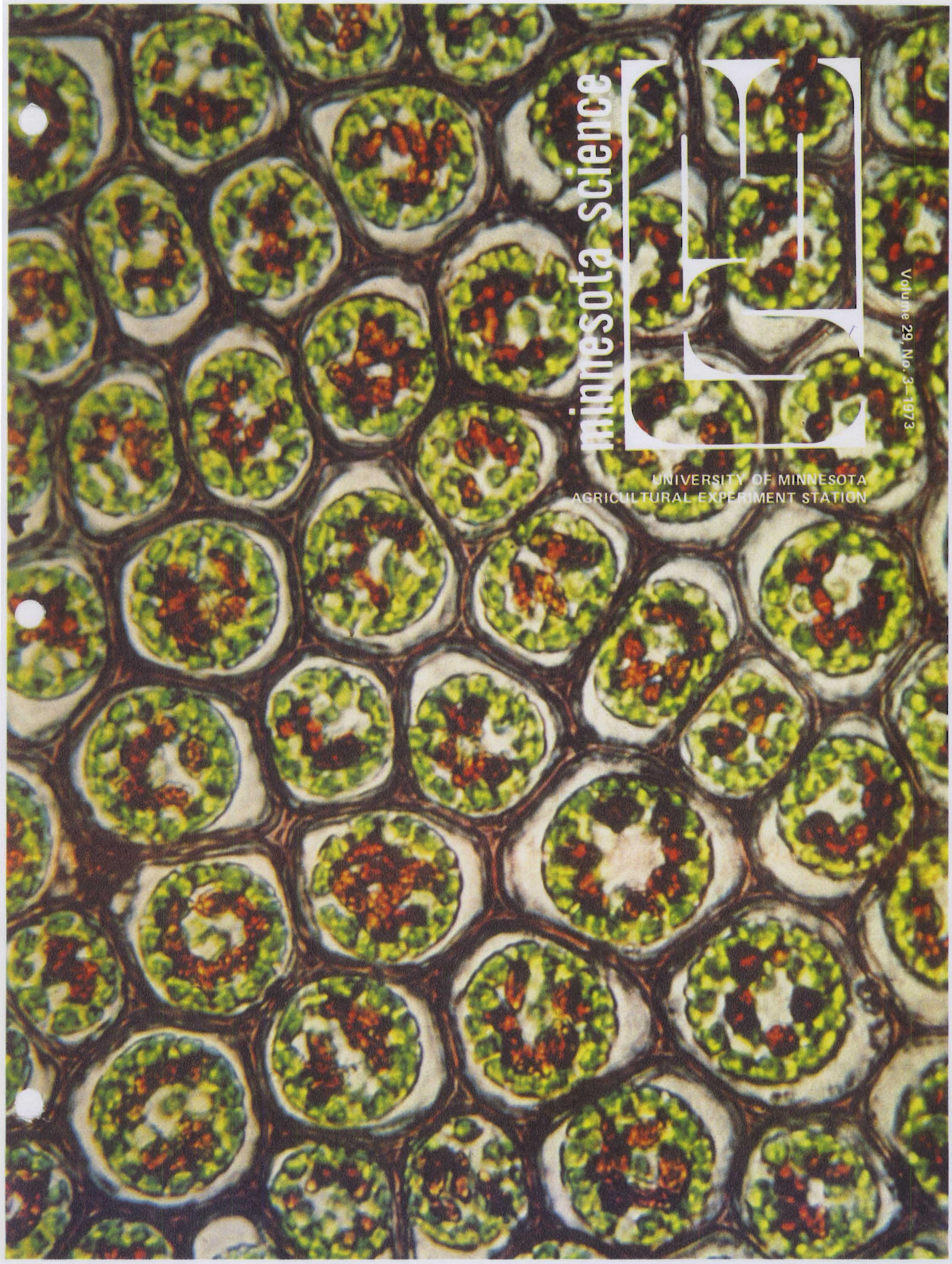

minnesota science
Volume 29, No. 3–1973
UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION

interview with the DIRECTOR

Our nation's capacity to produce an abundant food supply has made our influence felt around the globe. During World War II, the United States contributed food by the shipload to our allies. After the war, our food helped to sustain hungry populations and enabled a score of countries—friend and foe alike—to rebuild their economies. When that crisis was over, American agricultural know-how of machines, seeds, and fertilizers energized and modernized agricultural economies in many corners of the world. Regions previously chained to outmoded agricultural methods were lifted to unheard levels of food production. Successes scored in India, Pakistan, Mexico, the Philippines, and many other countries ended their heavy reliance on food imports and, in several instances, turned them into food exporters. At home, U.S. agriculture has provided its citizens with ample food of a staggering variety—at a far smaller percentage of average take-home pay than anywhere in the world.

However, the era of rising worldwide agricultural production and of cheap food at home is over. Drought on four continents and other factors have reduced food supplies. There, the specter of starvation looms over the land. In the United States, massive shipments of wheat and other food grains have done away with the safeguard of full granaries. The USDA has discontinued its monthly list of plentiful foods because there are not enough items to qualify with supplies tight and prices high and climbing.

Since research is an essential component of agricultural production, we asked Dr. William F. Hueg, Jr., Director of the Minnesota Agricultural Experiment Station, how he views the problem and what can be done to ease the present situation.

EDITOR: Dr. Hueg, can agricultural research stem rising food prices and tight food supplies?

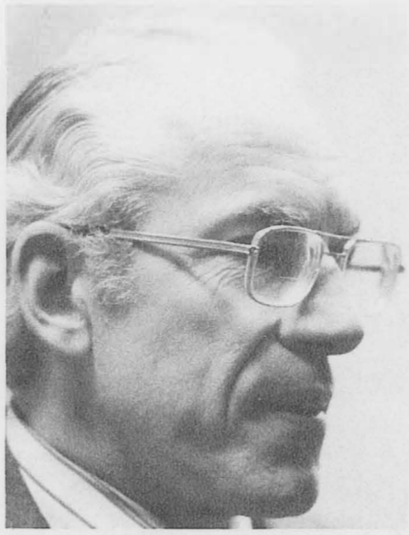
HUEG: Well, at a time when these two factors are becoming more important, agricultural research in the United States is being starved. If the attrition now afflicting agricultural research in this country is not reversed, the prospect for improvement of the current situation will be moved further into the future. We can help stem rising food prices in the long run, but have little effect on the short-run situation.

EDITOR: What is the present situation?

HUEG: Nationally, budgets for agricultural research, especially research aimed at production, are either stationary or shrinking. Paradoxically, at a time of much concern for urban and ghetto problems, funds earmarked for production research are being cut. Yet to the people living in these areas, getting enough cheap food is vitally important. In fact, you could say that getting food in adequate quantity and at moderate cost is the most keenly felt need of people everywhere.

EDITOR: What do you see as the solution?

HUEG: As a nation, we must resolve to put food production first. We must revitalize agricultural research. No single investment can do more to earn for this country goodwill abroad and at home to restore to Americans their traditional confidence in having a reliable supply of



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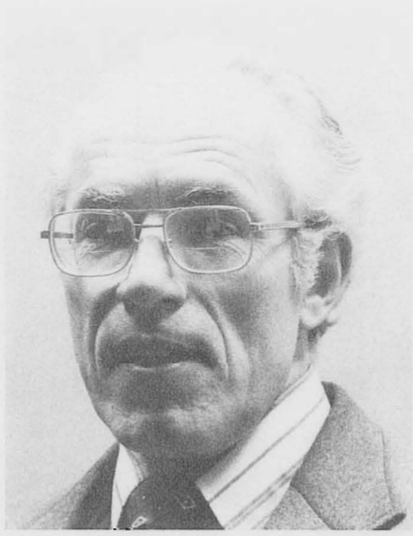

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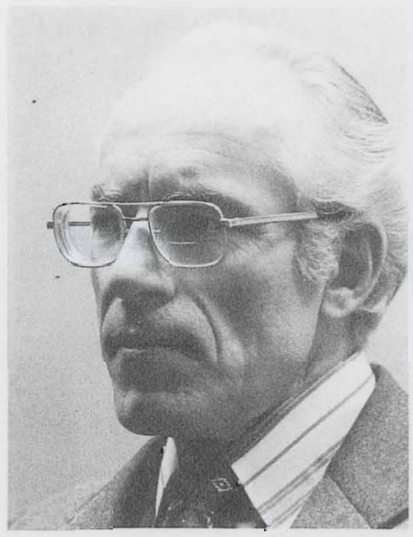

"If the attrition now afflicting agricultural research in this country is not reversed, the prospect for improvement of the current situation will be moved even further into the future."

minnesota science

Cover photo. (See story on page 8) A dramatic example of vitally stained plant cells. The cell walls (stained purple) seem to form a network between the isolated islands of living protoplasm (with its green chloroplasts). Actually the cell contents have pulled away from the cell walls and contracted together by osmotic action of an external solution applied to the cell. The red-colored materials are lipid (fat) bodies. (Cells are magnified 2,400 times.)

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Editor—Craig Forman
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ample, cheap food.

EDITOR: Are state and federal legislators responsive to your requests for funding?

HUEG: Well, the Minnesota Legislature seems critically aware of the situation. They provided the increased funding requested by us for the 1973-75 biennium. However, this did not begin to replace funds lost by the removal of nearly $450,000 in federal formula funds from our 1974 fiscal year budget.

EDITOR: Do you foresee any increases from federal sources?

HUEG: Just the opposite. The early indications we're getting from the Office of Management and Budget—despite the critical situation of food supply and prices—is that there will be no increases or even possible decreases for fiscal year 1975.

EDITOR: Are you taking any steps to change this situation?

HUEG: Yes. We have outlined our position with our congressional delegation and have asked that they oppose these moves. I believe that they would also appreciate hearing from others who support the continued need of agricultural research and recognize the need for increased funding.

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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.

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Skylab 3 astronauts (left to right) Owen Garriott, Jack Lousma, and Alan Bean chow down on space foods developed by Experiment Station food scientists. Tests of the intermediate-moisture foods are also being conducted with people who have lost their kidneys and require frequent and costly dialysis treatments.

ASTRONAUTS 'FEAST' ON UNIVERSITY-DEVELOPED FOOD

Skylab astronauts were asked to pass judgment on food they ate during their record stay in space last summer. The fruit and nut bars they ate were products resulting from research done by University food scientists.

Astronauts on the Skylab mission ate specially developed intermediate moisture foods. The special foods contain only 20 percent moisture and last about 6 months under extreme conditions without spoiling.

University food scientist Ted Labuza, however, didn't stand by idly waiting for the space crew's verdict. He and his associates continued researching various kinds of products for use on the upcoming Space Shuttle program. The researchers are formulating products and studying how fast they spoil and what can be done to prevent spoilage. Another aspect of the research is to determine how fast various vitamins and other nutrients are destroyed.

"We are trying to get basic data so food companies that make the products for space travel will know what kind of additives are needed and how to package these products for maximum stability," Labuza says. On recent space flights, the Whirlpool Corporation and Pillsbury Company manufactured intermediate moisture foods from concepts developed at the University under grants from the Agricultural Experiment Station and the National Aeronautics and Space Administration (NASA).

Minnesota research scored an early success with the astronauts with an apricot-type intermediate moisture food. Resembling a fig newton, the food was dispensed in the astronauts' space suits while they walked in space during the final Apollo mission. Astronauts also approved of another Minnesota-developed food—a mixture of marshmallow, granola, and peanut butter. This bar-like food, high in calories per unit of weight, lasts about 6 months without refrigeration.

Scientists updated an ancient food preservation concept borrowed from American Indians. Labuza says the NASA prototype foods are based on the same formula the Sioux Indians used for a food called pemmican, a mixture of buffalo meat, nuts, and berries. Food scientists instead combined chicken, peanut butter, and raisins. "It's really good," Labuza says.

Astronauts are not the only ones who will benefit from intermediate moisture foods. A drug company is interested in these foods for people who have lost their kidneys and require time-consuming and costly dialysis treatments every 2 or 3 days. Consuming the low moisture,

nutritious foods, these persons might be able to forego dialysis treatments from 10 to 15 days.

Three major food firms, General Mills, Kraft, and Nabisco, are now test marketing intermediate moisture breakfast "squares." These bars or squares have long shelf lives without refrigeration and supply one-third of the daily recommended nutritional allowance.

Since 1971 Labuza has been working at the University to develop food products that contain low amounts of moisture, but which are not dehydrated and won't spoil without refrigeration. One benefit of this research would be development of nutritious, tasty substitutes for candy. This would enable mothers to give their children treats that are highly balanced in protein, fat, sugar, and vitamins, and would taste good.

Intermediate moisture foods have been on the market to a limited extent in the form of dog food and a human breakfast item that looks like a pastry tart. Intermediate moisture type pet foods have garnered 30 percent of the pet food market.

Labuza began space food research under NASA contracts in 1965 at the Massachusetts Institute of Technology where he worked on food packaging for the Gemini space program. Since then Labuza has developed a mathematical formulation to determine how fast rancidity and browning occur in a specific food item. Food packagers can use Labuza's method to determine what type of packaging is needed to insure the shelf life of an item. Previously, food firms often guessed what packaging material was required. Using the new method, there will be only a minimum loss of nutritional value in products from the time they leave the plant until they are used by the consumer, Labuza says.

Pollution Study Readied

Experiment Station scientists are using a new technique to measure air pollution's effect on Minnesota plants. The scientists have built open-top air chambers that are placed over plants. Two chambers are placed side by side and air is pumped in the bottom of the chambers. However, an air filter is used in one chamber to filter out harmful pollutants. Plants inside the other chamber are subjected to unfiltered air.

"The concept is so simple that it should be easy to demonstrate results," says Francis Wood, head of the University's Plant Pathology Department. "If we're checking birch trees with the chambers and one tree looks good while the one inside the other chamber looks unhealthy, the difference has to be due to air pollution."

Plant pathologists are presently testing the chambers and their research project will begin next spring. The air-control chambers will be used in a study sponsored by the National Park Service of the U.S. Department of Interior.

"Goals of the project are twofold," Wood says. "We're measuring the effects of air pollution on vegetation in parks in the Minneapolis-St. Paul area, then comparing this to damage in the sparsely populated Voyageur's National Park area in northern Minnesota. JMS.

'Water Faucet' Approach To Research Deplored

Research can solve many of the world's food problems providing the earth's population doesn't get out of hand, predicts renowned scientist E.C. Stakman. The highly regarded plant pathologist, now professor emeritus, recently commented on the global food situation at an international gathering of scientists in Minneapolis.

Stakman said there are two extreme views on maintaining agricultural research at levels sufficient to feed the world. We have the "doomsday" prophets who are eternally pessimistic. On the other hand, when we have good years for crop production, we have others who say the job is done and we don't need more research on food production."

One of Stakman's former students, Norman Borlaug, won the 1971 Nobel Peace Prize for his scientific contributions to the "Green Revolution," which led to a dramatic increase in crop production in underdeveloped nations. India, for instance, once imported huge quantities of grain. But since 1965 it has almost doubled wheat production and last year it had a slight wheat surplus. Stakman expects this upward trend to continue, though there may be annual fluctuations.

"There are those who say that the Green Revolution is in trouble and that developing countries will soon run into serious food problems," Stakman said. "The droughts in Russia and parts of India and Africa presently causing crop failures are short-run effects. The long-range trend for food production is upward." Saying that the Green Revolution is in trouble is like saying that civilization is in trouble," Stakman declared. "Of course civilization is in trouble–we're human beings and prone to mistakes–not guided missiles. One problem is that we have a tendency to wait until we have a crop catastrophe. Then we appropriate money for research in a hurry, expecting miracles in return. We must learn to prevent, rather than cure, plant diseases," he emphasized.

"Take wheat rusts," said Stakman, who has been acclaimed the world's top authority on the subject, "Rusts could spread in India, Afghanistan, and Turkey in a few years, resulting in serious food shortages again. We must first preserve gains we've already made. A long-term commitment is necessary to insure future progress. It takes time to develop disease-resistant plant varieties and researchers can't do it if their funds are turned on and off like a water faucet."

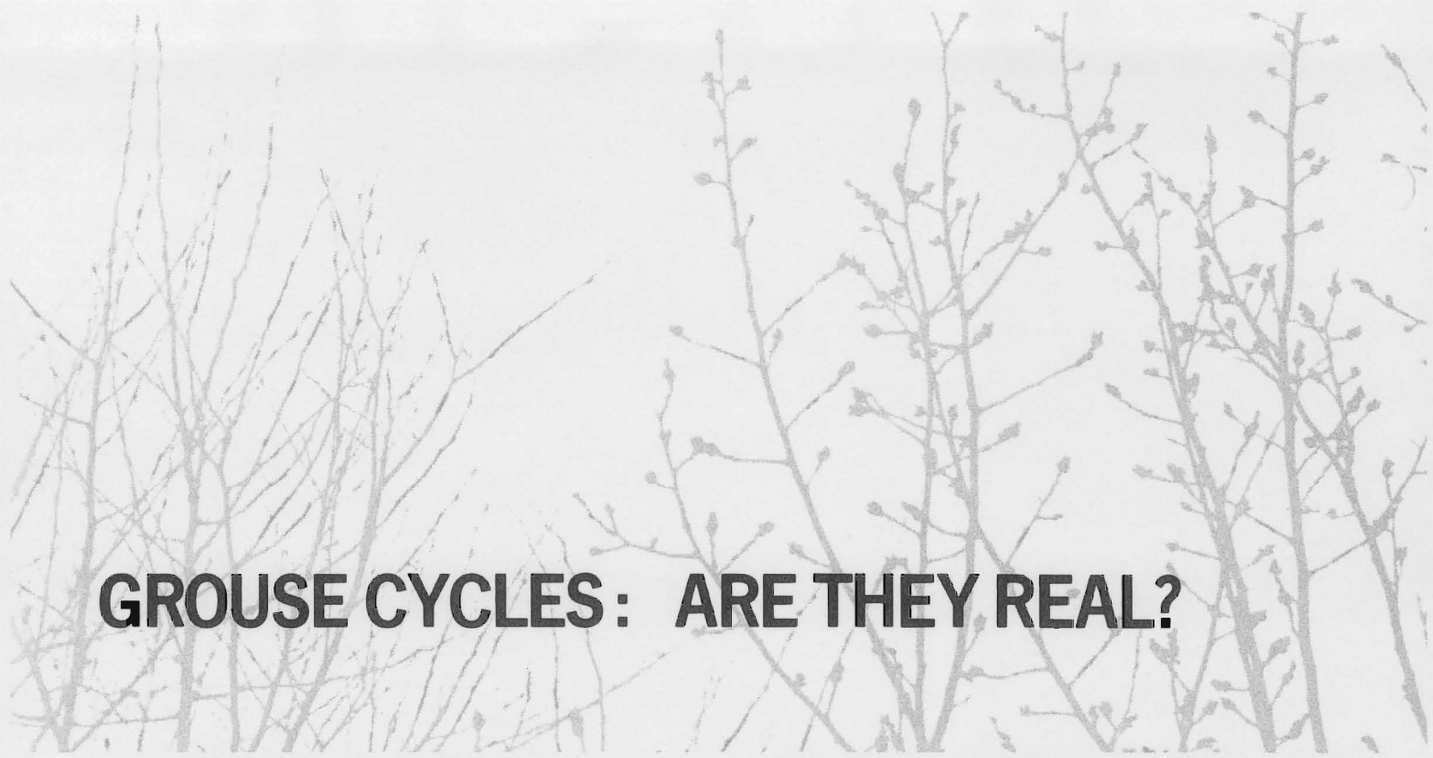
"Secondly, we need new standards for plant health–we need to do more than detect and treat plant diseases. We must put all things together for maximum yields: Factors such as resistance to frost, drought, heat, and disease need to be built into major crops."

With strong research support, Stakman thinks wheat varieties could be developed that will have 70 percent protection to all known stem rusts. But we can't guarantee this, he pointed out. Researchers must locate the characters that contribute to genetic resistance in wheat and combine them all in one variety before this 70 percent protection goal can be accomplished.

"But any way you look at it, research properly directed, supported, and motivated will pay big dividends for increasing world food supplies. It's just a matter of when," Stakman concluded. JMS

(Editor's note: In recognition of Dr. Stakman's contributions to plant pathology, science, and mankind, the plant pathology building on the St. Paul Campus was renamed Elvin C. Stakman Hall of Plant Pathology.)

GROUSE CYCLES: ARE THEY REAL?



Male or staminate flower buds on big-tooth aspen—one of two aspen species that provide a critical food source for ruffed grouse in Minnesota's northern forests.

GORDON W. GULLION
research associate
Entomology, Fisheries and Wildlife

If you define a cycle as something fluctuating between consistent extremes, you're wrong. However, there is no question that ruffed grouse and many other small animals periodically fluctuate in abundance.

These periodic upswings in population sometimes result in animals occurring in almost unbelievable numbers. Then the numbers seemingly dwindle to near extinction. This phenomenon has long been recognized and written about as characteristic of small animal populations in arctic and sub-arctic regions. Lemmings have attracted the most public attention because they become spectacularly abundant some years.

But the same rise and fall of populations is characteristic of many other species of small wildlife living in northern areas. In Minnesota, ruffed grouse and snowshoe hare are well known examples. After several years of pleasing abundance, ruffed grouse or "partridge" numbers are now declining over most of their range in Minnesota and eastward into Wisconsin as well.

This decline is part of what seems to be a continent-wide trend. It progresses from the northwest; in Canada, to the south and eastward. Alberta and Manitoba suffered drops in their grouse population 2 years ago. Even in northwestern Minnesota, the population dropped some. By 1972 the numbers of Canadian birds had dropped considerably, and the decline was general across most of Minnesota. But hunting was still much better in most areas here than it had been 4 or 5 years earlier. Not many hunters complained or were concerned about the decline then. But by the time 1973 hunting season has ended, we can expect the question "What happened to all the partridge?" to be common. Actually, this has been a common question 3 or 4 years out of every decade, perhaps for the past century in this part of the country. The interval from peak to peak of grouse abundance or from bottom to bottom of the decline is usually about 10 years. So this phenomenon is commonly called the "10-year grouse cycle."

We had a peak in 1960-61, and reached the bottom in 1964 and 1965. Then another peak, the highest in 3 decades, was reached in 1971. By 1974 or 1975, we can expect birds to be mighty scarce in most areas again. The 1973 season is the second year of decline, but the crash is just gaining momentum. The 1973-74 and 1974-75 periods will probably be years when "partridge" numbers really plummet.

Causes Of Decline

Wildlife biologists have been just as puzzled as hunters and others by the causes of dramatic changes in bird abundance. Despite several research projects of fairly long duration, the causes are still obscure.

This is the second decline we have monitored in the Cloquet area of northern Minnesota. Although we know a great deal about what is happening to and in the grouse population, we don't understand all we know! However, we have monitored some marked periodic changes in the ruffed grouse population, their habitat resources, and environmental conditions over the past 18 years. As we put these data together, comparing what we know about variations in grouse food resources; variations in winter snow conditions; and the temperature regimen with changes in grouse weights, color-phase ratios, age structure, and population densities, some probable cause and effect relationships are indicated.

First, we now suspect that probably four or five major

factors affect the season to season changes in ruffed grouse abundance. Surprisingly, hunting during fall seasons does not seem to be one of the important five!

We no longer consider winter food resources as catholic in the habitat of grouse. Rather, we now recognize that during the critical winter and early spring period these birds depend on a very restricted food resource: flower-buds and elongating catkins of male aspens or "popple." Nothing else appears to be a wholly adequate substitute for this food source. But grouse will feed on catkins or flower-buds of several other trees if the aspen bud supply is inadequate. During seasons or in regions where "partridge" cannot find sufficient aspen buds, they feed heavily in winter upon catkins of alder, hazel, birch, and ironwood, and upon flower-buds of willows, apples, cherries, and several other trees or shrubs. When this happens, we know grouse are in difficulty. And we expect fewer birds to survive winter and those that do are in poorer condition.

During the latter 1960's aspen flower-buds were consistently available to grouse in the Cloquet area. This, along with other factors, allowed bird numbers to increase at a pace of almost 30 percent per year from 1966 to 1971. But in the fall of 1971, aspen had only about 10 percent of the flower-bud crop they had during most prior years. In 1972, only a 5 percent increase in the breeding population occurred. Most of that increase represented birds that had delayed entering the breeding population until they were 2 years old. During the 1972-73 season, the aspen flower-bud supply was about double that of the 1971-72 season. But this still was only one-fifth of the level we had established as the norm when the grouse population was steadily increasing.

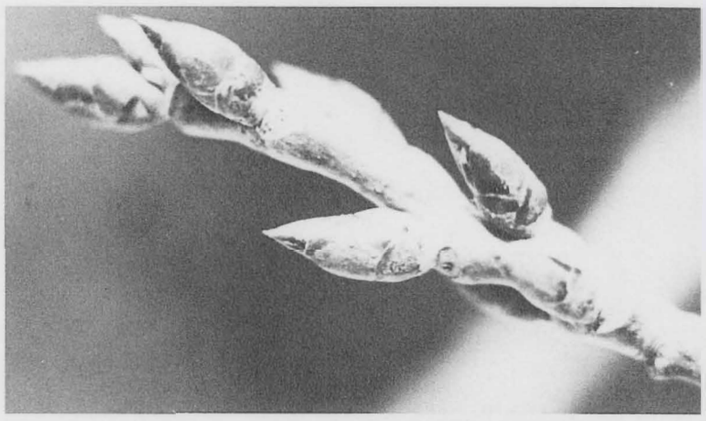
Some changes in the quality of the aspen food resources occurred at the same time, so quality as well as quantity entered the picture. The importance of food resources can be tempered or intensified by the quality of winter snow conditions. This importance can, in turn, be modified by that winter's temperature regimen. So winter climatic conditions are an important factor affecting population trends of these birds.

On top of these two factors, add a third, predation. Probably few grouse die a lingering death from old age, disease, or malnutrition. Most not harvested by hunters die suddenly in the talons of a hawk or owl (most often), or the jaws of a fox, bobcat, lynx, or some other mammal (less often). But the impact of predation is not independent of the food story nor winter climate. Instead, it is partly governed by both. The abundance of other small animals in the forest can also affect the amount of attention predators pay to grouse. Snowshoe hares, red squirrels, mice, weasels, blue jays, and even smaller hawks and owls are alternative prey for winged predators.

A fourth factor that can play a significant role at times is disease and parasites. Most wild grouse appear to carry at least a moderate load of various intestinal and blood parasites. Most parasites are transmitted from bird to bird. So when grouse populations reach high densities, contact between birds or with body wastes of infected grouse becomes more frequent. This increases the chance for infestation and for massive parasite loads. Disease or parasite loads do not have much effect on a grouse as long as it has an abundance of nutritious food and the snow is deep and soft. Then they can conserve energy during cold winter days and nights by roosting snugly in soft

(Continued on page 10)

Ruffed grouse exhibit periodic fluctuations in numbers. They may drop to one-tenth their abundance when populations are high—as in 1970-71. But quality of habitat determines ultimate densities at both the upper and lower limits of these fluctuations.



Flower buds of male aspens provide northern Minnesota's ruffed grouse with a winter-long, highly nutritious food resource. When present in sufficient abundance, these buds are preferred food for partridge from late October to early May.

Goshawks are probably one of the most important predators of ruffed grouse. These raptors are uncommon in our forests today and are protected to preserve them as part of our wildlife heritage.

DROUGHT RESISTANCE

Inside the Living Cell

CRAIG FORMAN
science writer-editor
Information and Agricultural Journalism

Man's centuries-old struggle against drought may eventually be helped by a unique Experiment Station study of the activity inside living plant cells. The Department of Horticultural Science's Protoplasmatology Lab, headed by Dr. Eduard Stadelmann, is the only facility of its kind in the U.S. The Austrian-born plant physiologist has been at the forefront in uncovering valuable information on drought resistance of plants and studies of living plant cells.

One technique used by Stadelmann, vital staining of cells, dates back to the early 18th century when the first successful, but crude, staining of living tissue took place. The field did not significantly advance for another 120 years until scientists in Germany, Austria, and France refined the technique. But only in recent decades of this century has interest in vital staining lifted it to the status of an important research tool in discovering some of nature's best kept secrets.

Vital staining differs from conventional staining methods that usually kill the cell. It is harmless to the living cells and enables researchers to "color code" specific parts of the cell for identification (see cover photo). Color coding is necessary since many cell components are colorless and have what scientists refer to as the same "optical density" under the microscopic lens. In other words, it is difficult or impossible to distinguish one part from another. But by using specific vital stains in solutions of defined pH, certain parts of the cell will take up stain vividly and appear colored. Certain stains also react with specific substances like tannins and make them detectable by conspicuous colors. In this way, the stain provides some kind of color reagent for certain classes of chemical substances inside the cell.

Exploring Living Cells

To the person untrained in cell biology, the importance of vital staining might be lost. But consider that a single pea leaflet contains roughly 2 to 3 million cells. Just one of these cells contains around 200 trillion various molecules. The heart of a cell, the living protoplasm, contains 1 nucleus, and, on the average, 100 chloroplasts, 700 mitochondria, 300 spheresomes, 100 dictysomes, a large central vacuole filled with cell sap, and many other structures like small fat vacuoles and so on.

Viewed under a powerful electron microscope, the most conspicuous part of a cell is its outside wall. Cell walls are the basic structural unit of all higher plants–living and dead. They give form and strength to such items as paper and wood. Inside this cell wall is a thin layer of living matter called protoplasm. This life-giving substance contains the chloroplasts that manufacture sugar and starch from carbon dioxide and sunlight. This process, known as photosynthesis, is the most fundamental biochemical activity supporting life on earth.

Inside the layer of protoplasm, similar to the airspace inside the bladder of an old pigskin football, is an aquaeous solution known as the cell sap. The sap contains a variety of solutes, inorganic and organic ions, sugars, alkaloids, and, often, tannin-like substances. It serves as a reservoir of water and as a depot for the protoplasm, which synthesizes and breaks down countless organic materials and compounds.

The outermost boundary layer of the protoplasm has attracted widespread scientific interest in recent years. This membrane acts as a gate-keeper for the cell: Expelling wastes, retaining a vital balance of nutrients, and letting in needed water are just a few of its functions. Most of Dr. Stadelmann's study of drought resistance has centered around changes in this outer membrane.

An important approach to these living membranes concerns the passage of materials through them in water-stressed plant cells. University findings suggest that under drought conditions the arrangement of the membrane lipid (fat) molecules changes and these molecules become more densely packed together. This change in packing density, in turn, affects the speed with which substances are able to move through the membrane.

Stadelmann found that pea plants can be "hardened" to drought if water stress is applied within 6 to 10 days after the plant germinates. However, if water stress occurs after the plant is 20 days old, it wilts and dies. Early water stress, in effect, "conditions" the plant to react to stress later on. The researchers found that conditioned cells adapt and the cell membrane changes under water-stress conditions. In plants stressed late, these changes don't occur.

Another well known phenomenon the scientists reconfirmed in water-stressed pea plants was changes in the concentration of cell sap during progressive stages of drought. This increases the water-retention power of the cell and enables it to compensate for water shortage within certain limits.

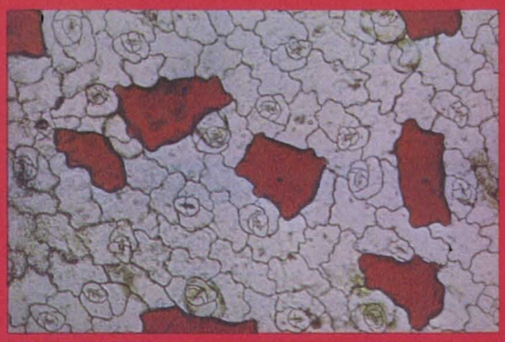
Drought Resistance And Avoidance

Despite all the recent scientific study of the role of water in protoplasm, many questions remain unanswered. A host of factors determine a plant's ability to withstand water shortage. Researchers know that drought resistance varies widely from one plant species to another. What holds true for alfalfa, for instance, may not be true for soybeans. Too, it is well known that leaf development is favored in many plants when water supply is abundant, but flowers develop only under certain conditions when water supply is specifically limited. Too much water, in this case, can inhibit flowering. Knowing the optimum watering rates during various stages of plant growth could not only prevent drought damage, but also save irrigators considerable expense.

Drought resistance in many higher plants is based mainly on water-stress avoidance. This avoidance occurs because plants can react or adapt to a shortage of water. For instance, plants can reduce the amount of water given up from its leaves; they can develop faster stomatal closure (stomates are tiny openings in the leaf surface that open and close in response to environmental changes); or they can modify leaves so there is a smaller leaf surface.

Plants are also able to adapt to water shortage by increasing water uptake from the soil. For instance, roots may develop a higher suction potential or develop more extensively to draw from a large volume of soil or grow more deeply into the soil for moisture.

When drought resistance is a result of the ability of the protoplasm to withstand drought, this quality is called drought tolerance. The basis of drought tolerance of protoplasm has to be visualized at the molecular level. It concerns the ability of

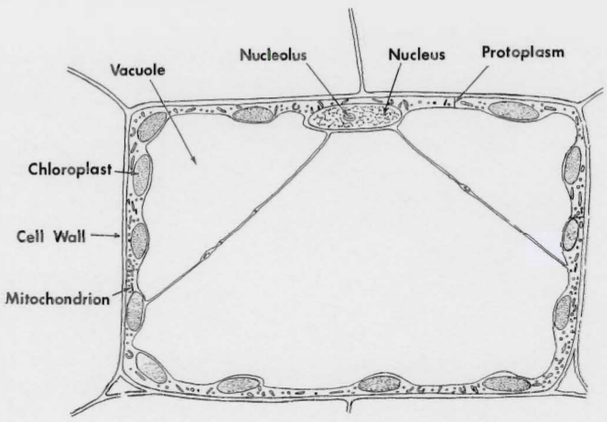


The dull brick-red cells shown here contain tannin-like substances, while the white or clear cells do not. The larger red cells have accumulated the tannin substances and thus stain darker.

Vitally stained cells from the epidermis or outer layer (inner side) of onion bulb scale. As in the cover photo, protoplasm has shrunk away from cell walls. Here, however, cell walls are not visible. Darker substances inside cells are aggregates of stain. Photo was taken while cell material was irradiated by ultraviolet light.

Two layers of onion bulb scale cells take up stain differently. The outer layer (outer epidermis) stains light blue-green while the lower layer (parenchyma) absorbs enough stain to acquire a deep violet hue. Note deep colored bodies in cell sap of light blue cells. Stain has accumulated to such a degree that it forms little dark colored bodies.

Cross section of a typical plant cell. Outer portion of cell is surrounded by cell wall. The next layer is protoplasm, which contains a nucleus, mitochondria, chloroplasts, spherosomes, and other bodies. The cell sap occupies the large central portion of the cell.



the protoplasm to rearrange its macromolecules in such a way that their proper spacing is assured and they are able to function sufficiently to synthesize and metabolize substances essential to the plants' life.

Worldwide Impact Of Drought Resistance Research

Drought resistance research could eventually have worldwide impact, according to Stadelmann. About one-half the earth's land surface is arid or semiarid. With increasing world population, the need for more efficient use of arid areas for crop production will grow apace. Most higher plants, especially crops of economic importance, require more water than is available in arid zones. However, if new drought-resistant varieties can be developed, the growing area for many crops could be extended.

Much of the research at Minnesota and elsewhere has by necessity concentrated on the basic mechanisms underlying drought resistance. But before it can be applied to agriculturally important plants, these mechanisms must be better understood. Since drought tolerance is caused to a certain degree only by changes in the structure of protoplasm molecules, but to a larger extent in their spatial relation to other molecules, chemical methods will not detect the latter difference. Instead, researchers will have to refer to physico-chemical methods of protoplasmatology in testing for drought tolerance. Eventually, Stadelmann hopes to develop a test for rapidly determining drought tolerance. This would eliminate the need for time-consuming test plot evaluation of potentially drought-resistant plants. By using appropriate types of plant tissues for tests instead, the screening process could be radically shortened and all varieties could be scanned for drought resistance. Before screening techniques can be devised, however, much work remains to be done.

An important step in advancing protoplasmic studies of drought, Stadelmann believes, would be to develop a program to train young U.S. scientists in the specialized techniques involved. With adequate support for such a program, the complex task of researching and solving the puzzle of protoplasmic activity during drought would be given a major boost.

GROUSE CYCLES

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snow 6 to 8 inches below the surface, inaccessible to predators.

If food resources are scarce, it's a different story. The bird spends 2 to 3 hours filling its crop rather than the customary 15 to 20 minutes. Instead of roosting in the security of a snow-burrow the grouse roosts in a tree or on the snow. Then, it not only has to feed its parasites, but also burn energy to keep warm. The stress becomes even greater when temperatures drop well below the level (about 20°F.) at which resting body metabolism will keep the grouse comfortable. This temperature is well above mean nighttime temperatures at the snow surface in northern Minnesota from mid-November to early April.

The hungry bird that spends a long time feeding and moving frequently in search of food is a prime target for a predator. The more time spent in the open, moving from one site to another, the greater likelihood of a chance encounter with a horned owl or goshawk.

Even without a parasite load, the ruffed grouse that spends too much time feeding or traveling too far to find sufficient food is the most likely to not survive to spring. If the bird is also slightly sluggish due to disease, parasites, or insufficient nutrition, or all three, it has little chance of escaping the attack of even inept, young predators. If these young predators attempted to live off a population of secure, healthy ruffed grouse, they might starve.

Finally, there appear to be some intrinsic characters that play a role in governing ruffed grouse population trends. These are evidently hereditary and represent changes in genetic structure of the population. These changes are apparent in the color phase composition of grouse populations. Several years ago we determined that male grouse in the Cloquet area having chestnut-colored tails (red-phased grouse) have a mean life-span about 69 percent that of males with gray tails. Gray-phased males have a mean life-span of 16.6 months after they are established on a drumming log compared to 11.4 months for the red-phased males.

But there is an interesting aspect to this. Following favorable winters with adequate food resources and good roosting snow, the proportion of young male red grouse increased at Cloquet in the fall. It went from about 40 percent in 1966 and 1967 to a high of 60 percent in 1969. As the population trend started downward, however, this percentage dropped to 36 percent by fall 1972.

Also during this period the weight and size of young male grouse in the fall gradually increased. From fall 1967 to fall 1971 the mean weight went from about 576 grams (about 20 ounces) to nearly 614 grams. In the fall 1972, however, it fell back to 580 grams, following the 1971-72 year of greatly lessened food supplies, which were consumed by the largest grouse population this area had seen since the early 1930's.

Then came another year of diminished food sources, still being used by a large grouse population. This situation was aggravated by unfavorable winter-long snow conditions and the heaviest invasion of goshawks and owls from the sub-arctic since the early 1960's.

The outcome? Seven percent of the young male grouse we banded last fall were found on drumming logs this spring. Compare this to the 54 percent that survived from fall 1969 to

spring 1970. Furthermore, our young males are usually only about 5 percent lighter than their fall weight when we take them in the spring. This year the weight loss was about 17 percent.

But heavy overwinter losses are not limited to young grouse. Seventy percent of the breeding adult males using logs in 1972 did not survive. This compares with a normal year-to-year loss of about 50 to 55 percent. From 1969 to 1970, while the population was still rising, overwinter losses took only about 40 percent of the breeding population.

Mystery Is Not Mysterious

In summary, the periodic ups and downs of Minnesota's ruffed grouse populations are not really very mysterious. Nor are they without explanation or unpredictable. Rather, they represent the impact of several environmental and biotic factors. In various years, these factors may operate in concert to either encourage an increase in grouse numbers or bring about a sharp drop in abundance. Or, on occasion, one or more factors operating independently may dampen the impact of the others. But climatic trends are probably most important because they directly affect the food resource and the abundance of other animals as well as grouse.

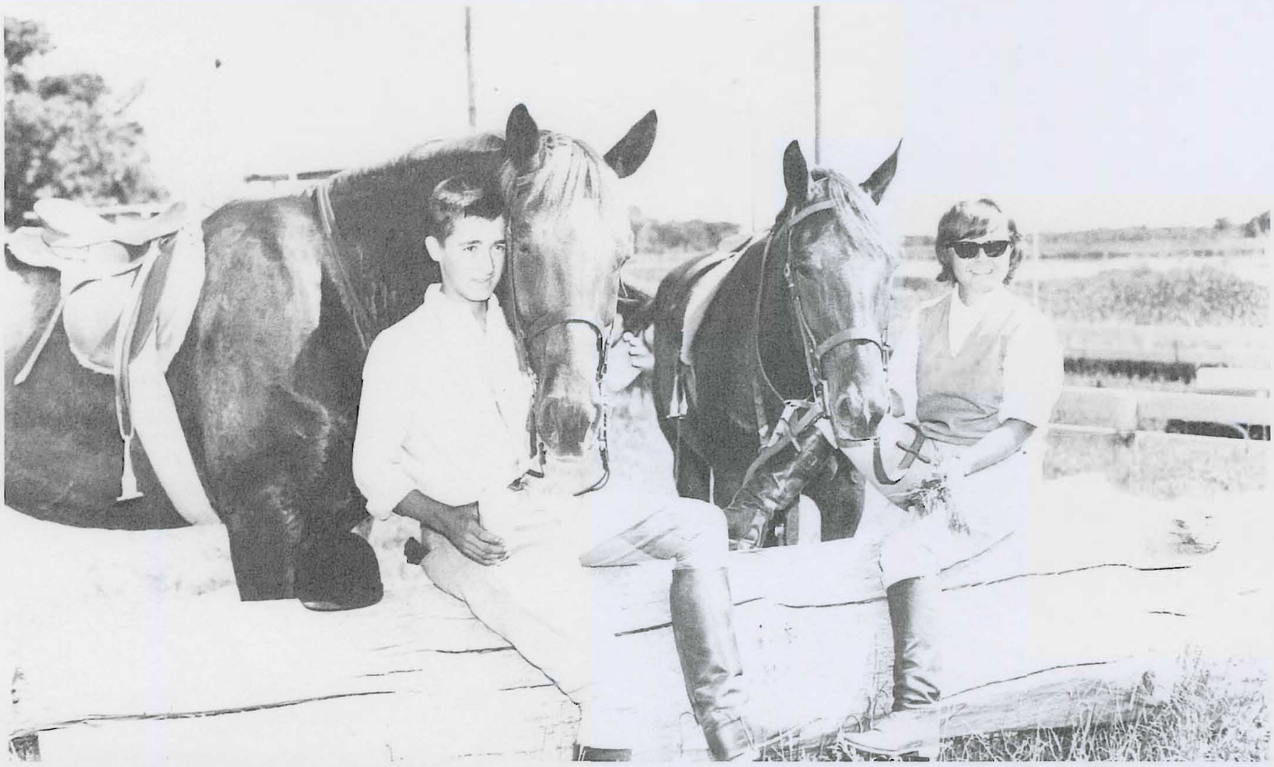
A good deal of the mystery long associated with grouse "cycles" is a result of insufficient data of the proper type. It is not only important to know how cold it is during winter, but how deep the snow is, and its crusting condition; how abundant the grouse food resource is; and whether there is an abundance of other small animals to absorb some of the pressure of predation.

We still do not understand many facets of the story. But there is enough knowledge about these fluctuations to allow biologists to predict quite confidently when these changes in grouse abundance will occur. We no longer become alarmed when birds become scarce in areas where they were numerous only 3 to 4 years earlier.

The available data also clearly indicate that recreational hunting of ruffed grouse in the fall, even during the periods of scarcity, has virtually no impact upon the population. Furthermore, while predation is important, control of predators to benefit these game birds is of little practical value. It is a waste of scarce wildlife management funds that can be better used to manipulate forest habitats for grouse.

The comment is often heard "Why do anything for ruffed grouse when they're going to become so scarce anyway?" We believe scarcity is relevant. During periods of population depression, grouse are much more scarce in forests that supported only one or two pairs per 40 acres during the recent high than in better quality habitats that produced one bird per acre in 1971 and 1972. During a depression, when grouse numbers drop to a tenth of their former abundance, one grouse per 10 acres of good habitat is more desirable than only one grouse per 100 acres in marginal habitat.

When snow is soft and more than 8 to 10 inches deep, Minnesota's ruffed grouse can spend cold winter nights in snow-burrows. Here, they not only conserve body heat in the spring-like temperatures of the snow, but are also virtually immune to attack.



Interest in horses spans all ages, but youthful riders are the most vital segment of Minnesota's equine industry. The state's 4-H horse project has over 5,000 participants and is one of the fastest growing projects in the 4-H program.

HORSE NUTRITION
Hearsay or Research?

R.M. JORDAN
professor
Animal Science

Few people appreciate how much Minnesota's horse industry contributes to our economy. But 165,000 horses that consume 873,000 tons of feed and straw per year—the production from some 300,000 acres of land—definitely qualify as big business. When you add the cost of veterinary service, farriery, trailers, saddles, training charges for show horses, and so on the figures begin to mount up. The estimated value of 158,000 backyard horses amounts to $15.8 million and the 6,600 show horses in the state are worth about $9.9 million. The total value of the state's horse population, then, is about $25.7 million. Estimated annual costs for maintaining these animals is $63.8 million or $320 for each backyard horse and $2,000 for a single show horse.

That's big business and it shows no sign of abating. Literally dozens of horse shows are held throughout the state every weekend from May to October. Minnesota's 4-H horse project members number over 5,000 and is one of the fastest growing projects. Dozens of all-weather indoor riding arenas have been built in the last 4 or 5 years.

Horse people, the most vital part of this industry, are unique in several ways. First off, they are usually from the city and have had little or no direct contact with agriculture. Many are truly great horsemen with a good understanding of most aspects of horsemanship, but the majority have fallen in love with horses and know little about their care. They trust they can learn the varied intricacies of horse husbandry without doing too much damage to either the horse or their pocketbook.

Another trait that sets horse people apart as a group is that their interest in horses stems from their children, particularly daughters. After 6 or 8 years, however, their children grow up. In many cases, since there is no longer the need for family closeness, the parents find other interests. Thus, there is a new group of interested horse people each year. This creates a different educational problem for the University.

To horse people, knowledge of all aspects of horses is as desired a culture as art, archeology, or the theater is to others. They have a horse to enjoy and high on the list of enjoyable activities is to test their own ability or their horse in the show ring. Obviously, this calls for a great deal of training plus a horse that looks fit and is sound of limb.

Looking fit and developing sound limbs require adequate

nutrition in a form and from sources that aren't exorbitant. Research at several land grant universities, including Minnesota, is contributing new knowledge in this field.

What is the state of the art in relation to nutrition? First, it's becoming more a science than an art. We know more things that aren't true than we did only 5 years ago. But there are still some mental hangups and still too much adherance to beliefs that have little foundation. Would you believe that a majority of horsemen are reluctant to feed alfalfa hay or corn to a horse? They feel that alfalfa's rich source of calcium will result in abnormal bone development. Corn is regarded as too hot a feed and causes a horse to sweat excessively. The case against corn stems primarily from the fact that horses are fed by measure rather than by weight. Consequently, the same size can full of corn provides almost twice as much energy as a can full of oats. Unfortunately, proving the point would call for some very sophisticated research equipment and techniques. Meanwhile, horses will be denied a less costly and higher energy ration in favor of more expensive feeds: at least until some horse like Secretariat proves the point otherwise.

In the case of alfalfa and the calcium and phosphorus requirements of horses, this couldn't wait. Alfalfa is one of the most available forages and some people were using it. Yet rumors of contracted tendons occurring on foals produced by dams fed alfalfa, splints (abnormal bone growth on the cannon bones), and abnormal ankle and knee joint development kept cropping up. In addition, horsemen were concerned about alfalfa's high protein content, which they felt was damaging to the horse's kidneys.

Minnesota Horse Research

In 1969, horse nutrition research work was initiated at Minnesota, the first since the late 1930's. The main objectives were to determine the protein, calcium, and phosphorus requirements for growth, bone development, reproduction, and lactation of horses. This work was conducted in cooperation with the College of Veterinary Medicine, which provided expertise regarding health and also bone and tissue analyses.

Twenty-four Shetland foals about 3 to 4 months of age were purchased. Shetlands were selected because of their low purchase price. They also eat a fraction of what a horse consumes and they require less costly housing yet provide data that can be directly applied to horses.

This calcium and phosphorus study would be the first and as yet only long-term study of its kind conducted in the U.S. Since it was to run uninterrupted for 4 years, a protein study was conducted concurrently. Two levels of calcium and phosphorus were fed: a) 0.9 percent calcium and .45 percent phosphorus with a Ca:P ratio of 2:1 and b) 2.4 percent calcium and .45 percent phosphorus with a Ca:P ratio of 6:1, which, incidentally, is about the same Ca:P ratio that occurs in alfalfa hay. With each of the two calcium and phosphorus levels, three different protein levels were provided: 12, 14, and 15.5 percent. All diets were ground and pelleted and the ponies were fed individually.

Prior to this experiment and two or three others conducted in Texas, New York, and California, it was concluded that the protein requirements were 12-13 percent for weanlings (National Research Council). In our study, weanling ponies from 4 to 8 months of age grew approximately 30 percent faster, grew taller, and ate 10 percent more diet daily when fed 15 percent protein rather than 12 percent. Even at the low protein level (12 percent), the intake of protein per kilogram of body weight was considerably greater than recommended by the Research Council. This added further evidence that the Council's values were too low. Thus, we concluded that a young growing horse needs 4 to 5 grams of protein per kilogram of body weight or a ration containing about 14 percent protein (see table 1).

Interestingly, after 8-10 months of age, the need and therefore the level of protein required is not nearly as critical. Further, by that age the horse's ability to eat greater quantities of feed is sufficient so that from 10-20 months of age they grew as rapidly with diets containing 11.5 percent pro-

Table 1. Effect of dietary protein level on the growth of weanling ponies.

	Age of ponies					
	4 to 8 months			8 to 21 months		
Percent protein in diet	12	14	15.5	11	13	15
No. ponies[a]	9	10	10	8	8	8
Initial wt., kg.	67.1	59.4	58.4	95.7	99.1	99.4
Avg. daily gain, kg.	.20[b]	.28[c]	.29[c]	.20	.21	.21
Relative gain, %	69	96	100	95	100	100
Avg. daily consumption						
Pelleted diet, kg.	2.2	2.4	2.5	3.2	3.2	3.3
Relative intake, %	89	98	100	97	97	100
Protein intake/kg. body wt., grams	3.5[b]	4.9[c]	5.6[d]	3.1[b]	3.5[bc]	4.1[c]

[a] The lightest pony refused to eat and died which accounts for the difference in initial weight. One or two ponies from each lot were sacrificed at 8 months for bone tissue samples.

[bcd] Values in the same line within a period and bearing different superscript letters are significantly different from one another, $P < .05$.

Table 2. Effect of dietary calcium and phosphorus levels on growth of weanling ponies.

	Age of ponies			
	4 to 8 months		8 to 21 months	
Calcium level, %	.90	2.45	.90	2.30
Phosphorus level, %	.45	.45	.50	.47
No. ponies	15	13	12	12
Initial wt., kg.	61.3	62.0	98.0	98.3
Avg. daily gain, kg.	.26	.26	.20	.20
Avg. daily consumption				
Pelleted diet, kg.	2.4	2.4	3.2	3.3
Calcium, grams	22.1	58.7	27.6	75.1
Phosphorus, grams	10.2	10.3	15.8	15.8
Daily intake/kg. body wt., mg.				
Calcium	274.9	731.5	200.6	540.8
Phosphorus	125.6	126.8	114.5	113.2

Reproduction Record
Showing estrus - All mares
Foaling - Equal number on each treatment
Abnormal Foals - None
Birth weight - No difference between treatments
Epiphyseal closure of foals - No difference between treatments.

University researchers concluded that a young growing horse needs 4 to 5 grams of protein per kilogram of body weight or a ration containing about 14 percent protein. After 8-10 months of age, the need and level of protein required is not nearly as critical.

tein as with diets containing 14-15 percent protein.

What about the calcium and phosphorus study? Did splint bones develop? Did the epiphysis close earlier or later on the abnormally high calcium intake? Was their growth affected? Did calcium intake affect their ability to breed or to produce milk? None of those traits was affected (see table 2). X-rays of the fetlock and knee joints indicated no difference in the date of epiphyseal closure. None of the ponies developed any abnormalities on their legs. On the basis of these gross measurements, we can say to horse people that high intakes of calcium such as when alfalfa constitutes the bulk of the ration, will not affect growth or bone development.

We did note that high calcium intake delayed hair shedding in the spring and that horses consumed more water and had wetter pens. Further, leg bones subjected to gamma ray absorption indicated that the shaft of the cannon bone and fibia are not as thick or heavy among ponies fed the high level of calcium. Microscopic examination of the thyroid and parathyroid glands also suggested that the effect on the bone shaft may have been influenced by greater endocrine activity. These last two items of the study are still being investigated by veterinarian Dr. Francis Spurrel. Considerably more analyses will be required before the final word on this phase of the study is in.

Other Studies

In 1972, 20 Shetland weanlings were used in a protein and amino acid study to obtain further evidence on protein requirements and to determine to what degree lysine, an amino acid, which occurs at increased level in opaque corn, would spare protein. Pasture studies involving bromegrass, orchardgrass, and Reed canarygrass are also in progress. We wish to determine the performance of ponies on these forages and the relative merits of these forages as pasture for horses.

Data from the amino acid study and pasture study are still being analyzed and will be made available at a later time.

RESCUE MISSION
Saving Injured Raptors

CRAIG FORMAN
science writer-editor
Information and Agricultural Journalism

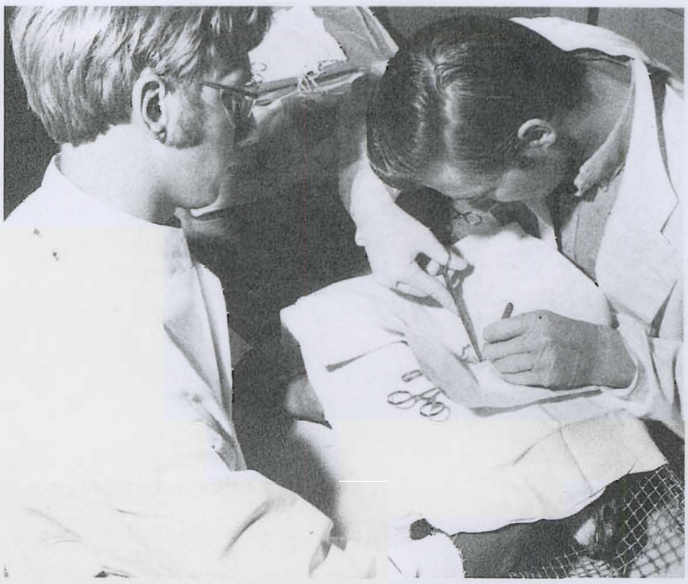
A wind-borne hawk soars high above a grassy Minnesota meadow. Turning in wide spirals, it searches for prey below. Then, weary of its futile hunt, the hawk sails lower, seeking a high perch where it can rest and scan the ground below for food. Wings spread, the hawk spots a vantage point atop a utility pole and begins its graceful, gliding descent. Suddenly, the silent tableau of a bird coming to rest atop the pole is shattered by the clang of steel. Thrashing its wings wildly, the hawk desperately struggles to pull its leg from the spring trap. Later, battered and exhausted from its escape attempt, the hawk hangs limply from the trap. In time it will die from dehydration, starvation, and exhaustion. If the owner of the trap is merciful, the bird will be clubbed to death, have its neck wrung, or be shot. Likely as not, though, the eagle will be removed from the trap days later and thrown into a ditch to die.

Despite recent public concern over the fate of our nation's wild predators, scenes such as this are still occurring daily. However, since 1972, a team of University researchers has been working overtime to change this situation. Avian physiologist Dr. Gary Duke, senior veterinary student Patrick Redig, and wildlife researcher Mark Fuller have carried on a unique volunteer rescue and rehabilitation project to save injured hawks, eagles, owls, and other birds of prey (raptors). The team has treated well over 150 injured and diseased raptors brought to them by private individuals and federal and state game officers. Forty raptors have recovered well enough to return to their natural habitat. Other birds that remain crippled were given to interested individuals, zoos, wildlife groups, or used for research.

The task of rehabilitating the raptors is complicated by the fact that many wounded or diseased birds are found in the wild. Often as not, they have not eaten for days, are dehydrated, and are in shock. If the bird has been shot, the wound is usually dirty and infected because the bird has thrashed about on the ground and the wound is filled with dirt and debris. Such infections must be brought under control before surgical repair of fractures can be attempted.

The team lauds the efforts of private individuals who attempt to save injured raptors. Pat Redig says many people have spent a terrific amount of time and energy rescuing in-

Graduate assistant Dan Rhoades "escorts" a great horned owl used in Dr. Duke's gastrointestinal research project. Note the thick leather glove worn for protection and the chain and leather strap to restrain the bird. Raptors, the researchers agree, make poor pets.



A lab assistant restrains an anesthetized red-tailed hawk while senior veterinary student Pat Redig makes an incision in the bird's abdominal cavity. Two electrodes will be implanted in the hawk's stomach, enabling researchers to monitor gastrointestinal activity.

jured birds. Most people make well-intentioned attempts to care for the birds, but they simply don't have the skill, know-how, or facilities to doctor the birds back to health. The time between injury and professional treatment, they say, is often the critical factor in saving the bird. Dr. Duke frequently receives inquiries asking for advice on how to treat birds. If the bird is a raptor, he tries to persuade the caller to bring it to the clinic or a team member will go and bring the bird in.

All team members emphasize that raptors make poor pets. Few, if any, show affection to their owners and they are difficult to handle. Trying to domesticate a wild bird such as an owl or a hawk is a disservice to the bird, especially if it is taken in when it is young. Judy Schroepfer, a volunteer worker at St. Paul's Como Zoo, spent nearly 3 months from dusk til midnight teaching a captive owl to hunt for its own food, Dr. Duke says. However, this worker was successful in preparing the bird for survival in the wild through both her diligence and knowledge of owl behavior.

Nationwide Effort Needed

Eventually, the rehabilitation team hopes to expand its efforts. The first step involves attempts to secure funding for the rehabilitation program and research on raptors. This would require at least one full-time veterinarian as well as backup personnel to assist with surgery and lab work.

"To make our program more successful," Redig says, "We have to know some basic things about raptors—what their normal blood composition is, what a normal throat culture looks like. When a sick bird is brought in and there are often no outward symptoms, we get involved in a lot of guesswork. If we had better knowledge of normal biomedical parameters, we could make more accurate diagnoses and carry out more effective therapy."

Dr. Duke sees the proposed research effort as an opportunity to educate other veterinarians about wild animals. "Most of them only treat domesticated animals. It's not that they don't want to work with wild birds and animals, they simply don't know how to treat them." Someday, he hopes to incorporate a course on wild animals into the veterinary curriculum along with the course he teaches on avian physiology. Eventually, he'd like to see this knowledge of wild animals spread to other veterinary colleges.

"Our rehabilitation work at Minnesota is a drop in the bucket compared to what could be done on a national scale," Dr. Duke says. "If three of us here can handle 150 birds a year, we could teach our methods to 70 some veterinary students each year. These veterinarians, in turn, could use these techniques in their practice. In this way, several hundred birds could soon be treated on a nationwide basis. Then the number returned to the wild would become significant."

The team would like to see other steps taken to preserve the raptor population, since many of the birds are on the endangered species list. They wholeheartedly agree that pole traps should be outlawed. All raptors are now protected by federal laws, but a permit to trap birds can be obtained in special circumstances. Dr. Duke and Redig believe that most problems involving the interaction of raptors with domestic animals could be solved by live-trapping birds and releasing them several miles away. Many private game farms in Minnesota pole-trap raptors despite the fact that their game birds are protected by wire screening. Too often, the trap maims or kills many birds other than the supposed culprit.

Myths Die Hard

The team is trying to spread the word about live trapping raptors, but old myths—what Redig calls "the chicken hawk concept"—die hard. Many people still believe, for instance, that raptors such as hawks prefer chickens. It isn't true, they say. "The great horned owl, which is among the largest raptors, weighs only about 3½ pounds. Taking on a chicken is a bigger fight than the raptor wants. If a hawk hangs around a chicken yard, it's because it's where many wild rodents congregate. It much prefers field mice and gophers. Only when the competition for food becomes extremely fierce does the raptor turn to other prey."

Most people don't realize that predators play a vital role

in the balance of nature. Dr. Duke cites the classic example of what can happen when a predator is eliminated: the Kaibab Plateau in the Grand Canyon. Game officials there decided to eliminate the wolf population that preyed on the park's deer herd. Within 2 years after the wolves were eliminated, the number of deer increased several fold. But the following year only a remnant of the original herd survived. The large herd simply ate itself out of food and wholesale starvation resulted. The same situation occurred just a few years ago at the Arden Hills Arsenal north of St. Paul. The deer population there was protected from natural enemies and hunters and the herd was confined to a relatively small area. Before long, food became scarce as the deer population grew unchecked.

Passive Persecution Of Raptors

Unlike deer, though, raptors have been persecuted for many years. Recent legislation has attempted to halt the shooting, but the birds are still victims of what the team calls "passive persecution." This form of destruction can be chemical killers such as pesticides and PCB's, changes in land-use management of forests, and man's movement into former wild areas. Researcher Mark Fuller says that encroachment of suburban sprawl on the habitats of hawks, owls, and falcons, as well as bald eagles, and now the yearlong use of recreational lands has resulted in increased human-raptor encounters. The result is that many birds are being shot, illegally trapped, and taken or driven from their nesting areas.

Regardless whether the persecution is active or passive, the rehabilitation team realizes this is only part of the story. For instance, there is a high natural mortality rate among raptors. Sixty to 75 percent of the hawks hatched in spring are dead by season's end. A study of pheasants, a nonpredator, shows the point even more dramatically. Researchers found that only 15 percent died due to predation and hunting. The other 85 percent were victims of starvation and disease. Clearly, the existence of wild birds is highly precarious. In the case of certain raptors, such as the bald eagle and peregrine falcon, the danger of extinction looms large.

Reversing this trend will require a nationwide effort, something that doesn't seem to discourage the Minnesota team. Dr. Duke has contacted over 30 public and private agencies in search of funds to support further rehabilitation work and research on raptors. His own research project on the gastrointestinal physiology of owls is adding to the fund of knowledge, but more study on other species is needed. In the meantime, the team plans to continue its volunteer rescue mission as long as possible. Hopefully, their unusual and extraordinary dedication will be rewarded so that a valuable wild resource can be preserved for future generations.

FINANCIAL STATEMENT
Minnesota Agricultural Experiment Station

Research Fund Expenditures
Year Ended June 30, 1973

Expenditures by Source

	Percent	Amount
Federal Funds	14.7	$ 1,792,100
State Appropriations	61.6	7,494,593
Gifts and Grants	12.5	1,467,684
Fees, Sales, Miscellaneous	11.7	1,422,528
TOTAL	100.0	$12,176,905

Expenditures by Object Classification

Personal Services	70.4	$ 8,567,680
Travel	1.7	213,342
Equipment, Lands, Structures	5.3	648,660
Supplies and Expense	22.6	2,747,223
TOTAL	100.0	$12,176,905

Expenditure by Location

University Campus–St. Paul	84.2	$10,257,201
Branch Stations–within Minnesota	15.8	1,919,704
TOTAL	100.0	$12,176,905

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