Volume 26, No. 2

Winter 1970

MINNESOTA SCIENCE

A publication of the University of Minnesota Agricultural Experiment Station

Research 1980: A Unique Planning Effort

The Minnesota Agricultural Experiment Station is currently engaged in a unique planning effort known as "Research 1980." It represents an attempt to project research trends and developments during the next decade. Every sector of agricultural, forestry, and home economics research at the University will be represented in the program. Planning committees are comprised of staff members from several different departments, each possessing a special expertise in a single problem area, such as environmental quality or resource development.

The planning effort is founded on the belief that Experiment Station research should lead rather than follow the research enterprises of state and federal agencies or private institutions and industrial concerns.

The present trend in agricultural research appears to be toward fundamental approaches to practical problems. This problem-oriented approach brings together scientists from several different disciplines, all with a common objective in mind. Evidence of this at the Minnesota Station is apparent in the work of scientists who are turning their attention to some of man's most nagging problems — namely air, water, and land pollution.

Pooling of scientific resources and expertise may become a vital necessity in years to come because of the increasing complexity of science both in training and practice. The number of scientists classified as "generalists" (experts in several fields) is rapidly diminishing. In terms of research planning and coordination, this means that departments or general areas of science will most likely be composed of a limited number of special areas.

Some of the other changes expected to take place in agricultural research during the next decade may influence Minnesota's overall research program. They are as follows:

- Computers will play an increasingly important role in agriculture, forestry, and home economics research.
- New emphasis will be placed on certain concerns of our society — problems of people in urban and rural settings.
- Additional researchers will be needed, but a greater demand will exist for more supporting personnel, services, and operating funds for present staffs.
- Greater attention will be given to retraining staff members and reorienting some of the existing research efforts.
- An increasing number of interdisciplinary and intercollegiate research programs will be organized around problem or program goals but departments will remain the professional home for research faculty.
- A larger percentage of Experiment Station research funds will come from state legislatures and from industrial and private resources.
- A larger percentage of federal funds from non-USDA agencies will come in the form of institutional grants rather than being allocated on a project-by-project basis.
- Input-output studies of agricultural research will promote more efficient and effective research management.

These are just a few of the changes that are expected to reshape research of the future. Some have already begun to take place. Some will happen at a later date or not at all. And other possibilities lie beyond our present ability to predict them. This latter possibility makes it essential that we continually review our "projections" and needs for the future so that important trends and opportunities are not overlooked.

The outcome of "Research 1980" should result in recognized goals and established priorities, and provide administrators with valuable information to guide them in the decision-making process.

At frequent intervals we will keep you informed on the progress being made under "Research 1980."

William F. Hueg, Jr.

MINNESOTA SCIENCE

A publication of the University of Minnesota Agricultural Experiment Station

Minnesota Science is published by the University of Minnesota Agricultural Experiment Station, Institute of Agriculture, St. Paul, Minnesota 55101.

Director—W. F. Hueg, Jr.

Editorial Committee—Craig F. Forman, chairman; Huai Chiang; Harold Dzuik; Joan Gordon; James Houck; Jean Lambert; A. J. Linck; and C. W. Young

Dean of the Institute of Agriculture—Sherwood O. Berg

Editor—Craig F. Forman

Design—Dianne Swanson

CONTENTS

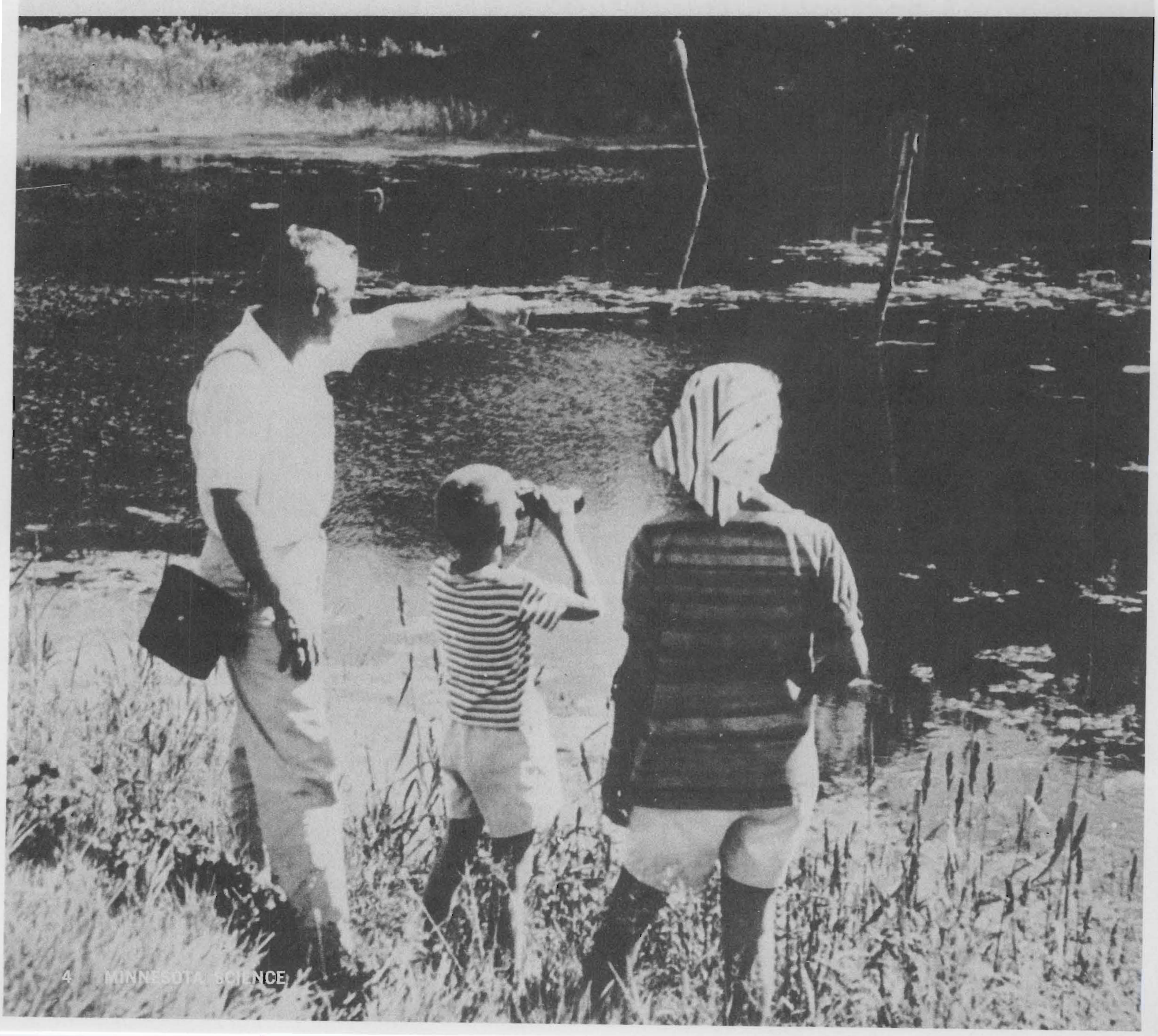
To simplify terminology, trade names of products or equipment occasionally are used. No endorsement of products or firms is intended, nor is criticism implied of those not mentioned.

IMPROVING OUR ENVIRONMENT

LEE R. MARTIN
professor
Department of Agricultural Economics

Concern for the quality of our environment has become serious only in recent times, despite the fact that conditions which led up to our present problems have existed for a long time. Economists generally agree that concern for environmental quality is primarily a phenomenon of affluence: as average income rises, the standards of environmental quality that people will accept also rise.

People living in low income countries and depressed areas of developed nations show a willingness to accept lower standards of environmental quality in order to obtain higher employment and income levels. But affluence



in developed nations has led large groups of citizens to no longer regard environmental deterioration as a necessary cost of rising standards of living. They believe that improvements in environmental quality can be achieved along with higher living standards. And some people even profess that they are willing to accept lower rates of increase in national income in order to improve environmental quality.

Rising levels of affluence are only a single instance of the way in which economic considerations touch upon problems of environmental quality. Environmental deterioration also decreases the quality or quantity of consumer satisfaction. Similarly, environmental deterioration by some producers may add to the production costs of other producers. On the other hand, most environmental improvements add to consumer satisfaction and may reduce production costs.

The decision to invest in environmental quality involves a comparison of relative costs, which are difficult to estimate. Costs of maintaining environmental quality are incurred when human and capital resources are diverted from other lines of production to environmental improvement. These improvements must be carefully weighed against the value of the production lost. In assessing the value of improvements, it is essential that we establish what the benefits are, how many people will receive them, and who the beneficiaries are.

Two other factors weigh upon the decision to invest in environmental quality. First, there must be a willingness on the part of the public to pay for environmental improvements. Secondly, willingness to pay should not be considered only on the basis of the total investment; each investment should be examined to determine what benefits and costs it will generate.

Economic considerations often dictate that standards of environmental quality be allowed to vary from one situation to another. Applying a single standard to several different situations can create acute problems. If a very high standard is chosen, the total cost of achieving and maintaining that standard everywhere may be greater than citizens are willing to pay. If a low (less exacting) standard is chosen, then it may not even approach its potential for increasing consumer satisfaction. For example, it is not necessary that every river or lake be pure enough for swimming. But it is necessary that the supply of open-water swimming areas be adequate to meet the needs of swimmers. Similarly, every body of water does not have to be free of thermal pollution. But it is important that thermal pollution be controlled and limited to areas where consumer satisfaction is not greatly reduced.

If funds for improving environmental quality are limited, as they surely will be, then economic considerations dictate that these funds be invested where returns in the form of consumer satisfaction are greatest. This argument, alone, offers strong support for a system of standards that is allowed to vary with each situation.

Some activities that bring about environmental deterioration have been legally translated into "property rights," which cannot be dismissed without due process of the law. Some of these activities go back to a point in time when there was little social concern for environmental quality. Polluting or despoiling industries were "invited" into a community because its citizens ranked the economic benefits above the social costs of deterioration.

Economic Aspects

Now, the most important economic questions are, can we raise the quality of the environment and income per person at the same time? If the answer is "Yes," how can we achieve this happy result?

Let us begin by trying to classify the aspects of environmental quality that have economic consequences.

1. Consequences for physical health: Some effects of environmental deterioration are universally harmful to the physical health of human beings. Our society has used legal restraints to deal with these sources of pollution whenever the association between cause and effect could be shown. When universality is lacking, violators have been treated leniently. In the past those who were adversely affected chose a more compatible environment in the suburbs. In the future, society may use legal restraint when the harmful effect is felt only by a majority or even by a substantial number of individuals, rather than the whole community.

2. Consequences for mental health: Some effects of environmental deterioration are adverse to the mental health of human beings. Such tension-creating phenomena as loud noises, flashing bright lights, and so on that disturb a community are likely to come under police jurisdiction. Zoning techniques could be used to relocate sensitive households or tension-creating firms in different parts of the community, and low social costs would be incurred.

3. Consequences for consumer satisfaction: Some effects of environmental deterioration significantly reduce (in economic terms) the various natural resources that contribute to consumer satisfaction. Here we are dealing with scarcities created by environmental deterioration, not with natural scarcities (there is only one Yellowstone National Park). Among the shortages induced by deterioration are swimming, fishing, and hunting opportunities, natural landscape, fresh air (even when no question of health is involved), flora and fauna in their natural habitat, and so on.

Here we are dealing with sources whose effects on man are known well enough to begin to deal with them. One method is to begin a sorting out process. What *supplies* of these natural environment "services" are consumers (or taxpayers) willing to pay for, if they are efficiently produced? This analytical approach to maintaining environmental quality seeks to satisfy present and future demands rather than preserve some sacred universal standard that ignores the cost or the volume of consumer demands to be satisfied. Means should be sought to levy more of these costs both against people who use the services and against those who don't use the services, yet insist that their options to use be kept open.

4. Unique opportunities for consumer satisfaction: Some natural resource complexes are unique in the sense that if man destroyed them, nature would never replace them. Examples are the Grand Canyon, Yellowstone Park and many other (but not all) national parks. Either man could not repair serious abuse, or he could only do so at great expense. These unique opportunities should be preserved regardless of the benefit to cost ratio. The term "unique" should be carefully applied lest society become reluctant to maintain them all.

It is important that the economic costs of maintaining or improving environmental quality be carefully estimated. The keynote is opportunity cost: What must society give up in order to have better environmental quality? What other uses could be made of land and water resources, of the funds, of the human resources that are required to meet our environmental quality goals? Society has as much reason to insist upon efficiently managed resource complexes as stockholders of business enterprises have.

5. Consequences of incomplete knowledge: Some environmental and ecological situations are beyond the range of our present knowledge and we are not always certain whether they present a problem. Or, if we are sure that we have a problem, we don't know how serious it is. Or we don't know how to deal with it. The DDT controversy is part of a larger concern with nondegradable organic chemicals, deposited either in water or soil. There are many potentially worrisome ecological phenomena that we don't know very much about. Many of them appear to have economic consequences.

Two suggestions can be made for this category. First, it is important that those phenomena that appear to have the greatest potential for harm be systematically investigated. We must learn more about the nature and possible solutions to these problems. We also need to know more about the full range of consequences of removing the offending agent: banning the use of DDT, moving a paper mill to another location, and so on. Specific answers are needed to understand the economic consequences: How much greater would the national food bill be if we banned the use of DDT? How much more would paper cost if treatment of all paper mill wastes was required? What economic consequences would result from forbidding plants to emit fumes under certain atmospheric conditions? What consequences would arise if industry was not allowed to dump waste materials into a stream when the stream flow was less than a set amount?

Secondly, an interim strategy must be worked out for cases where knowledge is incomplete. Quick investigations of practices that cause pollution would determine if it were economically feasible to abandon them. In other instances, low-cost alternative practices that would not lower environmental quality could be recommended.

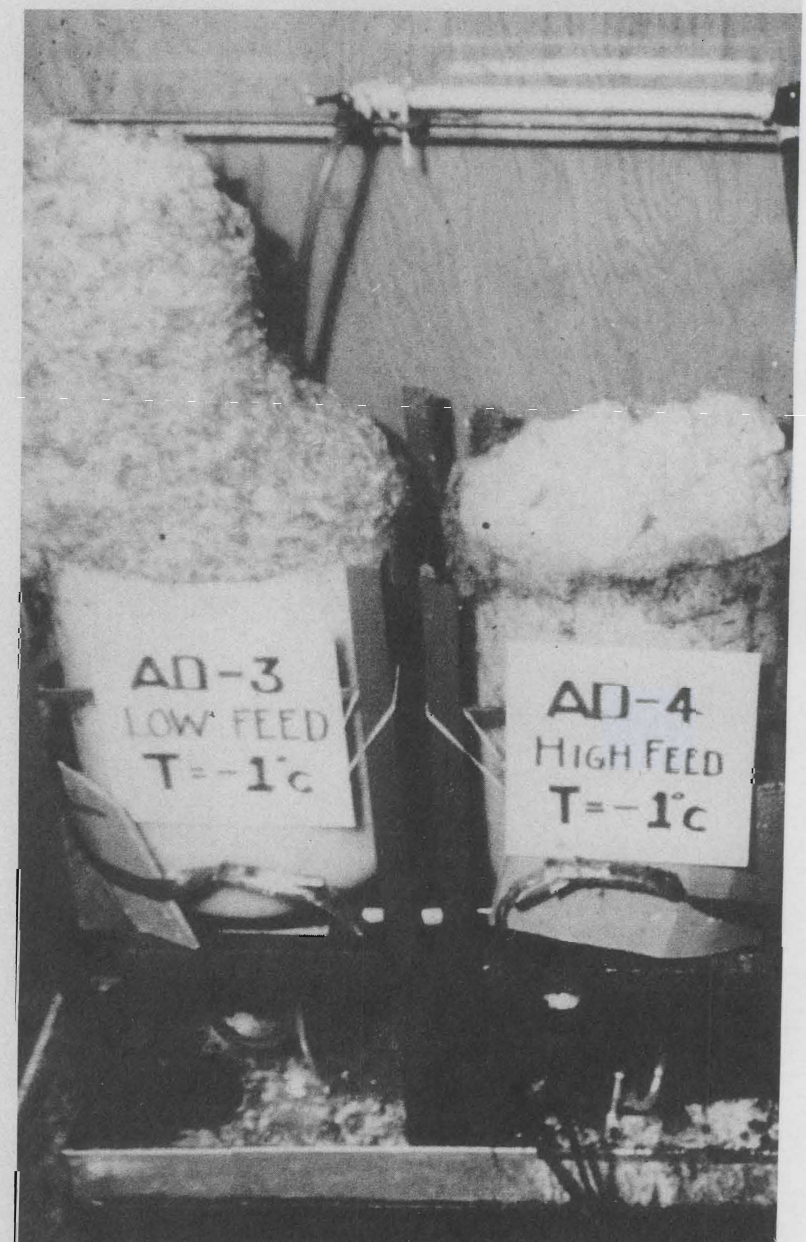
6. Intellectual values of resource complexes: Some ecological systems have a unique value that could be called intellectual. For example, observation or study of living organisms in their natural habitat often is an effective teaching device. In many cases, research investments in these systems will produce new knowledge, which may have economic value. Some investment to preserve ecological systems that present unusual educational and research opportunities is undoubtedly justified, particularly in an advanced society.

The social costs of a better environment may not be as high as some "scare" stories indicate. As more skilled managers and research scientists turn their attention to quality problems, new and effective technologies will be developed. These discoveries will make maintenance or improvement of environmental quality less expensive. This is even more likely if we provide incentives for those who maintain or improve the environment, and disincentives for those who despoil our environment. In the final analysis, this system is more likely to provide better results than outright legal restriction of deteriorating activities.

Animal Waste Disposal

CAN WE SOLVE THE PROBLEM?

WILLIAM P. MARTIN
professor and head
Department of Soil Science



Cold weather foaming problems in oxidation systems are being researched.

Agriculture is no longer solely concerned with the production and distribution of more and better food and fiber products. This remains the most important charge of our nation's farmers, but the threat posed by environmental pollution is assuming greater proportions. Widespread use of commercial fertilizers, confined feeding practices, increased herd size, and greater concentration of commercial feedlots have all contributed to our burgeoning animal waste disposal problem.

Since our nation's dietary is largely centered around meat products, we currently support a national livestock population that presents a waste disposal problem equivalent to a nation of nearly 2 billion persons. In Minnesota alone, we raise 14 million chickens and turkeys, 4 million cattle, 1.5 million dairy cows, 2.5 million hogs, and ¾ million sheep. The state's animal population, in effect, creates a disposal problem equal to a moderate-sized nation with a population of about 66 million.

The only way these wastes can be effectively handled is through our soil system, which includes the use of water resources. Manure must be returned to the land as part of a self-perpetuating system that supplies nutrients for crops, and crops, in turn, are fed to animals that produce additional wastes. The question, however, is to what extent this "self-perpetuating" environment can continue to accommodate the tons of waste coming from our agricultural industry. Is our soil system an effective medium for waste disposal or will it become polluted and, in turn, pollute our lakes and streams and reservoirs? The answer to these questions hinges upon our knowledge of soil.

Soil is not a simple entity. Minnesota has some 600 different soil types and 57 soil associations that represent major differences. The state's soils are roughly 10 to 20 thousand years old and were largely derived from the parent materials of glaciers. Our cool climate has promoted a thick accumulation of organic matter in the prairie soil areas, lots of potholes (many now filled with peat), extensive sandy outwash areas, loessal deposits (along the Mississippi), silts and clays (in the Red River Valley), and gray-forest soils in northern Minnesota. Over the years, cool temperatures and winter freeze have slowed the weathering rate so that leaching of plant nutrients has been modest and soils remain fertile.

SOIL SURVEY

The Minnesota Soil Survey, a cooperative effort of the Soil Conservation Service and the University, will eventually provide basic resource information for determining which soils are best suited for waste disposal. Soil structure, texture, porosity, pH, relief, drainage and horizon characteristics, and engineering properties are being examined in many locations. Special projects such as this provide a sound basis for planning and zoning. In years to come, soil surveys, land-use evaluations, and soil and water conservation programs will play an even greater role in rural planning. Locations for barnyards, lagoon areas, oxidation trenches or landfills, compost pits, and farm disposal areas will be based on careful evaluation of soil types, topography, geology, hazards to groundwater, and possibilities of erosion.

SOIL AS A DISPOSAL MEDIUM

The physical and chemical makeup of soils influences their ability to break down large quantities of manure. Soils that are capable of retaining moisture generally contain large numbers of microorganisms. These tiny forms contribute greatly to a soil's capacity to decompose organic matter, such as leaves, roots, and stems of decaying plants as well as manure.

Decaying plant residues, also known as humus, comprise the organic cement that holds inorganic soil particles together. Solid inorganic particles, such as sand, silt, and clay, make up about half the volume of most soils. The size, shape, and arrangement of these particles determine a soil's texture, structure, and its water-holding capacity. Sandy soils are not cohesive (or plastic) so they drain quickly. Silt particles are more cohesive, but they behave more like sand than clay particles. Clay is the most cohesive. Along with humus materials, it controls most of the important chemical and physical properties of soil.

Under conditions ideal for decomposing manure, the soil profile contains fairly large pores, extending from the soil surface down to the water table or drainage tiles. This type of soil structure insures rapid infiltration of rain or irrigation water, satisfactory percolation through the profile, and drainage of excess water from subsoil layers.

Soils of this type are also well aerated near the surface. Since decay-producing microorganisms function best where free oxygen is high, this environment hastens the breakdown of organic waste materials. And at the same time, it aids in forming nitrogen compounds vital to crop growth.

However, if large amounts of manure are deposited on coarsely textured sandy soils, they may eventually contaminate ground water supplies. This occurs because sandy soils infiltrate water rapidly, but have a low capacity for retaining moisture. As a result, water percolates down through the soil profile too quickly, carrying nitrates which pollute ground water sources.

On the other hand, finely textured soils, such as silty clay, are capable of absorbing large quantities of water, but water movement is slow. This can promote contamination of surface water supplies when animal wastes are spread on sloping or frozen soils and run off during spring melt or after heavy rains. An erosion control measure, such as growing plants on soils to utilize moisture and nutrients, is the best way to reduce nutrient contamination of water supplies.

CHEMICAL ACTION OF SOIL

Research findings show that soil acts as a highly effective filtering device to trap nitrogen and phosphorus, two nutrients often implicated as agents that accelerate the pollution process. Microbes in soil break down the nitrogen compounds in manure and release it as ammonia. These ammonia molecules usually are fixed to soil particles and completely immobilized. In well aerated soils, however, nitrifying bacteria convert the ammonia to nitrates in a two step process. Since nitrates are completely soluble, they will move down through the soil profile with percolating waters if they are not used first by plants.

But if the nitrates move down into poorly aerated areas of the soil profile, denitrifying bacteria will reduce the nitrates to elemental nitrogen. In this gaseous state, nitrogen rapidly escapes from the soil and is lost in the atmosphere. In fact, 30 percent or more of the nitrogen in manure is usually lost even before it is spread in the fields.

Other methods can be used to eliminate nitrates that might pollute groundwater. Holding lagoons or settling basins can duplicate conditions favorable to bacteria that function either with or without oxygen.

Phosphorus that is applied to soil or released from organic wastes by microbial action represents an almost negligible source of pollution. Like ammonia molecules, phosphorus is quickly fixed by soil particles and remains insoluble. Even when the soil containing phosphorus is eroded and runs off to a nearby lake, less than 10 percent of the phosphorus becomes available for aquatic plant growth. The rest remains fixed to sediment on the lake bottom. Phosphorus from other sources, such as from detergents, will also fix to soil sediments on contact and remain unavailable.

LAND DISPOSAL SYSTEMS

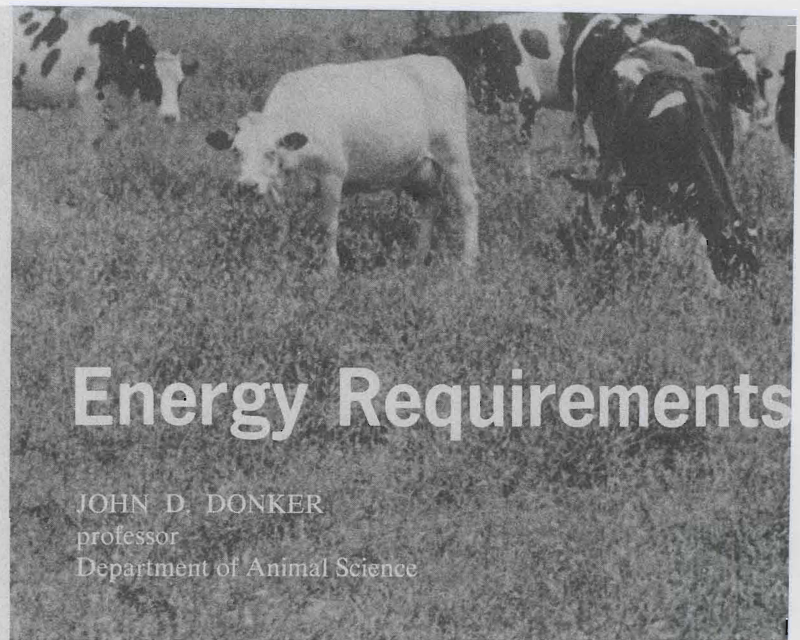
Research on disposal systems designed to reduce the nutrient content of soil and liquid wastes has intensified in recent years. Existing systems such as lagoons and recharge basins have been improved by using chemicals (lime and aluminum sulfate) to remove nutrients from collected wastes. But the present efficiency of lagoon systems falls far short of the demand placed on them. A 150-head dairy herd produces the same amount of wastes as a village of 2,500 people. A municipality of this size requires a 25-acre pond to adequately treat its wastes. So in most instances, farm lagoons merely serve as collection or holding pits until they can be cleaned out and the manure spread on nearby fields.

Farmers with sprinkler irrigation systems have successfully pumped liquid wastes from lagoons. An intake screen removes large solids and the electric sprinklers irrigate fields with the wastes flushed from confined feeding operations. Little additional fertilizing is required and odor is reported to be minimal. This disposal method has also gained wide acceptance among canning factories, cheese processing plants, papermills, and sugar and vegetable processors.

CONCLUSIONS

Further research on soils as a medium of disposal is needed. Soil surveys should be accelerated to provide basic information on soil types. Benchmark studies on key soils would provide valuable data on physical, chemical, and biological effects of pollution. They also could serve as a basis for developing design criteria for both rural and urban waste treatment facilities.

We have no medium other than soil that is capable of handling large quantities of organic wastes. But larger farming operations, combined with more economical management practices, have led to an over-concentration of animal wastes than in many instances overtaxes the soil's ability to rejuvenate itself. This situation can be averted, but before we can intelligently exploit our soil system to its fullest extent, a comprehensive program of research must be implemented.



Energy Requirements

JOHN D. DONKER
professor
Department of Animal Science

For decades dairy nutritionists have been urging dairymen to feed their cows scientifically by using feeding standards. But balancing a cow's current nutrient intake against her current need for certain nutrients has proven a difficult task. Few, if any, high-producing cows can be kept in nutrient balance during early lactation. Most often they draw upon their own body reserves for energy-providing nutrients, protein, minerals, and vitamins. Even though an energy balance at peak yield is almost always not achieved, rations can be balanced in other ways and should be.

Like other farm animals, the high-producing dairy cow's performance depends on a balanced supply of all required nutrients. A lack of any required nutrient can cut down on production, but most often the relative lack of energy-supplying nutrients limits the dairy cow's output.

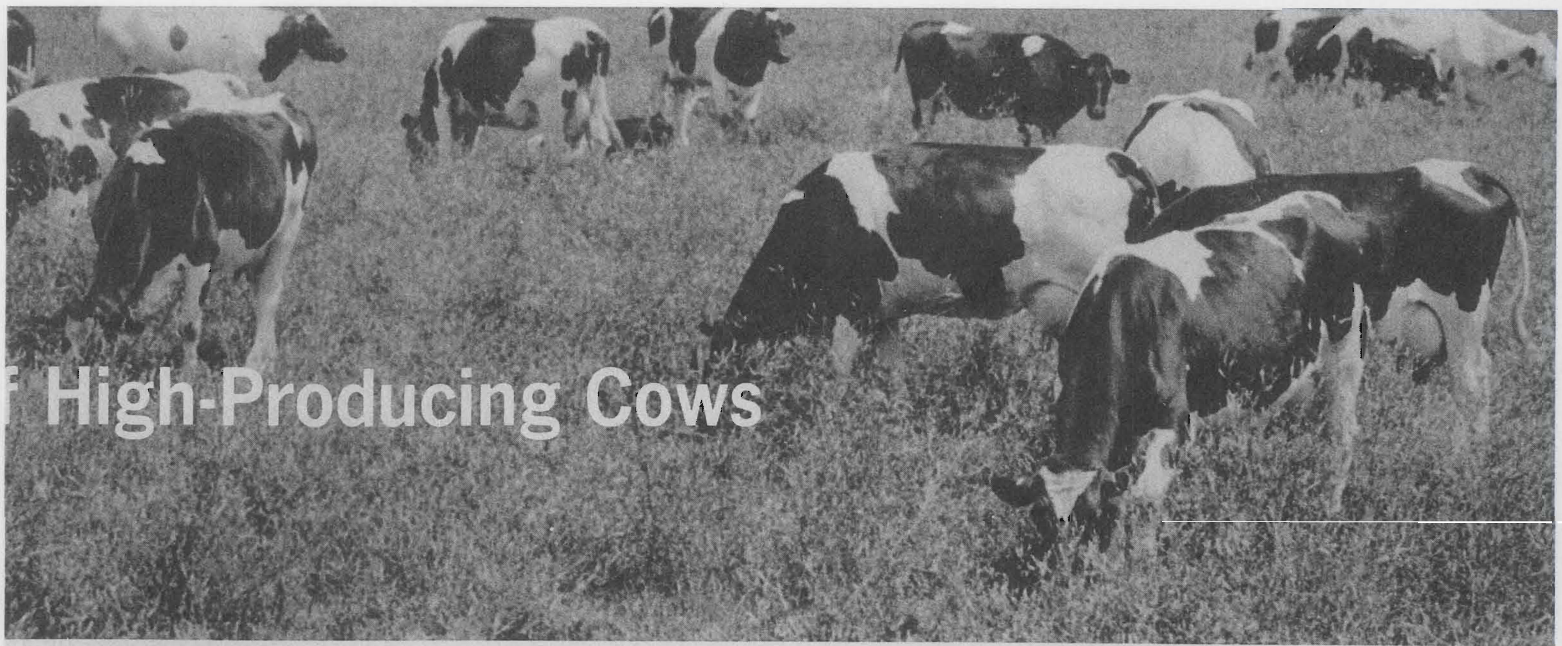
FORAGE QUALITY

Dairy cattle are forage-consuming animals by nature. But genetic breeding has developed the high producer's mammary system to the point where the udder can secrete milk nutrients after calving faster than the cow can supply them with feed nutrients. This is especially true if the ration is forage or, to a lesser degree, even mixed rations high in concentrates. Forage quality, in turn, affects milk production. As the quality of forage drops, milk production is lowered unless the ration is enriched with extra concentrates.

Recent studies at the University indicate that as the fiber content of an all-forage ration increased between 27 and 42 percent of the dry matter, lactation yields of good quality Holsteins dropped 430 pounds fat-corrected-milk for every percent increase in fiber. Findings also showed that there are practical limits on lowering fiber content in forage. The most economical solution is to supplement even high quality forage rations with concentrates.

Adding concentrates to rations increases energy intake in two ways. First, the concentration of energy in rations is increased and, secondly, the cow consumes more total feed. For every pound of concentrates that is consumed, only about ½ pound of forage dry matter is displaced. The question that remains unanswered is how much concentrates should be used under what circumstances.

Dairymen should be aware, however, that the relationship between feed level and milk production is not reversible. For example, cutting down feed levels will lower milk production. But often the reverse is not true. Only



f High-Producing Cows

during early lactation do dairy cows respond fully to increased feeding levels. Studies with Holstein cattle on high quality pasture revealed that for every pound of concentrates removed from rations, losses of 1 pound of milk occurred each day. On the other hand, for each pound of concentrates added to rations, milk production only increased 0.1 pound each day.

FEEDING STANDARDS

For several decades the scientific feeding method was based on noting the level of productivity and then feeding the cow accordingly. This concept was replaced by challenge feeding, which involved feeding the cow increased amounts of concentrates each day and seeing if it responded with increased milk production. What this has turned out to be is feeding concentrates freechoice after calving until it is obvious that production has reached its peak. Despite successful feeding programs of this nature, most animal nutritionists caution against increasing daily amounts more than 1 to 2 pounds. High concentrate feeding can give rise to such conditions as milk fat depression, off feed problems, or founder.

The foremost objective is to get milking cows as close as possible to an energy balance. And at the same time dairymen must keep in mind the animal's health, the fat content of milk produced, and the cost of rations.

Present day feeding standards reflect an awareness that as milk production increases, the nutrient cost per unit of milk also goes up. This is due to the fact that the cow's digestive process becomes less efficient at higher levels of intake. Since forages normally cost less per energy unit than concentrates, the cow, both high and low producers, should be fed all the forage they will consume. Forage intake can be regulated by adding or withdrawing concentrates, since the cow prefers them to forage rations.

In attempting to attain a nutritional objective, the composition of the ration is a more reliable guide than simply using a ratio between roughage and concentrates. A minimum of about 15 percent crude fiber on a dry basis is the lowest feasible amount to attain an energy intake that will not adversely affect milk fat content. Generally, after calving the cow is fed a ration which is calculated to keep her in nutrient balance, except for energy requirements. It is assumed that she will use energy reserves from her fat deposits. However, a very real danger exists that the cow may overtax her ability to mobilize body fat reserves. The solution to this problem is to supply a ration with high energy content, which may be an all-in-one ration or a mixture of roughage and concentrates controlled by the proportion of concentrates added.

Cows should be supplied this ration free-choice early in lactation. However, cows are usually unable to consume as much feed immediately after calving as they can a month or so later. There's no satisfactory answer why this condition prevails. Perhaps it just takes time for the cow's gut to adjust to the demands that are placed on it. At any rate, maximum intake usually occurs after the cow begins to decrease her production.

The art of feeding dairy cows is to feed them enough to stimulate maximum milk production, but not enough to add excess weight. Feeding cows a high energy ration throughout lactation is wasteful because they gain weight and this increases maintenance costs and lowers the gross efficiency of milk production. Increasing the feed input to responsive animals, however, increases the gross efficiency of milk production. This occurs because maintenance costs are spread over more units of milk production. But as their feed intake increases, the digestive process becomes less efficient. An ordinary cow uses about 50 percent of her energy intake for maintenance. The gross efficiency of well-fed, high-producing cows is considerably higher, despite the lowered efficiency of the digestibility process.

SUMMARY

The high-producing cow has very high requirements for energy-supplying nutrients, protein, minerals, and vitamins. The amounts required are in excess of what can be obtained from the food, but body reserves supply the difference. It is important not to overtax the reserve energy supply because ketosis may set in. Under modern day conditions the fresh cow should be challenged with very liberal concentrate feeding. The important point about liberal concentrate feeding is to adjust it downward after production has started to decline. The concentrate portion of the ration should be decreased in such a way as not to accelerate the drop in milk production. This is where experience and awareness become important. The animal's condition is very important in judging how much concentrates to feed. For most efficient milk production cows should not be allowed to get too fat or gain weight too rapidly.

FORESTRY and Central America's Future

HUGO H. JOHN
professor
School of Forestry

Most people usually think of tropical rain forests as tangled jungles. This misconception stems from exaggerated descriptions in adventure novels or similar scenes from movies and TV. In a few instances this impression is not too far astray. There are areas where it is necessary to hack your way through heavy brush and vines. However, these areas are usually found in poor forest stands comparable to the dense brush in poorer stands of the United States. Good tropical forests actually have little underbrush beneath their extremely dense canopies.

Generally the tropical forest is extremely hot and wet during the day, and cool and wet at night. Snakes are present, but the threat is no greater than in some regions of the United States. The clouds of insects associated with the tropics are no more annoying than in the northern forests of the Lake States.

Tropical forest problems may appear insurmountable to foresters from temperate zones. But they are no more foreboding than the problems a tropical forester would encounter if he came to northern Minnesota. The greatest deterrent to tropical forestry development, human and institutional problems aside, is the lack of logging and shipping facilities.

Seen from the air, the Central American isthmus appears to be covered by unlimited forest areas. But the actual area is small in comparison to the U.S. Central American forests cover approximately 75 million acres which is about 1/10th of the U.S.'s forest area. Hardwoods comprise 80 percent of the tropical forests and the remainder is conifer (mostly slash pine).

Almost 60 percent of this Central American region is forested, extending along its eastern coast and inland to the central regions. The forest lands are difficult to describe because very little detailed inventory has been carried out. Extensive reconnaissance inventories, which set the stage for more detailed studies, have been completed in a few select areas of the region. A survey of northern Guatemala revealed the presence of more than 300 species with a diameter of 6 inches or more. In Nicaragua over 60 tree species with a diameter of at least 16 inches were identified. But the volume there averaged less than 7,000 board feet per acre.

The outstanding characteristic of a tropical hardwood forest stand is its great diversity. Seldom is any species strongly dominant. If it is dominant, it rarely represents more than 10 percent of the stand volume. Unfortunately, the more common species presently have little or no commercial value. The two tropical species most widely used in the U.S., mahogany and Spanish cedar, are relatively scarce. Central American mahogany is highly prized for cabinets, furniture, and boats. Spanish cedar has long been used for cigar wrappers and boxes.

These two species have been logged for years, but good forest stands may contain only two mahogany trees per acre. As a result, most areas within 3,000 feet of streams that will float logs have been divested of mahogany trees. Most tree cutting is done with an axe, and logs are hand-rolled to a stream where they are floated to the mill.

Increased forest industry development depends upon expansion of the number of marketable species so that per acre yields will be profitable enough for mechanical logging operations. Presently, only seven or eight tropical species are accepted on the world market. But even with these additional species, very few stands yield more than 3,000 board feet per acre of marketable timber, which makes mechanical logging unfeasible.

The problems underlying future development of tropical forests can be best understood by looking at the past. At some point in time forestry was an important part of the economies of most Central American countries.

In Nicaragua, for example, forests contributed to the overall economy before the turn of the century. However,

In this article Central America includes Guatemala, British Honduras, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. The author spent 1965-66 as Forest Inventory Expert in Nicaragua for the Food and Agriculture Organization of the United Nations.

their major role in foreign trade began about 1910. Between 1915 and 1930, wood exports accounted for about 12 percent of the total national export value and reached highs of 22 percent in 1917 and 19 percent in 1930. For the 20-year period from 1945 to 1964, the percentage of total export value attributed to wood exports steadily declined and averaged less than five percent. Part of this decline was caused by the rapid gains in Nicaragua's total economy. But this shift also reflected a basic alteration of wood resources.

If you look at only the forestry sector of the Nicaraguan economy, some alarming factors come to light. Over the 5-year period from 1960-1964, the total value of wood exports equalled the total value of wood imports. If these same data are examined on a year-to-year basis, the conclusion is very different. In 1960 wood exports exceeded wood imports by $1.7 million. But by 1964 there was a $1.7 million deficit of imports over exports.

Two basic causes appear to have brought about this abrupt change. The primary cause is that over 95 percent of the wood export value comes from the export of logs and lumber, mostly pine and mahogany. Intensive logging of these two species over the years has depleted the supply.

The second factor affecting wood export-import values is that 95 percent of import expenditures go for finished or secondary products such as paper and plywood. Thus, exports represent a high volume of roundwood equivalent per unit of value and imports a low roundwood volume per unit of value.

The case history of Nicaraguan forestry is representative of the other countries in that region. All Central American countries have the same problems when it comes to forest resource use and development. All have the great diversity of species, generally low volumes of desirable trees, and poor or nonexistent transportation systems. On top of these problems Central America's shifting agriculture is destroying large forest areas.

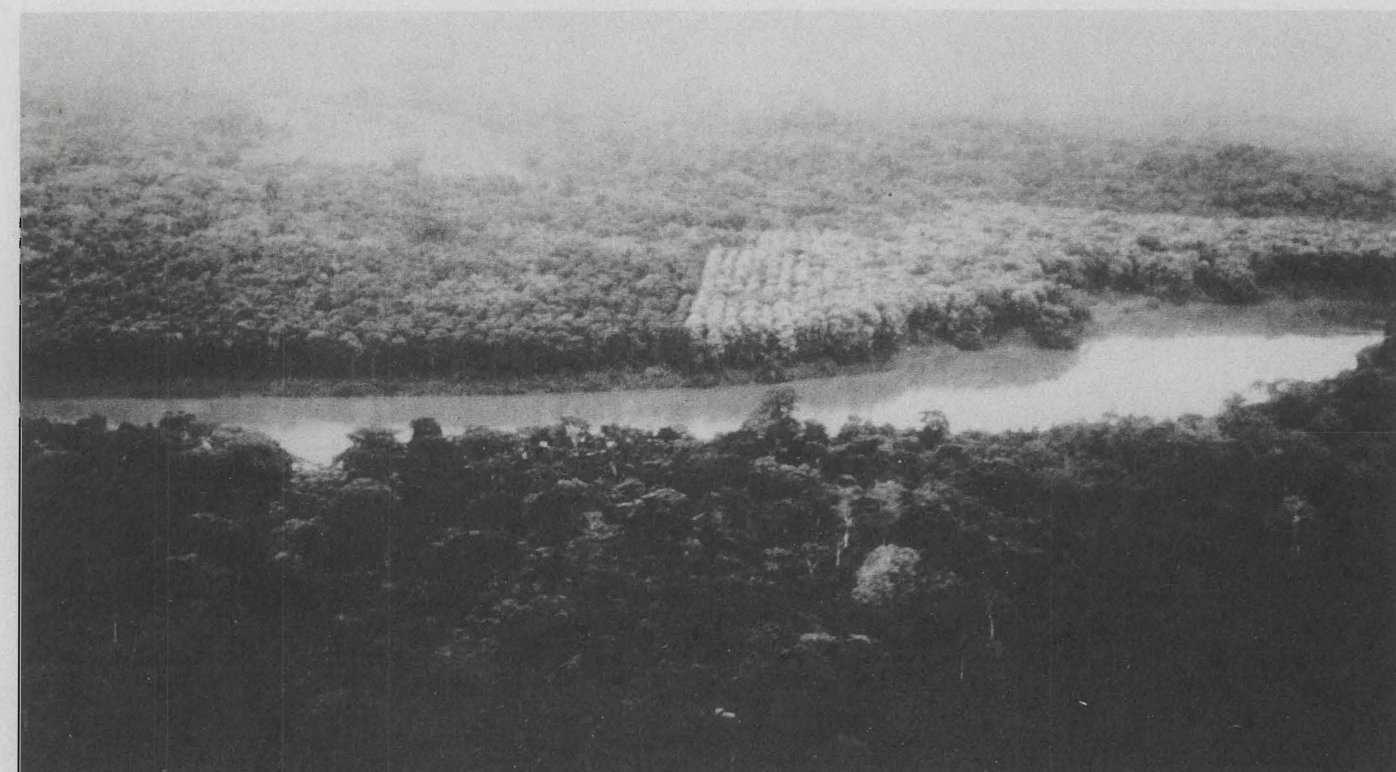
Tropical forests are a potentially valuable resource that can improve the economies of developing countries. Recent events indicate that increased forest industry development in Central America could become a reality in the near future.

One of the most promising occurrences is that some government officials are now aware that forestry can be an important factor in overall general and economic development. Forest industry development usually is centered in less developed regions, which often are plagued by underemployment and poor transportation. Forest industries frequently promote other developments that benefit the economy. Also, legislation is being enacted by some Central American countries to encourage secondary processing of the timber resource domestically. And initial attempts to encourage resource management are evident as well.

The current low supply of veneer-sized hardwoods in the U.S. has increased the prospect for tropical forest development. Many U.S. users are interested in experimental use of more tropical species.

The primary need in Central American forest development is to establish industries that export secondary forest products and use a variety of wood species to manufacture these products. With innovation and courage on the part of some industries, Central America's forest resources can give these countries increased stability and provide more hope for the future.

An aerial view of a teak and mahogany plantation in Nicaragua. The plantation is located on the far side of the river.



The aster leafhopper carries aster yellows, a disease that is deadly to lettuce, celery, and carrots.

INSECTS RIDE JET WINDS

Each spring Minnesota's croplands are silently invaded by a multitude of insect species that inflict costly damages on the state's varied forage and cash crops. For years it was assumed that the extent of the damage hinged upon the number of insects able to survive Minnesota's harsh winter climate. But during the past 17 years, several Upper Midwest researchers have uncovered convincing evidence that many insects are actually transported here from southern states by warm, low-level jet winds.

As early as 1932, research scientists believed that the potato leafhopper was unable to overwinter in the northern states. Both the adult leafhopper and its offspring had been found in Minnesota as late as November, but they always disappeared after temperatures dropped below 20 degrees.

Yet each spring, thousands of adult potato leafhoppers suddenly reappeared in Minnesota, usually toward the end of May. Since they couldn't overwinter in northern states, and since adult leafhoppers live only 60 to 90 days, the problem attracted the attention of several entomologists. Painstaking research eventually established that leafhoppers overwinter only in areas of the South with 260 to 270 frost-free days each year.

A regional project designed to study the causes of potato leafhopper outbreaks in the Upper Midwest was initiated in 1954 by a dozen North Central states, including Minnesota. Professor Allan G. Peterson has headed the University's study during this time.

The research teams collected leafhoppers by sweeping alfalfa and clover fields with 15-inch insect nets and totalling the catch after 100 sweeps. Minnesota also employed light traps in several locations and air socks with 5-foot openings, installed on the roofs of Green Hall on the St. Paul Campus and the 14-story Mayo Memorial Hospital on the Minneapolis Campus.

The cooperative study revealed that the appearance of leafhoppers was closely related to the arrival of warm air masses from southern United States. Typical conditions that marked the arrival of leafhoppers were then carefully noted. A low pressure area over the Western Plains area (Wyoming, Nebraska, and South Dakota) was usually matched with a high area in the eastern United States or Canada. Strong, sustained south or southwest winds resulted from the clockwise movement of air around the high center. The counter-clockwise movement of air around the low also aided the rush of warm air to the north. When the warm southern air met with colder air from the north, it was discovered, a stationary front formed and the leafhoppers dropped from the air currents.

On May 20, 1957, fields in southern Minnesota were extensively swept with nets just before a warm front approached. No potato leafhoppers were netted by the research team. But on May 21, the warm front arrived and it was pushed across the southern counties by a cold front. Two days later the team collected an average of 42 leafhoppers per 100 sweeps in the southeastern border counties. Leafhoppers were found in smaller numbers as far north as Goodhue County and as far west as Martin County (Fairmont). A subsequent warm front brought the leafhoppers to St. Paul on May 27. From then on, the leafhoppers gradually worked their way north. They reached Grand Rapids on June 10, and Stephen by June 23. They apparently did not reach Roseau on the Canadian border until after June 27.

A USDA research scientist further verified the theory when he collected leafhoppers from an airplane at varying altitudes of 200 to 4,000 feet over Louisiana, Arkansas, Indiana, and Illinois.

Studies in successive years bore out the 1957 findings. In 1959 an alfalfa field near St. Paul failed to yield any leafhoppers on May 24. On May 26, a warm front passed over central Minnesota. Then on May 27, the field was swept again and the nets yielded 23 potato leafhoppers in 100 sweeps.

These later studies also showed that it wasn't possible to connect the arrival of leafhoppers in northern Minnesota with regional weather patterns. Researchers assume that the distribution of leafhoppers in northern counties results from local movement of the insects.

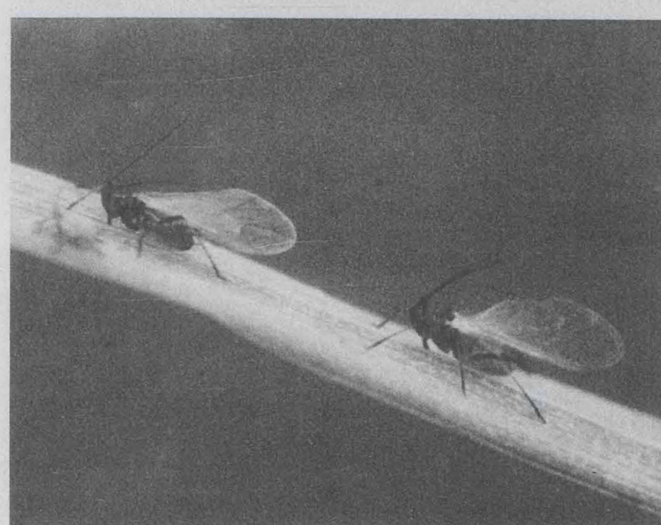
Aster Leafhopper Dispersal

The aster leafhopper, which caused extensive crop losses in 1957, is another leafhopper species transported to the north by warm air currents. However, in its egg stage, it can overwinter in Minnesota in the stems of rye, bromegrass, quackgrass, crabgrass, and timothy. But adults from winter grain areas in Texas, Oklahoma, Kansas, Louisiana, and Arkansas generally arrive here 3 to 4 weeks before overwintering eggs hatch.

Some of the adults from the south carry a disease, aster yellows, which is deadly to lettuce, celery, and carrots. Most Minnesota vegetable growers are prevented from cashing in on the profitable Twin Cities lettuce market because of aster yellows. Disease-free aster leafhoppers become infected by feeding on diseased plants, and after aster yellows undergoes an incubation period inside the insect's body, the leafhopper can transmit the disease to healthy plants.

Prior to the heavy crop losses of 1957, no aster leafhoppers were detected at Rosemount, Minnesota, on May 1. On May 7, though, strong south winds prevailed and 2 days later 100 sweeps over a field of winter wheat netted 90 leafhoppers. This marked the beginning of a period of heavy infestation and an unusually large proportion of these leafhoppers were infective with aster yellows.

Heavy outbreaks of aster leafhoppers do not always indicate the amount of damage that will be done. During late March and early April in 1963, aster leafhoppers were reported to be a serious pest on barley in Oklahoma. Strong southwest winds brought them to Minnesota on April 17. Another strong south wind on May 7 added to the infestation. One hundred sweeps on a field of winter wheat at St. Paul the following day yielded a record 1,500 aster leafhoppers. But the feared outbreak of aster yellows never came since few leafhoppers were vectors of the disease. A later study by University of Minnesota re-



Lettuce plant (left) infected with aster yellows, right one is healthy.
Close-up photo of English grain aphids found in oats.

searchers indicated that outbreaks of aster yellows depends on the number of leafhoppers, on the weather during May and June, on the presence of succulent plants for the insect to feed on, and also on the incidence of aster yellows among the leafhoppers.

Dispersal of Grain Aphids

Four species of grain aphids, the greenbug, the English grain aphid, the apple grain aphid, and the corn leaf aphid, are dispersed throughout the North Central states by warm, low-level jet winds. Only one species, the apple grain aphid, is able to overwinter in Minnesota. These aphids attack cereal crops and are also vectors of the barley yellow dwarf virus (known as red leaf in oats).

Minnesota has studied the problem of windborne aphids since 1961. Findings show that the aphids are transported to the state under the same weather conditions responsible for long-range migration of the aster leafhopper. All the aphids appear after strong south or southwest winds, lasting 1 to 3 days, move into Minnesota.

Definite proof that jet winds disperse leafhoppers and aphids from southern U.S. to the North Central states is lacking. Unfortunately, insects cannot be banded like birds and so their point of origin has never been precisely established. But the weight of the evidence seems convincing. Each year the same pattern is repeated: (1) Early collections of insects prove negative. (2) Then adult insects appear suddenly. (3) This sudden appearance follows close on the heels of warm air masses moving northward from the southern states. (4) And the first adults usually appear too early to have developed from overwintering eggs. (5) Finally, the number of insects arriving in northern states seems related to the number that overwinters in the South.

University entomologists Alexander Hodson and Edwin Cook definitely associated the 1959 outbreak of the greenbug with weather patterns and suggested that future outbreaks of greenbug in Minnesota can be predicted. Researchers, they say, could alert farmers well in advance if the number of insects overwintering in the south was determined. Then, by watching weather maps, entomologists could determine when favorable conditions exist for long distance transport of greenbugs. The same method could be used to predict arrival dates for the English grain aphid, the apple grain aphid, and both leafhopper species.

Pinpointing the arrival of insects from the South would enable farmers to inspect their fields during the period of early infestation and determine whether control measures were required. This would eliminate undesirable application of insecticides. And if control was necessary, insecticides could be applied before extensive damage occurred.

The solution to our pest problems, however, is far from being completely untangled. Further study of the conditions that favor rapid multiplication of these insects after they reach Minnesota will have to be carried out. University scientists also agree that there may be several additional periods during each growing season when weather conditions are favorable for long-range dispersal of these insects. But a large gap in man's knowledge of how insects migrate to northern areas of the U.S. has been considerably narrowed. Additional research will undoubtedly provide solutions to a problem that has beset Minnesota farmers for decades.

Deadly Protein May Increase Animal Fertility

University of Minnesota animal scientists have isolated a toxic protein from bat semen that in purified form is as deadly as rattlesnake venom, yet offers potential promise as a means of increasing fertility in both humans and animals.

Professor Alan G. Hunter, who heads the research project, says the protein might have several uses, but the most promising appears to be as an agent to increase fertility in animals.

"If it is possible to synthesize large quantities of the protein, it could be added to bull and dairy cattle semen.

Animal scientist Alan Hunter is shown extracting a minute quantity of bat protein isolated by electrophoresis.

The protein might allow the semen to remain in the cow's reproductive tract longer and increase the possibility of fertilization."

Last year the research team collected nine proteins from the reproductive organs of several male brown bats. Each protein was subjected to rigorous tests, which included injecting small amounts into rabbits and mice. One protein, referred to as BSV, killed the laboratory animals.

Close examination of the dead animal's organs revealed that all their smooth muscles, which normally are in a state of contraction, were relaxed. This finding led the researchers to believe that the protein, though not toxic to bats, had a similar effect on smooth muscle lining the female bat's uterus.

If their theory is correct, it solves the long enshrouded mystery of how certain species of bats reproduce. The mystery stems from the fact that the male bat produces sperm only during late summer or early fall — nearly seven months before the female produces a ripe egg. The bats mate in the fall and then hibernate during winter.

The Minnesota researchers believe that BSV protects and preserves the sperm, which are stored over winter in the female's reproductive tract. Then in spring, the female bat simultaneously produces a ripe egg and a strong enzyme that destroys the protein and allows fertilization to occur.

Normally, sperm cells that enter the uterus are carried through the organ to a small opening at the top by muscular contractions. Here they enter one of the fallopian tubes, which extend from either side of the uterus like tiny arms. If conditions are right, fertilization takes place in a small chamber near the end of the tube.

The bat protein, according to their theory, delays the sperm's journey to the fallopian tube by relaxing the uterine muscles and somehow immobilizing the sperm.

At the same time, BSV wards off attacks from the female's white blood cells. Without their protective coating, sperm cells would be engulfed by the white cells and destroyed in a matter of hours.

BSV also drastically reduces the number of lymphocytic white cells in the female's blood. This finding suggests that the protein might someday provide a means of combating leukemia, since its victims suffer from an excess of white blood cells. But at the present time, too many questions about how BSV affects blood remain unanswered. More research will have to be carried out before they can begin to assess the value that BSV may have for man — as well as animals.

Members on the University research project besides Hunter include Professors L.D.S. Barker, Melvyn Fahning, and Richard Schultz, and research assistant Walter L. Johnson.

MINNESOTA AGRICULTURAL EXPERIMENT STATION
Research Fund Expenditures—Year Ended June 20, 1969
Financial Statement

Expenditures by Source

	Percent	Amount
Federal funds	15.7	$1,399,717
State appropriations	60.4	5,394,705
Gifts and grants	13.8	1,236,423
Fees, sales, miscellaneous	10.1	903,723
Total	**100.0**	**$8,934,568**

Expenditures by Object Classification

	Percent	Amount
Personal services	68.3	$6,102,201
Travel	1.5	136,436
Equipment, lands, structures	6.8	607,588
Supplies and expense	23.4	2,088,343
Total	**100.0**	**$8,934,568**

Expenditures by Location

	Percent	Amount
University Campus-St. Paul	85.5	$7,641,331
Branch Stations-within Minnesota	14.5	1,293,237
Total	**100.0**	**$8,934,568**

MINNESOTA SCIENCE is published by the University of Minnesota Agricultural Experiment Station. It reports the results of research conducted by the Station, both on the St. Paul Campus, and at outlying branch stations throughout the state.

YOUR COPY of this magazine is sent you by your local county extension agent. He represents the University's Institute of Agriculture in your county and helps make results of University research available to you.