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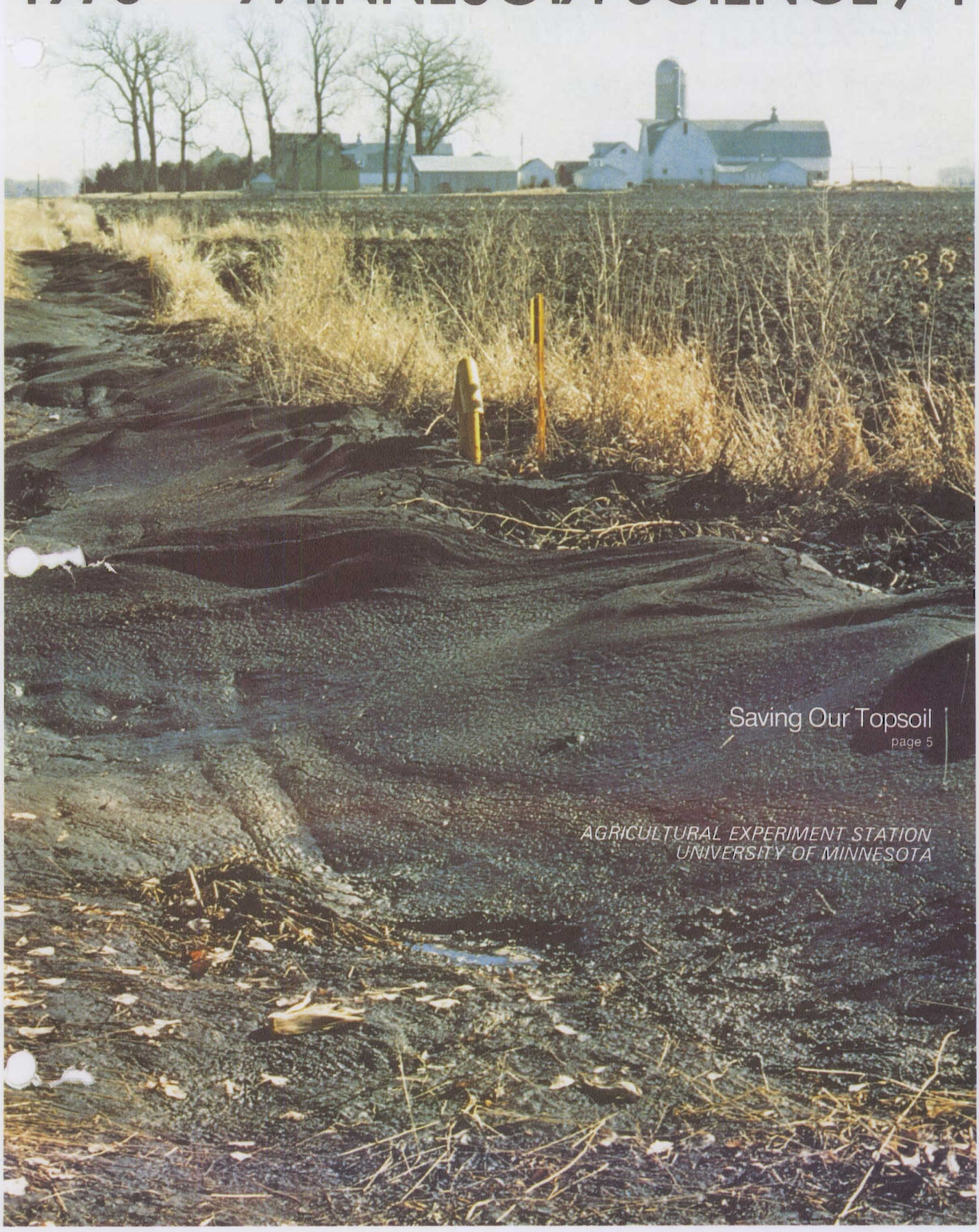

Saving Our Topsoil
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AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF MINNESOTA

Research for Today and Tomorrow

KEITH HUSTON
Director, Minnesota Agricultural Experiment Station

IN 1973, and for almost 3 years, world supplies of food and feed grains and oilseeds were barely adequate to meet world needs. The United States, as one of a few major exporters, saw her sizeable reserves depleted and farm incomes rise sharply. But now, once again, US supplies are building, and prices are very low. Minnesota farmers are deeply concerned about the future.

Although world grain and oilseed reserves are near the record level of 1972 — 60 days supply — world population has expanded sharply. Since 1972, 900 million people, enough for another China, have been added to the world's population. And population growth continues. Although countries with the largest populations have had good crop years, there are many countries in which food supplies are not adequate, and they will need help. Unusual climatic conditions or dry weather in two or three heavily populated countries could easily reduce world supplies to intolerably low levels, as happened in 1974.

Minnesota agriculture depends heavily on exports to other states and other nations. Depleted world supplies usually mean greater export demands and higher prices for Minnesota products. But in times of abundant supplies, Minnesota farmers must compete with farmers from other states for the limited markets.

Maintaining a competitive advantage for Minnesota farmers is a central issue in research. A number of special concerns surface around this issue. As energy costs increase, our crop production and transportation costs likely will increase somewhat more rapidly than will happen in warmer and dryer states closer to markets. Controlling pollution and disposing of wastes probably are more difficult in states like ours where winter is long and severe. Special energy conservation and pollution control technology will be required.

Protection from calamitous losses from each new wave of diseases and insects is a continuing aspect of research. Resistant varieties, new techniques for diagnosis and control, new chemicals, and, for livestock, new vaccines, and sanitation techniques are needed. Losses from corn borer, rust, smut, root rot, and pseudorabies are very fresh in the minds of Minnesotans. Other potentially dangerous pests in other states are being watched closely.

Although higher yields are often major products of research, lower costs are too. Adequate and precise use of fertilizers and pesticides, more effective tillage methods that reduce the number of tillage operations, timely marketing decisions, and new technology in processing are among the many opportunities. Attracting higher prices for our products through production and marketing techniques that emphasize quality have important potential in capturing a bigger share of the market.

Research provides answers for today's contributions. It also provides technology for the future. Consider the time required to develop a new disease-resistant soybean variety, a new high-protein wheat, a vaccine for a livestock disease. Our research investment is not only for today, but for many years hence–adding certainty to an occupation with many uncertainties.

MINNESOTA SCIENCE
Volume 33 □ Winter 1978 □ Number 1

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COVER: Severe topsoil erosion may eventually lead to a major decline in crop yields. Agricultural Experiment Station researchers are studying ways of reducing wind and water erosion in the state (see story on page 5). Photo by Gyles Randall.

MINNESOTA SCIENCE is published by the University of Minnesota Agricultural Experiment Station; Institute of Agriculture, Forestry, and Home Economics; St. Paul, Minnesota 55108.

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Address all correspondence and requests to Editor, *Minnesota Science*, 448 Coffey Hall, University of Minnesota, St. Paul, MN 55108.

New Corn Disease in Minnesota

JACK SPERBECK
Department of Information and Agricultural Journalism

A mosaic pattern (yellow streaks) appears on the leaves of corn plants affected by maize dwarf mosaic virus. Stunting, tillering, and reduced ear development occur in these plants (photos by Richard Zeyen).

A NEW CORN DISEASE tentatively identified as maize dwarf mosaic virus was discovered throughout Minnesota for the first time during the 1977 growing season.

The disease has affected mainly late-planted sweet corn—especially that planted after June 1. Some sweet corn was planted that late to allow for flexibility in the fall harvest schedule. Both sweet and field corn may be affected, but sweet corn is generally more susceptible. Minnesota is one of the largest producers of sweet corn for canning in the upper Midwest.

The disease was discovered through a new early warning plant disease system that has plant disease specialists in 10 Midwest states checking for diseases in corn, wheat and soybeans.

In some late-planted sweet corn fields, there was almost 100 percent infection, says Erik Stromberg, a plant pathologist stationed with the U. S. Department of Agriculture and University of Minnesota in St. Paul. Stromberg's in charge of the new early warning system in Minnesota.

It's hard to predict loss figures; only about 15 percent of the state's sweet corn was planted after June 1. However, losses in scattered fields were severe. "When you see corn only 2 feet tall compared to neighboring fields that are 8 feet, you know there's going to be a serious yield loss," Stromberg says.

The disease was previously reported in the neighboring states of South Dakota and Iowa. A decade ago it was largely responsible for eliminating sweet corn as a commercial crop in Indiana and Ohio.

The disease causes stunting, mosaic pattern (yellow streaks), tillering, and reduced ear development. It's easy to identify. "You can spot it going 55 miles an hour down the road by the stunting and yellow color," says Stromberg.

Plants infected with the disease may reach a height of only a few feet causing severe yield losses.

As an example of how late plantings are more seriously affected, Stromberg told of a farmer near Moorhead who had 65 acres of sweet corn, planted on four different dates. There was no problem with the early planted corn, the second planting date resulted in some reddening of the plants, the third planting date had reddening and limited stunting, while the last corn planted after June 1 had severe stunting with 100 percent infection

University of Minnesota plant pathologists Richard Zeyen and Herbert G. Johnson are working with Stromberg on the project. They hope to have more information regarding yield losses and sources of the disease infection later this year.

"B" Strain

Maize dwarf mosaic virus was first isolated from Minnesota grown corn in late summer 1976, says Zeyen. Positive identification of the virus requires extensive laboratory and greenhouse work, so exact identification (viral cause) of the 1977 epidemic will take 6 to 8 weeks to determine after the growing season has ended.

Since viruses like maize dwarf mosaic can only be maintained in living hosts, samples of the field infected corn are taken into the laboratory and transferred to young corn plants for more testing. Electron microscopic identification of the virus particles is used to confirm visual symptoms. However, the particles of maize dwarf mosaic are similar to at least one other virus (wheat streak mosaic) that also causes a similar disease in corn. So plant host range tests plus serological tests must be made to establish the final identity of the virus(es) responsible for the epidemic.

Extensive laboratory and greenhouse tests are already underway, says Zeyen. Exact identification of the virus(es) or their strains is extremely important in determining whether the disease might become established in Minnesota and be a chronic problem. After the exact nature of the virus is established the pathologists will begin work to find what native grasses may harbor the virus and will search for virus-resistant corn varieties.

If the disease has become established in Minnesota, then genetic resistance in corn would be the most effective control measure. Maize dwarf mosaic resistant or tolerant field corn is already in use in southern states. However, resistance in sweet corn is not well understood or widely investigated.

All in all, it could spell trouble for sweet-corn producers in Minnesota. Scientists will release additional information as it is available.

Saving Our Topsoil

JACK SPERBECK
Department of Information and Agricultural Journalism

TOO MUCH TOPSOIL is being lost from some Minnesota soils. And if the trend isn't reversed, soil losses spell trouble for farmers and consumers alike.

Tolerance Limits

"The greatest loss we can tolerate is 4 to 5 tons of topsoil per acre a year. On some shallow soils we can't tolerate more than 2 to 3 tons a year," says Minnesota soil scientist William E. Larson.

Many of southern Minnesota's fertile Clarion and Nicollet soils have annual losses of 3 to 5 tons per acre. Although this may be high, some scientists consider it within a "tolerance limit," because most of the soil sediment stays somewhere on the farm.

Soil from south central Minnesota farms may move down gentle slopes to the lower areas of the same farm (or a neighbor's farm). It doesn't show up as sediment in streams. "Still, it's not a good idea to have 4 feet of topsoil in parts of the field and 2 inches in others," says Gyles Randall, soils scientist with the University's Southern Experiment Station, Waseca.

But there's an area in southeastern Minnesota where losses often double the tolerance limit. And because of the topography, more sediment enters streams.

"There are areas in southeastern Minnesota where losses are 10 tons per acre," says Larson. In part of Iowa, losses average 20 tons per acre.

"When losses get above 5 tons per acre, you start having large nutrient losses. And farmers don't have to be reminded how expensive it is to buy nitrogen, phosphorus, and potassium in fertilizer form.

"You also get gullying when losses go above the 5-ton level. Gullying may break up large fields into 5- and 6-acre fragments, making field work more difficult. "Down-stream sediment also becomes a problem. With large losses, sediment builds up, making dredging and other clean-up work necessary."

Crop Rotations

Mike Lindstrom, Larson's coworker stationed at the U.S. Department of Agriculture's North

Wind erosion in southwestern Minnesota. Soil in the ditch to the right was blown from a field that had been in corn and was fall plowed with a moldboard plow. On the left, there's no erosion from the field that was in soybeans and fall chiseled (photo by Gyles Randall).

Central Soil Conservation research center in Morris, calculated how changing crop rotations in a southeastern Minnesota Fayette silt loam soil can reduce erosion problems.

With the 4 percent slope that causes many soil erosion problems, even a no-till planting system has losses above the 5-ton per acre tolerance limit. But changing to a 4-year rotation of corn, oats and two years of hay reduces the average loss figures dramatically.

Public Awareness

Sediment is the nation's number 1 solid waste problem—a fact that most people don't recognize. "About 4 billion tons of sediment enter the nation's streams and rivers annually, and about half of it originates from farms," says Larson, who has appointments with the University of Minnesota and U.S. Agricultural Research Service.

Although we have slowed erosion down somewhat since the 1920s and 1930s, the job is nowhere near complete. "Many people think we've licked soil erosion, but it just isn't true."

However, Larson is optimistic that increased public awareness will help. "Just a year ago I was at a meeting and put in a plug for more emphasis on programs to combat soil erosion. People laughed at me—but they're not laughing now," he adds.

The magazine *SCIENCE*, isn't laughing either. A publication read by the nation's top scientists and opinion leaders, *SCIENCE* has published three major articles on soil

Water erosion in southeastern Minnesota. Many fields in this part of the state averaging yearly top soil losses of 10 tons per acre from erosion (photo by Breneman).

erosion in the past year. On the same note, in a recent editorial, the New York Times said "...the time has probably come to insist that farmers follow good soil management practices as a condition of receiving...Federal Aid."

"Food production and soil erosion are issues right now and I think they're here for awhile," Larson says.

Consequences of soil erosion are the irreparable loss of good topsoil—soil that has taken thousands of years to form. Scientists estimate that it takes nature anywhere between 100 to 1,000 years to create an inch of topsoil. At any rate, it's too long.

Tillage and Residue Management

The best way to reduce erosion problems is with better tillage and residue management programs, says Larson. Although some people think legislation is necessary as a deterrent to bad soil management practices that provoke erosion, Larson says farmers need viable management alternatives—with or without legislation.

"We could prevent erosion by planting all Minnesota farm land to forages, but we need the corn and soybeans that the state grows," says Larson. Legislative attempts at erosion control such as the Iowa Conservancy Law are regarded as "educational" laws, almost impossible to enforce. The Iowa law makes it possible for suits to be brought against people who allegedly contribute to soil erosion, but such erosion is hard to accurately measure and even more difficult to prove in court.

Many farmers just go over the field too many times with heavy tillage equipment, packing the soil and destroying the soil aggregates. This leaves the finely pulverized soil more susceptible to water and wind erosion.

On the Clarion, Nicollet, and Webster soils where much of the state's corn and soybeans are grown, Larson recommends fall plowing with a moldboard plow or use of a chisel plow. If the moldboard plow is used the field should be left rough over winter followed by springtooth or disk tillage in spring. The chisel plow probably works best following soybeans and on lighter soils. "In general, the fewer trips over the field the better," Larson emphasizes.

Reduced tillage practices such as chisel plowing and till planting with a mulch between the row are becoming more popular in Minnesota. Larson is optimistic about reduced tillage programs for Minnesota farmers. "There's a general awareness that over-tillage is costly and may have harmful effects. Recent tillage practices for row crops such as strip till and no till have given farmers many new options."

"Many farmers are using chisel plows on soybean ground. Soybean ground is potentially very susceptible to erosion since it's mellow and has little residue," says Randall.

Although water erosion is generally more of a problem than wind erosion in Minnesota, many southern Minnesotans remember ditches filled with dirt from the severe dirt storms of Easter weekend 1976.

"Every case of severe wind erosion that I saw involved moldboard plowing, where little residue was left on the surface," says Randall.

Non-farm Erosion

Erosion problems aren't limited to farms. A tremendous amount of soil erosion comes from places like building and highway construction sites where contractors leave soil bare and subject to erosion. To cut down on non-farm erosion, soil scientists say we need tougher municipal regulations to curb contractors who are mainly interested in getting the job done irregardless of future soil loss.

Learning From History

A quick lesson from history should tell how uncontrolled erosion can ruin productive farm land. Many once-rich regions of the Near East and North Africa have been stripped almost bare of good soil. Many of these areas were densely populated and intensely farmed thousands of years ago.

Closer to home, parts of the South lost much of their topsoil a hundred years ago. Main reason: intensive culture of intertilled crops, such as corn, tobacco, and cotton, with few if any conservation practices. Millions of once fertile acres are now confined to growing pine trees.

Soil's importance to any society is paramount. We may be able to clean up air and water pollution, but topsoil is different. Likewise, we may be able to get by without airplanes, cars and electricity—but we can't do without food.

Farmers' tendencies to put short-term profit ahead of conservation is largely due to the need for higher returns to offset skyrocketing production costs. However, failure to reduce erosion to acceptable levels will eventually lead to a major decline in crop yields.

"Below that thin layer comprising the delicate organism known as the soil is a planet as lifeless as the moon," said G. V. Jacks and R. O. Whyte, in *Vanishing Lands, A World Survey of Soil Erosion,* published in 1939. Those words are still true today.

Science Strives to Make Irrigation More Efficient

JACK SPERBECK and EMMANUEL D'SILVA
Department of Information and Agricultural Journalism

This "box" or weighing lysimeter being lowered into the soil will help tell when to irrigate and how plants consume water. A scale is attached to the apparatus to measure weight differences due to water gain or loss by the plants and soil (photo by Don Baker).

HOW MUCH AND WHEN to irrigate is a problem faced by many farmers who have installed irrigation equipment.

A Sophisticated Box

A "box" in the soil could give researchers some answers that will give farmers guidelines not only on when to irrigate, but also on how plants consume water.

Called a weighing lysimeter, the 5 × 6 foot box is installed to a depth of 4 feet in the soil. Underneath is a sophisticated scale, which looks much like a scale used to weigh trucks. The scale measures weight differences due to water gain or loss by the soil and plants. The gain may be due to rain, dew, or irrigation, while the loss is due to evaporation.

"The scale instrumentation is capable of measuring the equivalent of $^{1}/_{1000}$ inch of water; thus, even dew can be detected," says Don Baker, agricultural climatologist at the University. Total weight in the apparatus is 7 to 8 tons.

"We hope to learn more about evaporation and what happens to water," say Baker and Jim Swan, extension soils specialist. Swan is co-leader of the project. "If we learn how fast water leaves the plant relative to atmospheric and soil conditions, it should give farmers some clues on the timing of irrigation water."

Nutrient Losses

Generally, over-watering doesn't happen as much as under-watering. Still, too much water can result in soil nutrients being leached into the ground water and polluting drinking water. In a different project, soils scientist Alfred Caldwell is measuring loss of nitrogen and sulfur fertilizer to the aquifer. So far, studies have been done only on bare gound, with no crop to take up the nutrients.

The research was done at Staples, Minnesota, where soils are sandy and the water level is only 11 feet below the surface. "Under these conditions we know that nitrogen and sulfur can move quickly through the soil to the water table if enough water is applied," says Caldwell. However, he emphasizes that the study is not a realistic indication of what would happen since no crops were in the ground to take nutrients up. Future studies with corn and potatoes in the ground will give more information on nutrient leaching.

With future studies, Caldwell would like to learn more about nutrient movement due to irrigation. "It's possible that alternating shallow and deep-rooted crops could be important in nutrient conservation.

"More research could tell the best time and method to apply nitrogen to high requirement crops like wheat and corn. With irrigation, you have more time flexibility for applying nitrogen than you do with dryland farming.

"Theoretically, water applications should give you normal crop growth and allow no excess water to leach through the soil," says Caldwell. But it's not always easy to apply the exact amount. Heavy rains such as several inches in a few hours or 5 inches over a couple of days defy water control. "We need research to find out if certain quantities of water over given time periods will create excessive nutrient movement, nutrient loss, and water contamination," says Caldwell.

"We also know that underground water moves. How long it takes some aquifers to cleanse themselves is another question that needs answering. And the nature of the fertilizer material may be an important factor.

"These questions also need answering: Do greater losses of nitrogen occur from inorganic rather

than organic sources? What influence does N-Serve have on nitrogen retention in the soil? Are elemental forms of sulfur more lasting than the sulfate forms?"

Depth of water table is another factor in nutrient contamination. "At Staples we traced nutrient movement to the aquifer 10-11 feet down. We need to know if nutrients will move into 20, 30, and 50-foot aquifers," Caldwell says. (He suspects the answer is yes; it just takes a bit longer for nutrients to move farther down.)

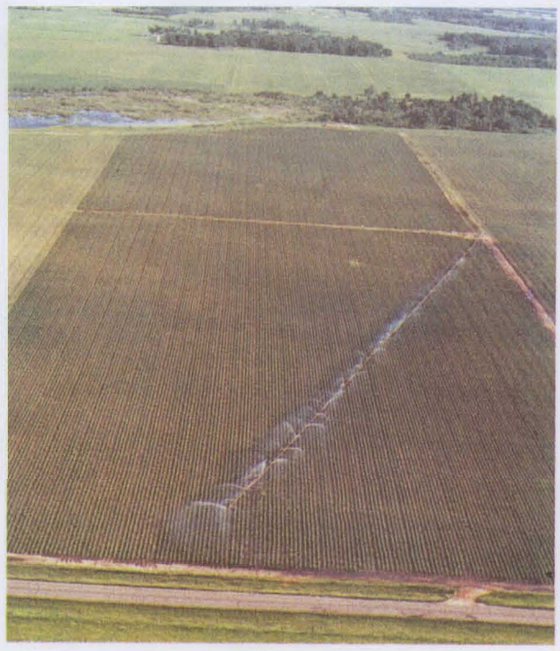
Crop Factor

"Crop factor" studies were done on corn at the Lamberton Experiment Station last year to correlate crop evapotranspiration with evaporation from a U.S. Weather Bureau evaporation pan. Research is also underway to determine the relationship of crop temperatures with the moisture stress under which crops are grown. Once the methods are formulated, it would be possible for a farmer to tell the moisture in the soil by taking simple temperature measurements of his crop, says Evan Allred, UM agricultural engineer. Such correlations would help the farmer work out irrigation schedules.

In addition, other scientists say it won't be long until better sensors will be used to electronically turn on the irrigation equipment to areas of the field needing moisture.

Management Practices

For now, good management practices should help conserve water and avoid nitrate leaching. Fred Bergsrud, extension agricultural engineer, emphasizes that an irrigator must have a good knowledge of the soil, the moisture needed and how long it takes to complete an irrigation cycle. "Note the moisture balance and follow it up with field checks," he says. Tensionmeters and soil moisture blocks could be a big help. Placing half a dozen of either set of these tools (cost is about $200) on a field may save an inch of water. In such cases, the savings in pumping costs of the excess water will pay for these instruments, he says.



Research on the relationship of crop temperatures and moisture stress may help farmers establish more effective irrigation schedules.

Potential in Minnesota

Steve Grannes remembers well the harsh summers of the past 3 years. With less-than-average rainfall, the sun scorched his family's 80 acres of corn near Litchfield, Minnesota. The yield in 1976 was a meager 10 bushels per acre. An irrigation-applying neighbor got a record 185 bushels per acre just a year earlier. Concerned with the possibility of a continuing drought, Grannes applied to the Department of Natural Resources (DNR) for a permit to install an irrigation facility.

There are hundreds of similar cases at the DNR. In fiscal year 1976, 783 irrigation applications were made (only six were rejected). "But we are now taking a closer look at surface water and appropriations and the effect a new well may have on the ground water of the neighboring wells," explains a DNR official.

An irrigation well pumping from the same aquifer as neighboring domestic wells may cause a temporary lowering of the water level in the domestic wells. Only in rare cases will this level not return to near normal levels when the irrigation pump shuts down. A new law requires pumping tests in areas where adequate information on the groundwater is not available. This should significantly reduce these interference possibilities.

A University agricultural publication reports on the results of monitoring water levels in the Bonanza Valley over a 10-year period. Despite a dramatic growth in irrigated acreage in the valley (from 1,000 acres in 1966 to 23,000 acres in 1976), "to-date (there is) no evidence that the increased withdrawal of water for irrigation from the aquifer has had any significant effect on the water levels (of the Valley)."

The study is reported in "A Statement on Groundwater and Irrigation" prepared by Soil and Water Conservation District Supervisors and irrigators in central Minnesota. The authors are O. M. Gunderson and J. E. Morris.

Long Way

Irrigation in Minnesota has come a long way from the 1920s when just a few patches of vegetables and fruit trees were watered in the Twin Cities by hand-operated systems. Today, over 200,000 acres get moisture during their hour of need by the most modern water-spouting equipment. And the potential for growth in the state is substantial, says a report prepared by the Minnesota Department of Agriculture. Indeed, 2 million acres of agricultural land in the state may be suitable for irrigation, mostly in the sandy soils of central and southeastern Minnesota.

Corn Borer Under Attack

MARY KAY O'HEARN
Department of Information and Agricultural Journalism

A female fly of *Lixophaga diatraeae*. The fly is a natural parasite of the sugarcane borer, but attacks the European corn borer under experimental conditions (photos by Dan Palmer).

MINNESOTA RESEARCHERS are launching an attack against the European corn borer this winter in an effort to control the pest which did an estimated $32 million damage to the state's 1977 corn crop. Parasites (wasps and flies) that could become enemies of the corn borer and may help control it biologically have been provided by researchers in Yugoslavia and Trinidad. In return, Minnesota Agricultural Experiment Station researchers will share the results of their work.

"One of the problems we face is getting the wasps and flies to multiply in large numbers," says H.C. Chiang, Experiment Station entomologist. Chiang and D.F. Palmer, research scientist, began work on the corn borer problem this past summer as the start of a 3-year initial phase program.

"Biological control has always been considered a useful tool in insect control, but situations with marginal to moderate effectiveness tended to be dismissed or overlooked," explains Chiang. "In no way does our approach diminish the importance of cultural control (practices such as tillage and irrigation) or chemical control. Every inroad made against the corn pest helps," he emphasizes.

Researchers are aware that some parasites (as long ago as 1934) were shipped from South Africa to Canada in an attempt to control the corn borer. However, no information is available on the results of that importation, according to Chiang.

Chiang and Palmer are conducting experiments to find ways of increasing the types of parasites that attack the corn borer and developing methods of mass propagating at least three of the parasites.

A parasite of the sugarcane borer (*Lixophaga diatraeae*) from Trinidad turned out to be a fly which would attack the corn borer. It had been cultured for 14 genera-

tions at the U.S. Department of Agriculture-Agricultural Research Service Bioenvironmental Insect Control Laboratory in Stoneville, Mississippi and sent to Minnesota. The parasites which didn't develop an affinity to the corn borer included: *Apanteles sesamiae,* parasite of the African corn borer collected in the Republic of South Africa in spring 1977 and shipped to St. Paul via the Beneficial Insect Research Laboratory of USDA in Newark, Delaware; *Apanteles flevipes,* a parasite from India collected in Florida; and *Chelonus knabi,* parasite of the wild rice borer collected in Aitkin County, Minnesota.

Mass propagation techniques are being attempted with the following (the first two are wasps, the second two, flies):

- *Macrocentrus grandii,* the most prevalent parasite in the north central region, collected in spring and summer 1977 in various areas of Minnesota.
- *Eriborus terebrans,* from the Yugoslavian consignment.
- *Lixophaga diatraeae,* the parasite of sugarcane mentioned earlier.
- *Lydella thompsoni,* a species of parasite from Yugoslavia which had a significant impact on the corn borer population before 1965, but has mysteriously disappeared since.

Both the Newark, Delaware and Stoneville, Mississippi USDA facilities serve as quarantine locations for overseas shipments. Before any distribution is made in the U.S., it must be determined that no hyperparasites exist (this is a parasite of a parasite) to throw the research off. After emerging from the cocoon and being thoroughly examined for a period of time, adult wasps and flies, packed in small cartons like ice cream containers with styrofoam fittings, are sent to St. Paul.

Feeding wasps and flies and corn borers is important to the research, Chiang explains. Parasite wasps are placed in screen cages and exposed to freshly cut pieces of corn stalk (9-10 pieces) in a dish 3 inches deep and 7½ inches in diameter. This is after 20-30 corn borer larvae have been there for a day and produced frass (excrement). The wasps respond to the frass and lay eggs. The dish is removed from the cage and the larvae dissected from the corn tissues. Larvae are kept in vials and supplied with fresh corn tissue as needed. Parasite larvae emerge in about 3 weeks at 25° C. A new dish with fresh corn pieces, frass and larvae is placed in the cage, more eggs laid, and the process repeated as long as the wasps live. "The presence of corn tissue is important in the laboratory method. Apparently it stimulates the parasite wasp to search for corn borer larvae," Chiang says.

Flies are fed sugar water and caged. Variations in laboratory lighting situations are being studied for the effect on the reproduction of fly parasites. Corn borers eat a cereal mixture about the consistency of pudding. It contains vitamins and mold and bacteria inhibitors. A generation of corn borers can be produced in the laboratory in less than 60 days.

There has been one clue, perhaps, to the disappearance of *Lydella* in the 1960s. This past summer a few of these parasites were placed in field cages over corn plants which were infested with corn borers. Five *Lydella* puparia were recovered and two of the puparia produced 20 wasps of the family *Pteromalidae.* This indicates that 40 percent of *Lydella* were eaten by another family of parasites.

The egg parasite *Trichogramma spp.* will also be tested in research studies. It will come from both domestic and foreign sources. Killing European corn borer eggs before the larvae emerge could deal a lethal blow to the insect before it does damage to the corn crop.

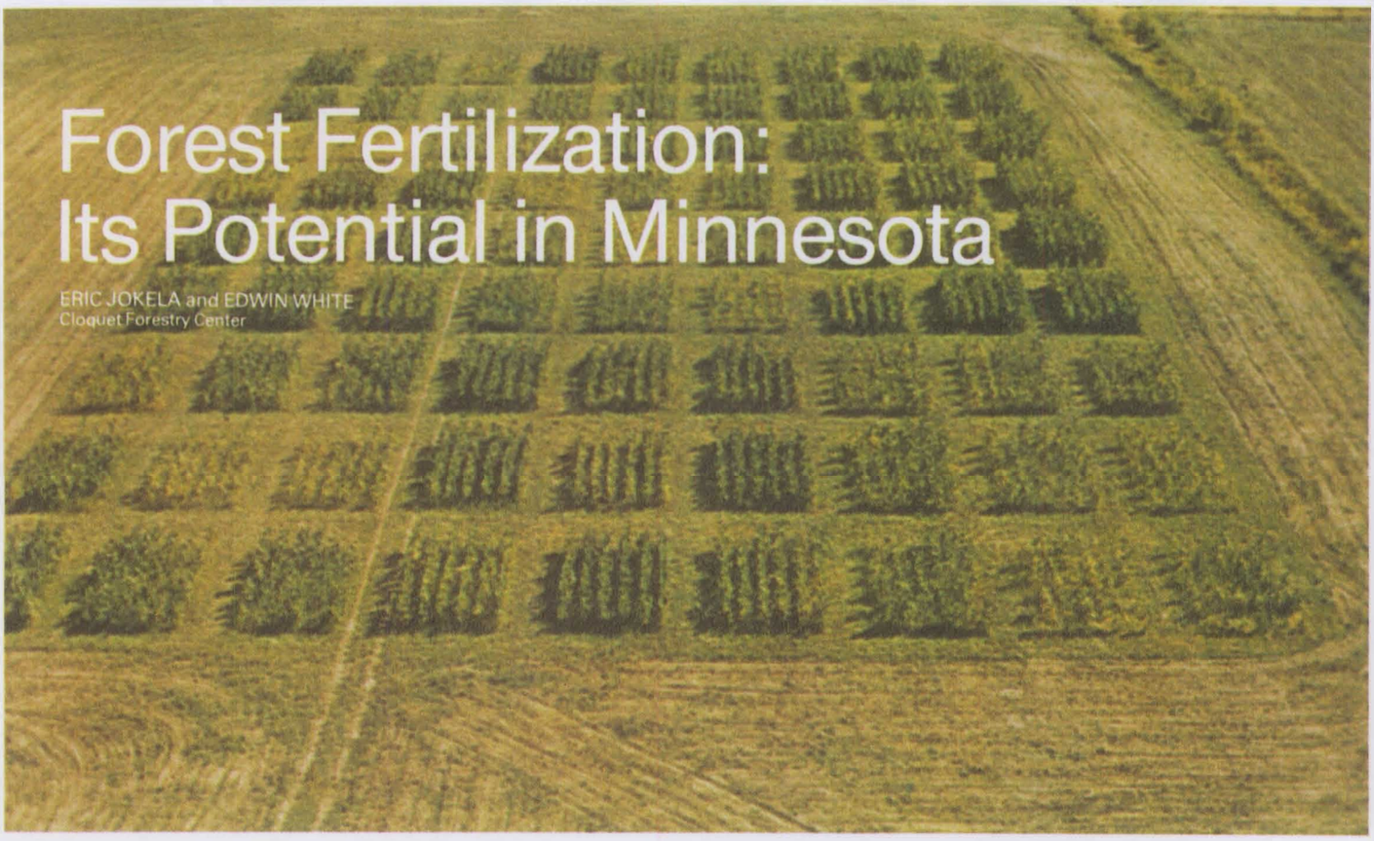
Besides biological methods, field and sweet corn varieties resistant to European corn borer are being developed through the cooperation of plant breeders in horticulture and agronomy at the Experiment Station, Chiang concludes.

A female fly of *Lixophaga distraeae* with the uterus dissected out in order to extract the maggots (many of which are shown). A maggot is placed on a corn borer larva then enters and feeds inside it.

A female wasp of *Macroentrus grandii* with the long ovipositor. This is the most prevalent corn borer parasite in the north central region.

Forest Fertilization: Its Potential in Minnesota

ERIC JOKELA and EDWIN WHITE
Cloquet Forestry Center



Fertilizing forests to increase production may help forest managers meet the rising demand for wood products. This experimental energy forest illustrates the effect of varying fertilizer rates. Yellow trees received no nitrogen fertilizer (photos by Edwin White).

HOW DO FOREST managers reconcile the need for more lumber and wood products with the fact that available land to raise timber is shrinking? The answer may lie in fertilizing the forest to increase production on the land that is available.

The growth response to fertilization varies, but the response is significant enough to merit further study. Several universities, including the University of Minnesota, are now studying forest fertilization.

Timber Production

The demand for wood products has risen 70 percent in the last 30 years. At the same time the demand for land for highways, pipelines and urban developments has also risen, and areas such as the Boundary Waters Canoe Area and Voyageur's National Park take more land out of timber production.

More demand and less land to produce timber could lead to wood shortages. Shortages, in turn, could increase the need for expensive wood replacements such as steel, aluminum, and plastic. These materials take more energy to produce and are nonrenewable resources.

Forest land managers and researchers face the question of how to increase the growth rates of various kinds of trees. Accelerating tree growth with more intensive forest management is one answer to this question. Practices such as weeding, thinning, irrigating, genetic selection, and fertilization are being used to increase production.

Forest fertilization has gained in popularity during the last 25 years. The process is occurring at both the research and the operational level. In the Pacific Northwest the commercial use of nitrogen has produced a 38 percent cubic foot growth response in Douglas fir during a 5- to 7-year period, with variation from 0 to over 100 percent.

Phosphorus and nitrogen additions to slash pine and cottonwood forests in the Southeast resulted in growth response. Slash pine averaged 15 to 20 percent in cubic foot volume response to phosphorus applications, while cottonwood responded to nitrogen by over 200 percent in some instances.

Potassium has increased growth of red pine in the Northeast but commercial applications are rare. Research continues to fully evaluate growth responses, nutrient uptake by selected species, and the fate of fertilizers applied to forest ecosystems.

Universities and Industries Cooperate

Cooperative efforts in fertilizer research have been occurring between forest industries, chemical suppliers, and universities since the late 1960's. Fundamentally, they all attempt to achieve similar goals. Annual grants donated by cooperators are combined with university funds to purchase equipment and supplies and to finance graduate students and supporting scientists. Research em-

phasis promotes forest soil management through fertilization and assisting forest managers in making the most effective use of their land resources.

Fertilized and non-fertilized 15-year-old pine trees. Larger trees in the background were fertilized with phosphorous while smaller trees in front were not fertilized.

Forest Fertilization in Minnesota

The use of fertilizers in Minnesota to increase forest production is currently under study. Recent information indicates that species native to northern Minnesota may well respond to additional levels of nutrients although the knowledge of the nutrient requirements and growth limiting factors important to Minnesota's commercial tree species are limited.

Canadian work from Ontario shows striking growth responses with nitrogen where soils, species, and climate are similar to that of northern Minnesota. For example, nitrogen applied to 55-year-old jack pine resulted in merchantable volume increases of up to 49 percent over untreated trees. Similar results have been reported for both white and black spruce.

Canadian results served as a focal point for research initiated by UM's College of Forestry in 1976. To date, 186 experimental plots have been established in stands of red pine, jack pine, white and black spruce, and trembling aspen over a wide variety of soils encompassing much of the northern forested part of the state. Fertilization with N, P, K, either alone or in combination, is uniform among plots and elemental sources include urea (45 percent N), nitrate (33.5 percent N), triple superphosphate (20 percent P) and muriate of potash (48 percent K). Working in cooperation with scientists of the UM Agricultural Experiment Station, are scientists of the Chippewa and Superior National Forests, Diamond International Corporation, Potlatch Corporation, and the Blandin and St. Regis Paper Companies.

The additional increment due to fertilization usually takes 5 years to reach a reasonable, measurable magnitude; therefore, it would be premature to present response data at this time.

Non-Wood Production

Besides having the ability for increasing timber volume production, fertilizers are being used for a number of special forest-related products and purposes. Unlike wood production, non-wood uses frequently require shorter time demands to produce a given result. Quick vegetative establishment and survival are imperative in many management situations. Roadbank stabilization, forest nurseries, Christmas tree plantations, wildlife habitat management programs, and the maple sugar industry are among the many non-wood production areas which could benefit from fertilization.

The Energy Forest

Perhaps the newest fertilizer-related proposal attracting attention in Minnesota is the energy forest or fuel plantation. Proponents of this system see wood as an attractive and competitive alternative to fossil fuels for energy production.

Conceptually, genetically superior clones of poplars are grown on short coppice rotations ranging up to 15 years. Intensive cultural techniques may include site preparation, weeding, fertilizing, irrigating, and mechanized whole-tree harvesting and chipping. The wood chips (which contain a large percentage of bark) would be transported to a local generating plant. The process repeats itself on a sustained yield basis. Such repeated harvesting on relatively short rotations might tend to "crop the soil" excessively and thus be removing substantial quantities of nutrients that would have to be replenished by the use of fertilizers.

Large land requirements and high capital investments are obvious drawbacks of the fuel plantation concept, although increased growth due to the use of fertilizers might result in a smaller land requirement. Estimates indicate 166 square miles or a plantation having a 7.3 mile radius would be necessary to supply the annual electrical energy needs for a population of 100,000. However, this estimate does not preclude the potential of wood as a supplement for conventional forms of energy if land areas are available and total production costs do not exceed other alternatives.

Fertilization, one of many tools forest land managers can use to increase wood fiber production, has advanced exponentially in recent years. A wide variety of forest uses and products are now associated with fertilizer additions and future uses like the fuel plantations may not be far behind.

Additional investigations are needed to fully quantify the effects of nutrient additions to the forest ecosystem. It must be stressed that forest fertilization like agricultural fertilization requires the careful diagnosis of soil, site, and species requirements for effective and efficient use. Without careful analysis of these parameters, dangers of fertilizer misuse exist.

New Apples for 1978

DAVID A. ZARKIN
Department of Information and Agricultural Journalism

Sweet Sixteen (top) and State Fair (bottom) were grown and tested by Cecil Stushnoff and Shirley Munson (UM horticulturists), David Wildung, North Central Experiment Station, and Wesley Gray, West Central Experiment Station (photos by Cecil Stushnoff).

A MID-SEASON APPLE, Sweet Sixteen (Mn #1630), and an early season variety, State Fair (Mn #1639), will be released by horticulturists at the University of Minnesota Agricultural Experiment Station in 1978.

The two new cultivars have been grown and tested at experiment stations in Minnesota and other states for several years.

Sweet Sixteen, a cross of Mn #447 and Northern Spy, matures slightly earlier than McIntosh under average conditions, producing broader diversity of cultivars for this season, says horticulturist Dr. Cecil Stushnoff. Good storage, handling and cooking properties characterize Sweet Sixteen, which has a round, conical shape.

Trees have been moderately resistant to fireblight and have not shown abnormal susceptibility to apple scab or cedar apple rust, Stushnoff says. Winter hardiness has been consistently good and growth has been moderately vigorous and consistently productive on seedling rootstocks. Sweet Sixteen in grower retail market tests is popular with consumers because of its unique flavor and high quality.

State Fair, a cross of Mantet and Oriole, ripens August 15-30, slightly ahead of Beacon. Crisp, juicy white flesh with a sprightly moderate acid flavor characterize the fruit, which is more durable than other early, hardy varieties, such as Mantet and Oriole. Ripening for State Fair is uniform and premature drop has not been a problem. Medium in size, the fruit is round and smooth with an attractive, bright red glossy finish.

State Fair trees have been cold hardy in central and western Minnesota and grow vigorously as seedling rootstocks. They have been most productive when grown on dwarfing rootstocks.

Stushnoff says State Fair apples are quite susceptible to apple scab under moist conditions, although an adequate spray program can prevent this problem. State Fair is recommended for trial in the north central region where good quality and early maturity are desired.

Science Notes

MANKER BARLEY RESISTANT TO SPOT BLOTCH

The barley variety Manker, recently released by the Minnesota Agricultural Experiment Station, is resistant to spot blotch disease.

Spot blotch caused yield reductions of 20 to 30 percent in Larker, the most widely grown variety, at the Crookston Experiment Station in 1977. Similar yield reductions undoubtedly occurred with Larker in many fields throughout the Red River Valley.

"Manker is very resistant to spot blotch," says University agronomist Don Rasmusson, who worked with plant pathologists Ernie Banttari and Roy Wilcoxson to develop the variety. Manker has been commercially produced for 2 years.

Malting tests have been conducted, and Manker has been classified as an acceptable variety by the malting and brewing industry. However, malters have been paying more for Larker than for Manker. "This may change as the malting and brewing industry becomes more familiar with Manker," Rasmusson says.

Because 1977 was a good year for barley production in most places in Minnesota, yields were generally above average. But Larker yields were reduced due to the spot blotch, which causes the leaves to die and contributes to lodging. "Some farmers who grew Larker were burned pretty badly by lower yields due to spot blotch," Wilcoxson adds.

PINE TREE DISEASE COULD SPREAD TO MINNESOTA

A serious disease that has killed thousands of red and Scotch pine trees in New York could spread to Minnesota and neighboring states.

Scientists are worried that the disease could spread into the Lake states where red pine is a major timber species. "The disease could wipe out pine Christmas tree plantations in Minnesota, just like it's done in New York," says Minnesota plant pathology researcher Darroll Skilling.

Scotch pine is the most common Christmas tree species. Ponderosa pines in western states are also extremely susceptible.

The state of New York has recently announced a quarantine prohibiting cut Christmas trees and pine nursery stock from being transported out of the diseased area. The disease can be spread by cut Christmas trees being transported to previously disease-free areas.

However, the disease can also spread by spores, insects, and a variety of other ways, Skilling says.

The fungus disease, Scleroderris canker, has affected over 34,000 acres of pine plantations in nine northern New York counties over the past 3 years. This recent and dramatic rise in tree mortality has scientists worried that a new and more virulent strain of fungus is present in New York.

"This strain is different from any other strain of the fungus present in North America. Our research shows it's identical to the strain that has caused extensive damage to conifers in Europe," says Skilling.

In Sweden, the disease killed 20 million nursery seedlings in one year. However, trees in Europe have built up more resistance to the fungus, compared to the more susceptible U.S. pines. "Hard" pines such as red, jack and ponderosa are more susceptible to the disease while softer species such as white pine have more resistance.

POTATOES RESISTANT TO APHIDS

In crossbreeding wild potato plants with US varieties, University of Minnesota Agricultural Experiment Station workers produce potatoes with significant sources of resistance to green peach aphids —one of the most destructive of the insects which attack potato plants in this country.

Minnesota researchers are now hopeful about special laboratory

UM researchers are studying a fungus disease called Scleroderris canker which could spread to Minnesota from New York where it has killed thousands of red and Scotch pines.

and field screening methods developed here. "It looks like we can move ahead effectively," says UM horticulturist Florian I. Lauer who has teamed up with UM entomologist Edward B. Radcliffe.

The screening procedures give the scientists assessments of host plant aphid resistance. Resistant plants reduce aphid reproduction. "From a genetic point of view, it appears that host plant resistance can be transferred readily," says Lauer.

With US potato growers losing about $50 million annually from aphid-borne virus diseases, researchers in other states also are interested in the Minnesota work.

Some of the wild species from South America and Mexico are resistant to the aphid and some are resistant to one of the major virus diseases called potato leaf roll. Ultimately, it may be possible to develop horticulturally acceptable varieties that are resistant to both the virus and aphid.

Why not grow the wild South and Central American potatoes in this country? These plants are not commercial types and many would not even produce tubers given the long Minnesota days.

Some highly effective insecticides are available for aphid control, says Radcliffe; but the grower has to choose carefully, because green peach aphids have developed resistance to many of the previously effective insecticides. When an ineffective insecticide is used the result can be serious, because the insecticide will kill predators of the aphid and leave enough aphids to cause a great, rapid increase in aphid numbers.

RESEARCH TECHNIQUES HELP DEVELOP DISEASE RESISTANT PLANTS

New crop varieties with long-lasting disease resistance are the result of new computerized research techniques plus an idea that's 65 years old.

Central to the improved varieties is the concept of slow rusting, where cereal crops may have a small amount of disease damage from stem rust but are generally resistant to all known rust diseases.

"Prof. E. C. Stakman first observed this slow rusting concept back in 1912," says Roy Wilcoxson, plant pathologist at the University of Minnesota. Stakman, professor emeritus at Minnesota, earned world-wide recognition for his plant disease research.

But it's only been recently that plant scientists started developing disease resistant varieties based on this concept. Instead, they have developed new varieties such as Era wheat that have specific disease resistance to known rust races. And they've been very successful—there have been no epidemics of stem rust in U.S. cereal grains in the last 20 years.

The only problem is that within 5 to 15 years these varieties usually become susceptible to rust. "What happens is that disease pathogens may change through mutation or hybridization so that new rust races are produced against crop varieties that had previously been resistant," says Wilcoxson.

Wilcoxson and co-workers in a few other states plus India and The Netherlands are working on the slow rust theory. They've found that they can use very small plots consisting of 1-foot grids to analyze disease resistance for specific varieties. This way they can use computer programming to analyze thousands of varieties and rust races.

"If generalized resistance can be exploited, we should be able to reduce rust losses to about 10 to 15 percent during a severe epidemic. Varieties without generalized resistance can suffer extensive losses of 50 to 90 percent."

General resistance can help solve wheat rust problems in developing countries as well. Leaf rust is the most serious threat to wheat production in underdeveloped countries, according to Wilcoxson.

"In India the disease is reducing yields by 25 percent. These sources of resistance could cut this loss in half, which translates into a 10 bushel per acre saving."

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Publication
Penalty for private use, $300

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