricultural Experiment Station have convinced us that the following points are important for any farmer who is planning to install concrete drain tile.

1. Buy tile only from a reliable manufacturer who has established a reputation for producing high-quality products.

2. Buy only high-quality tile, regardless of price. Low-priced tile may or may not be of good quality. If it is poor in quality it is expensive at any price.

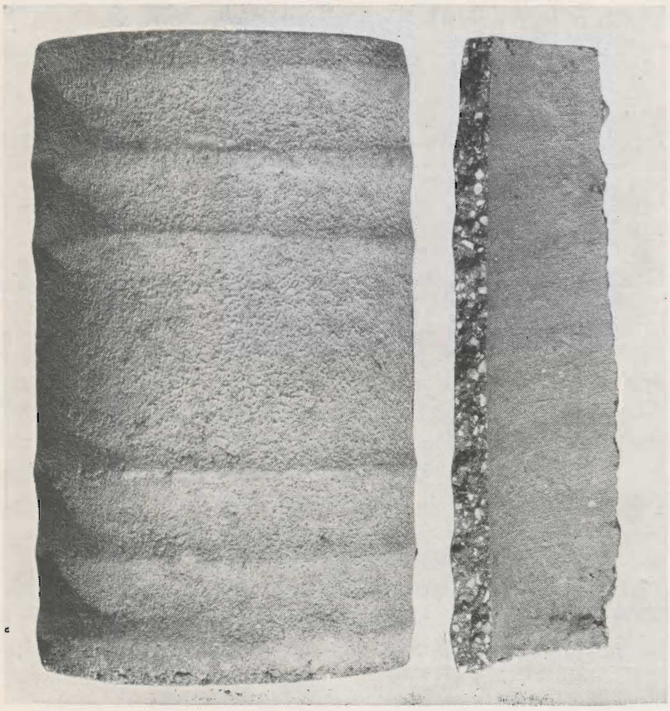

Figure 1. Good tile. Note the stippling and the rocks.

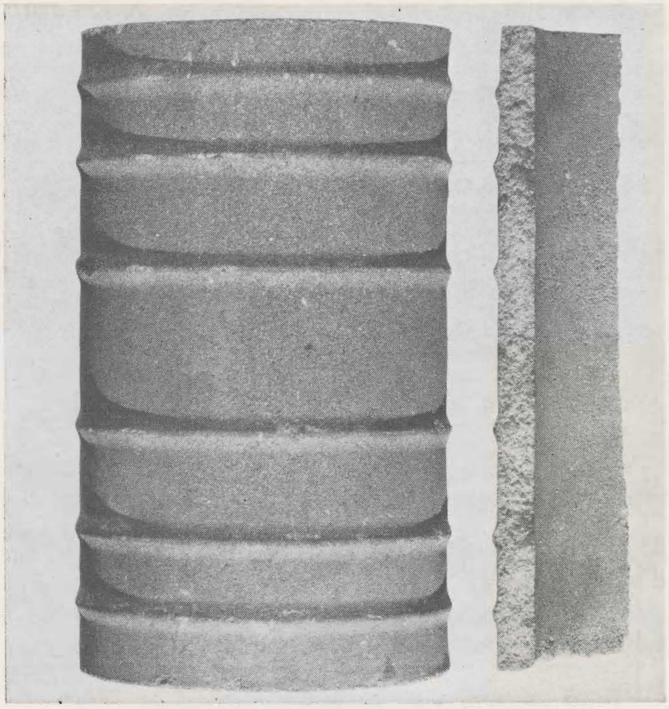

Figure 2. Poor tile. Note the smooth surface and lack of rocks.

3. Do not insist on smooth tile, for much good tile is rough and much poor tile is smooth. A rough interior wall does not materially affect the flow of water through the tile.

4. Look closely for water marks on the surface of the tile. This is important, for in making tile of small diameter the manufacturers tend to use insufficient mixing water. If too little water has been used, the surface will appear smooth. If the proper amount of mixing water has been used, the tile surface will generally have a stippled or web-like appearance. This stippling or webbing, which is shown in figure 1, occurs because some of the wet concrete mix sticks to the jacket as the jacket is removed.

5. High-quality tile can be made only from aggregate mixes that contain considerable coarse material ranging in diameter from ⅛ inch to about ¼ inch. As in the photo, a broken section of a high-quality tile will show an abundance of these small stones that have been broken. So never buy tile produced from a fine sand mix. Prefer the tile that contains pea-size rock, even though this rock may give the tile a rough surface. This sort of roughness has no drawbacks, and it generally indicates high quality.

6. Choose tile made from about one part cement and three parts aggregate rock by weight. This high-quality combination produces about 30 tiles of six-inch diameter from one regular 94-pound bag of cement.

7. Do not demand perfectly round tile. Actually, when enough mixing water has been used, the tile often slumps a little. Perfectly round tile often has been made from a too-dry mix. Tile that is not perfectly round (because of slump due to adequate mixing water) generally is of better quality.

8. Do not buy cracked tile. You can test a tile by holding it in your hand and striking it sharply with a piece of steel. Buy the tile only if it gives a clear ring.

9. Properly steam-cured tile need not be kept wet after it has been removed from the steam-curing room. No tile should be installed until it has aged enough to attain Standard Quality. That means the tile must have a crushing strength of 800 pounds or more per linear foot. We generally recommend that no tile be installed until it has reached an age of two to four weeks.

10. Do not depend entirely on appearance to judge tile quality. Nowadays the concrete drain tile manufacturers in Minnesota have an association. Every member has to have his tile tested for quality two or more times each year by a reliable testing laboratory. Before you buy tile, insist on seeing the results of a test known as ASTM Specification C412, "Concrete Drain Tile." The test results will reveal whether the tile you are about to buy is "Standard Quality," "Extra Quality," or "Special Quality."

Standard Quality Drain Tile is intended for draining ordinary soils where the tile is laid in trenches that do not generally exceed five feet in depth or three feet in width. Standard Quality Drain Tile should not be used for diameters exceeding 12 inches. Its average minimum crushing strength is 800 pounds per linear foot, and its maximum average absorption is 10 percent.

Extra Quality Concrete Drain Tile is better than Standard Quality because it is stronger and absorbs less water. The minimum average crushing strength of Extra Quality Tile up to 16 inches in diameter is 1100 pounds per linear foot, and its maximum average absorption is 9 percent.

Table 1. Allowable trench depths in feet (see notes below)

Tile diameter inches	ASTM Class	Crushing Strengths lb. per linear ft.	Width of trench[1]							
			18″	20″	22″	24″	26″	28″	30″	36″
5	Standard Quality	800	8.7[2]	7.5	7.5	7.5	7.5	7.5	7.5	7.5
	Extra Quality	1100	Inf.	12.2	9.5	9.5	9.5	9.5	9.5	9.5
6	Standard Quality	800	8.8	6.8	6.6	6.6	6.6	6.6	6.6	6.6
	Extra Quality	1100	Inf.	12.3	8.7	8.4	8.4	8.4	8.4	8.4
8	Standard Quality	800	9.0	7.0	5.8	5.4	5.4	5.4	5.4	5.4
	Extra Quality	1100	Inf.	12.5	8.8	7.3	6.9	6.9	6.9	6.9
10	Standard Quality	800	9.2	7.2	6.0	5.3	4.9	4.9	4.9	4.9
	Extra Quality	1100	Inf.	12.7	9.0	7.5	6.6	6.0	6.0	6.0
12	Standard Quality	800	9.4	7.3	6.2	5.5	5.0	4.7	4.7	4.7
	Extra Quality	1100	Inf.	12.9	9.2	7.7	6.8	6.1	5.6	5.6
15	Extra Quality	1100	....	13.1	9.5	8.0	7.1	6.3	5.8	5.2
18	Extra Quality	1200	....	....	....	9.6	8.5	7.5	6.9	5.7
21	Extra Quality	1400	....	....	....	....	....	9.3	8.3	6.8
24	Extra Quality	1600	....	....	....	....	....	....	10.0	7.9

Notes:
1. The width of trench is measured at the top of the tile.
2. Inf. indicates infinity.

Special Quality Concrete Drain Tile may be made to have special ability to resist strong acid and sulfate waters and to resist heavy soil loads. If the acidity of your organic soil is pH 6 or lower, you should use Extra Quality Tile or Special Quality Tile. Or if magnesium sulfate, sodium sulfate, or the two together are 3000 parts per million or more, you should use Special Quality Tile. It can be used in wide, deep trenches, for its individual minimum crushing strength is 1100 pounds or more per linear foot and its maximum average absorption is 8 percent.

For excessive soil loads resulting from extra deep and wide trenches, you should have a drainage engineer calculate the expected soil load. Then you should specify tile of sufficient strength to withstand the calculated load.

Table 1 will give the allowable trench depths in feet for tile ranging in diameter from 5 to 24 inches, and for trench widths ranging from 18 to 36 inches.

11. Under no circumstances should you use tile that does not meet at least the Standard Quality classification. You might also keep in mind that Extra Quality tile is better and often sells for about the same price.

12. Do not buy tile from manufacturers or dealers who do not display in their offices the results of tile tests completed recently by a reliable testing laboratory. *Such test results will be on sheets that clearly show the quality classification of the tile as Standard Quality, Extra Quality, or Special Quality.*

13. In Minnesota, it has been the general practice not to use tile smaller in diameter than five inches. Because of the difficulty of laying tile to true grade, 6-inch diameter tile is often used as the minimum size.

14. A tile drainage system generally empties into an open channel. Make sure that the tile outlet is free-flowing at all times. Where natural outlets are not available, pumping outlets have proved satisfactory.

15. For an average loam soil of moderate permeability, we recommend a spacing of about 80 to 100 feet between laterals and a depth of about 4 feet. For tight soils of low permeability, the spacing and depth must be reduced. For light soils of rapid permeability, the spacing and depth of tile may be increased.

Tile Installation

16. Surface inlets are recommended for low areas where large quantities of water collect and where the soil is so impermeable that it slows down the flow of water to the tile line.

17. Water does not flow at high velocities through agricultural drain tile. Accordingly, a 90-degree angle is as satisfactory as a 30-degree or 45-degree angle where a lateral line joins a main line. For ease of construction, join your laterals at the most convenient angles.

18. In most soils the space between tile ends should average about ⅛ inch. In fine soils the spacing must be less, or the joints must be covered with a material that will keep fine soil out of the tile. Special lugs sometimes are placed on the ends of 12-inch lengths of tile, or tiles with openings in their walls are used. But these special lugs and openings do not improve land drainage appreciably.

19. Determine the slope of your land, then consult Table 2 to find the diameter of tile to use. Down the left edge of the table are tile diameters in inches. Left-to-right across the top are slopes of 0.05 foot per hundred

Table 2. Number of acres that can be safely drained by tile of different diameters

Tile diameter in inches	Slope per hundred feet (same as percent)							
	0.05′ (⅝″)	0.1′ (1¼″)	0.2′ (2⅜″)	0.3′ (3⅝″)	0.4′ (4⅞″)	0.5′ (6″)	0.75′ (9″)	1.0′ (12″)
5	......	8	12	15	17	19	24	27
6	9	13	19	23	27	30	36	42
8	20	29	41	50	57	64	80	91
10	37	52	74	90	104	117	143	165
12	60	85	120	147	170	189	233	268

feet, 0.1 foot per hundred feet, and so on up to 1 foot per hundred feet. The main body of the table shows the number of acres that can be drained satisfactorily by tile of five different sizes on various slopes. In this table we assume that a layer of water ⅜ inch deep needs to be removed per day and that no inlets at the surface of the ground can admit surface water directly into the tile.

20. Table 3 gives the approximate footage of tile needed per acre when the laterals are 33, 50, 66, 80, 100, 150, and 200 feet apart on a grid-designed system. By a grid we mean a main line with side branches extending at right angles to the main.

Table 3. Amount of tile needed per acre for lateral spacing indicated

Spacing in feet	Feet of tile per acre
33	1320
50	872
66	660
80	545
100	436
150	291
200	218

21. Unless you are experienced at designing and installing drainage systems, you will be wise to hire a reliable drainage engineer. To do so probably will save you money.

22. Plan a complete drainage system even though you can not install it at one time. If you are in a watershed district, it may be advisable to coordinate your drainage plan with the soil and water conservation plan for the whole watershed.

Record-Setting Red Pine Found in Minnesota

A record-setting, 120-foot Red Pine has been discovered in Itasca State Park by University of Minnesota foresters. This takes the "Big Tree" record away from a 98-foot Red Pine in Wisconsin. The Red Pine is Minnesota's official state tree.

The tree, which is about 300-years-old, was discovered recently by Sidney Frissell, University of Minnesota forestry instructor, and Stephen McCool, forestry graduate student, while they were working on a research project at Itasca.

Located several hundred feet from where Nicollet Creek flows from the west arm of Lake Itasca, the tree shows evidence of fire scars from at least six forest fires.

The new giant is 120 feet in height, 37 inches in diameter, and 115 inches in circumference, with a crown spread of 36 feet. The previous record tree in Wisconsin is 98 feet in height, 33 inches in diameter, 106 inches in circumference, and 34 feet in crown spread.

Certification of the new record was made by the American Forestry Assocation, which maintains records of American big trees.

Frissell has looked for a possible record-breaking Red Pine in the Itasca area for about two years while conducting research on the fire history of Itasca State Park for his doctoral thesis in forestry.

How Molds in Soil Cause Root Rot

Surprisingly, the molds that cause root rot do not thrive in plain soil, and they become inactive unless plants or plant wastes are present. Minnesota Scientists who have studied these molds say that tillage practices that starve out molds can make next year's crops healthier.

By Thor Kommedahl, Robert F. Nyvall, and L. T. Palmer

Battlefield generals say that the first rule of war is to know your enemy. Those of us engaged in the war against plant diseases find that this same rule is just as important for us. Before we can fight a disease of crops, we have to find out all we can about it. After we understand it thoroughly, chances are we can find a way to fight it.

Sometimes even our early studies of an enemy of crops turn up knowledge that growers can start using right away against crop diseases. That happened recently when three of us did some research on molds. We were trying to find how molds in the soil grow and how they often attack and damage plants.

Molds, yeasts, and mushrooms belong to the group of primitive plants that scientists call fungi. Members of this group have always fascinated people, and scientists have studied fungi extensively. They find that most fungi perform a valuable service by consuming dead animal and plant material, because one fungus or another can live on (and eventually use up) almost any sort of dead organic material.

But occasionally some kinds of fungi also start growing on and using up living tissues of animals or plants. That's when fungi become our enemies. Ringworm and athlete's foot are common fungus infections of man.

Among crop plants, the main enemies are various fungi, for they cause most of the rots, smuts, mildews, wilts, blights, rusts, scabs, cankers, blothches, curls, and leaf spots that damage or kill crop plants. Fungi also cause damping-off of new seedlings.

Of all these diseases, those that cause easy-to-see symptoms above ground get the most attention. But we are realizing nowadays that unseen root-damaging fungus diseases that have not been studied much may actually be more serious.

The fungi that cause root rots of agricultural plants require somewhat special conditions to grow and survive in soil. To grow, they require a constant and renewed source of food, such as the roots of their host plants; and if they are introduced into soil where no such food is present they soon die, presumably of starvation. They may survive for some time in a dormant or resting state in soil, usually by means of special tough structures with thick walls. These may be masses of thickwalled, threadlike hyphae (sclerotia), thickwalled spores (chlamydospores), or thickwalled individual threadlike hyphae.

The fungus *Fusarium moniliforme* causes root rot and stalk rot of corn. We found that it overwinters in Minnesota soil by producing thickened hyphae (figure 1). If the fungus does not produce thick hyphae within plant tissues, the fungus usually dies. But if thick hyphae form and remain alive, they can infect living roots again in spring. The low temperatures in winter actually aid in survival because they prevent drying out of host tissues. Also, in our studies the fungus survived in host tissue buried about a foot deep in soil better than it did in tissue present on the ground surface or buried only a few inches.

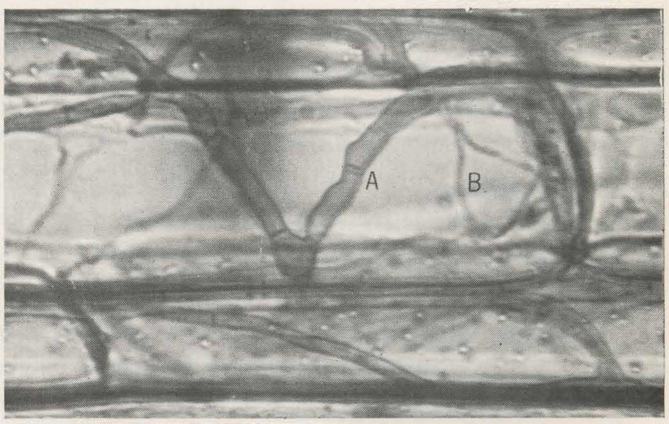

Figure 1. Shown magnified 400 times, this corn tissue was invaded by F. moniliforme, the fungus that causes rot. Letter A marks a tough, thickened hypha, and B marks a normal thin hypha.

Thor Kommedahl is a professor, Robert F. Nyvall is an instructor, and L. T. Palmer is a research assistant, Department of Plant Pathology.

Even though this fungus causes both root and stalk rot of corn, the fungus survived better in stalk than in root tissues, and the larger the tissue fragment, the higher the chance of survival. So to reduce the population of fungus structures that would account for diseases in the field, we may someday recommend that growers chop corn residues into small pieces and leave them on the soil surface, or at least not disk them in deeply. The less protection given the fungus the more likely it is to die from drying, starvation, or from competition with other soil-borne organisms.

How do fungi in soil or debris avail themselves of nutrients in soil? Nutrients become available in either of two ways. Fresh organic matter plowed down as green manure or disked into soil as crop residues provide ample food supplies for microorganisms. Animal manure and inorganic fertilizers also affect some fungi.

Food also becomes available in substances given off by roots. Such exuded materials consist mainly of amino acids, sugars, and vitamins. We found that dormant survival structures of fungi are stimulated to grow and to infect roots when root exudates are available. This means that the fungus structures have to be close enough to roots to actually contact them. The population of hungry bacteria and other microbes in soil alongside roots is so high that nutrients from roots seldom spread far enough to influence organisms not in contact with roots.

We demonstrated with the pea wilt fungus that the resting spores in water would not germinate, but if these spores were placed in solutions containing exudates from pea roots, 90 percent of the spores germinated. Also, if such resting spores were placed on live pea roots, 80 percent or more germinated. So spores can remain dormant as long as food is scarce. But spores germinate readily when they are on the root surface where they can get and use root exudates.

Since conditions in soil seem so formidable for growth and survival of root-infecting fungi, how can enough of such fungi survive to cause root rots and blights? The explanation borne out by our observations and experiments is that roots grow to the fungus structures. Nutrients diffusing out from roots do not attract the fungi.

How do roots find the fungi? By growing into and through the innumerable tunnels and cracks in the soil. Other scientists have shown that these channels in the soil happen to be the same places where fungi grow, sporulate, and form resting structures. Such tunnels may have been used previously by roots, and their decayed tissues may still remain in those tunnels together with the root rot fungi.

Tunnels are made and utilized also by worms, insects, and other soil animals; their feces deposited in the tunnels provide organic materials for fungi to grow. Many soil fungi form spores on freely evaporating surfaces of soil or soil tunnels, especially if organic material is also present. In this way such tunnels provide just the right ecological situations for the development of soil fungi, the growth of roots, and the travel routes of soil animals. In fact, soil animals can spread fungi throughout the tunnels by carrying spores on their bodies. So roots that grow through tunnels encounter fungi and exude substances that stimulate growth and development of fungi; the fungi may then infect the roots.

Tillage practices do not necessarily destroy tunnels unless the soil is sandy. Instead, tillage may break soil into clods that still have tunnels. Roots grow between clods or through their tunnels if the clods are oriented appropriately to root growth.

Roots encounter root-disease fungi also by growing next to or even through fragments of dead plants—crop debris. In the field we often found where corn roots had grown through fragments of corn stalks left from the previous year's crop, as in figure 2. Not only was the fungus present in such fragments, but roots were infected when they emerged from these fragments. Here again the roots had grown to the fungi; the fungi did not seek the roots.

Figure 2. The old piece of cornstalk in the soil contained living fungus. The new corn roots have grown through the old stalk.

So even though the conditions in soil may be unfriendly to root-infecting fungi and may result in fungi that turn into thickwalled survival structures and remain dormant in soil, the situation can quickly become dynamic when fresh organic matter is introduced into soil, or when growing roots encounter the survival structures. Penetration and infection of roots frequently follows because both roots and fungi occupy the same tunnels and cracks in soil.

Insect Resistance
In the Potato

Two Minnesota scientists have made the first step toward development of insect-resistant commercial varieties of potatoes. By testing hundreds of wild potatoes from Central and South America, they have discovered some that are highly resistant to aphids.

By Florian Lauer and Edward Radcliffe

At the University of Minnesota Agricultural Experi ment Station, research on control of potato insects involves two approaches: the testing of new insecticides and application methods and the identification of sources of insect resistance in wild potato species for possible incorporation into future potato varieties. The latter approach may ultimately prove more successful.

In Minnesota, the potato is attacked by several insect pests. These include aphids, leafhoppers, potato flea beetles, and the Colorado potato beetle. The two most comon aphid species are the green peach aphid, *Myzus persicae*, and the potato aphid, *Macrosiphum euphorbiae*. Because these aphids transmit various virus diseases such as leaf roll, virus Y, and spindle tuber, producers of certified seed potatoes regard them as their most serious pests.

Florian Lauer is a professor, Department of Horticultural Science. Edward Radcliffe is an assistant professor, Department of Entomology, Fisheries, and Wild Life.

Other insects are of greater importance to most growers, however. The most injurious of these is usually the potato leafhopper, *Empoasca fabae*. This insect injects a toxin causing the leaves to brown and curl. This condition, termed hopperburn, results in premature plant senescence. The aster leafhopper, *Macrosteles fascifrons*, can also be important. This insect transmits aster yellows, producing the disease known as purple top wilt in potato.

The adult potato flea beetle, *Epitrix cucumeris*, causes injury by chewing small holes through the leaves. Injury can be extensive enough to reduce yield.

The Colorado potato beetle, *Leptinotarsa decemlineata*, is well known to Minnesota potato growers and home gardeners. Both larvae and adults feed on the leaves.

Other insects causing occasional injury to potatoes in Minnesota include various species of wireworms, cutworms, white grubs, grasshoppers, leaf miners, lygus bugs, crickets, seed corn maggot, cabbage looper, and European corn borer.

Field in Grand Rapids where insect resistance of potatoes was tested.

Despite the numerous species of insects which attack potato, none threatens Minnesota potato production at present. Modern chemical insecticides have provided an effective means of controlling these pests. Evidence is accumulating, however, that many insect species can develop a tolerance to previously effective insecticides. The resistance of the housefly to DDT is a classic example. Strains of aphids, potato flea beetle, and Colorado potato beetle have developed a tolerance to several modern insecticides. Other problems arising from the use of insecticides may include the upset of natural enemies of the pests; this may cause a resurgence of the pest. For example aphid populations may actually increase after the application of the insecticide carbaryl. Traded pests such as mites may increase dramatically due to the selective nature of insecticides.

Such problems have contributed to increasing interest in the possibility of developing insect resistance in various crops, including potatoes.

Research on aphid resistance in potato began at the University of Minnesota in 1965. There is a good possibility of discovering resistance to aphids because a huge reservoir of potato germ plasm exists. More than 175 wild tuber-bearing potato species are found in South and Central America. In this country, the cultivated potato is a single species, *Solanum tuberosum*. Most of the wild species can be hybridized with it so that desirable genes can be introduced into the cultivated potato.

In studies conducted elsewhere, good sources of resistance have been found to potato leafhopper, potato flea beetle, and Colorado potato beetle. Several wild potato species possess resistance to the potato leafhopper. These include S. *polyadenium* and S. *polytrichon* from Mexico, S. *chomatophilum* from Peru, S. *spegazzinii* from Bolivia, and S. *kurtzianum* from Argentina. S. *polyadenium* is also resistant to the potato flea beetle.

The best source of resistance to Colorado potato beetle has been S. *chacoense,* a wild species of potato native to southern Bolivia and northern Argentina. European studies indicate this resistance can be transferred to the cultivated potato. This resistance is recessive and due to several genes.

Because of the economic importance of the green peach aphid and potato aphid, and because good sources of resistance to these pests had not previously been identified, our research dealt primarily with these insects.

In 1965, more than 400 potato introductions representing nearly 70 wild species were evaluated for aphid resistance. In 1966 and 1967, the more resistant introductions were retested and new entries were added. These potatoes were obtained from the Inter-Regional Potato Collection (IR-1 Project) at Sturgeon Bay, Wisconsin, where a large and representative collection of wild species is maintained.

Each year, these potatoes were tested at the North Central Experiment Station, Grand Rapids. Approximately 5000 plants were tested each year. We evaluated resistance by sampling the number of aphids present on

Aphids feeding on a potato leaf.

individual plants. With a little practice the two aphid species may be distinguished quite easily. Although both are almost invariably found on the underside of leaves, they generally do not occur on the same portion of the plant. Potato aphids prefer upper and mid-leaves. Green peach aphids are found predominantly on lower leaves.

We have found the highest degree of resistance to green peach aphid in two closely related species, S. *stenophyllidium* and S. *michocanum*. Some of the introductions within these species appear almost immune. The best examples of potato aphid resistance were found in S. *stoloniferum* and S. *hjertingii*. Other species having appreciable resistance to one or both aphids include S. *bulbocastanum*, S. *polytrichon*, and S. *multidissectum*. Interestingly, all the aphid-resistant species originate in Central America. Their botanical relationships, however, suggest that the sources of resistance to the two aphid species arose independently.

We found a high correlation between resistance to green peach aphids and potato aphids. However, aphid resistance has proved to be more complex than this first suggested. Within given species, resistance to the two species of aphids was not always correlated. For example, all S. *stenophyllidium* entries are virtually immune to green peach aphids, but are no better than the cultivated potato in resistance to the potato aphid.

Some wild potato species are difficult or impossible to hybridize with the cultivated potato, S. *tuberosum*. However, some of the crosses suggested by our data have been achieved at the Potato Introduction Station. For example, crosses of diploid S. *tuberosum*-S. *phureja* hybrids have been made with S. *stenophyllidium* and with S. *bulbocastanum*. Crosses of tetraploid S. *tuberosum*-S. *phureja* hybrids have also been made with S. *stoloniferum* and with S. *hjertingii*. Thus, the first of many steps has been made toward possible incorporation of aphid resistance into future potato varieties.

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THE COVER PHOTO shows an aluminum model of a six-inch drain tile and the apparatus used to determine stress distribution in the walls of a tile under external load. Professor Harold Cloud, who works with Professor Manson at the Drain Tile Research Laboratory, is shown making a test. See the article on page 16.

Introducing Our New Editor

Robert E. Turner is the new editor of *Minnesota Science.* Bob has a double career, first studying and working at science, later studying, practicing, and teaching science writing.

During his student days here at the University of Minnesota he did both undergraduate and graduate work in biological sciences, and for two years he was a research assistant in what is now our Department of Animal Science. He went on to work as a biochemist for a Minnesota food processing firm. He has been a member of several scientific societies.

After several years he turned to a longtime interest of his, science writing. To get a good start, he returned to this university and took a master's degree in journalism. Later he worked as a technical writer for the USDA and for private industry. He also taught technical writing at Montana State University.

Bob lives in a big old house on 3 or 4 acres in Chisago County. His two younger boys and his teenage daughter are active in 4-H, and his two older boys are students of sciences here at the University of Minnesota. His wife, Peggy, is a mathematician for a St. Paul firm.

On a weekend you might find Bob hiking and taking pictures along the St. Croix River near Taylor's Falls. But his main interest these days is finding out about the readers of *Minnesota Science* so that he can tailor this magazine to their interests and needs.

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