minnesota science

volume 31 number 4 winter 1975

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AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF MINNESOTA

Research Promotes Quality Living

Minnesota Science Interviews the Director

Q. *What is the experiment station's scope of research on rural development?*

A. Recently the US Congress defined rural areas as those outside the standard metropolitan areas of 50,000 people or more. In many midwestern states, including Minnesota, that meant not only the non-urban areas but also most of the cities and towns were identified as rural.

The experiment station has many research investigations dealing with ways in which rural areas may be developed to better serve the residents of those areas. Many investigations focus on improving economic opportunities so as to make jobs available for local youth to find lifetime work in their home community. Others center on social concerns such as attracting a physician and providing a community recreation center for children.

Keith Huston, Director of the University of Minnesota Agricultural Experiment Station.

Most current experiment station activities have an agricultural flavor: developing wild rice industry, specialty irrigation crops, or blueberries. But some are more general: research on tourism and hospitality activities including services of restaurants, resorts, and multiple-use forests.

Q. *What are experiment station scientists' involvements in environmental quality?*

A. Environmental quality means something special and different to each person. To a farmer, it may mean freedom from urbanization, or freedom from crop destruction by wild animals. To a hunter, it may mean hedgerows, unmowed roadsides, and scantily used pastures where wildlife may flourish. To a naturalist, it may mean wilderness virtually unaltered by any human activity except the naturalist's own. To a city dweller, it may mean song birds, squirrels, and other urban wildlife; or avenues of disease-free shade trees; or parks and roads. Somehow, all these concerns—oftentimes conflicting with each other—must be accommodated. Most Minnesota land is devoted to agriculture or forestry, major contributors to the state's economy, while providing life-sustaining food and fiber. Experiment station scientists must explore biological and environmental consequences of new agricultural and forest technology they develop. Though these efforts may temporarily slow the utilization of new technology, the ultimate gain from wise and provident use of new technology is much larger. Scientists in fisheries, wildlife, and recreation areas of research have special concerns for the consequences of agricultural, forest, and other technological changes on those areas. Urban concerns for lawns, trees, shrubs, flowers, and gardens similarly are a concern of horticultural scientists. And, of course, most of the state's research experts in plant and animal diseases and control of pests are in the experiment station. Hopefully, experiment station scientists can furnish facts relating to the consequences of various activities that affect the environment, as well as their economic and social consequences. Then, normal political processes can help to resolve the issues.

Q. *How did the experiment station get involved in research into human development and family living?*

A. When the land-grant colleges were created, they were intended as colleges for children of farmers, mechanics, and others of the "working classes." But as agricultural colleges attempted to meet the needs of farmers, the needs of the farmer's family also demanded attention.

Women and children, the families of the farmers, shared in the activities of the father and in earning a livelihood; whereas, in the city this was not usually the case. In our early agrarian society, farm life and its family life were idealized as being a highly desirable national way of life.

Needs of women as homemakers and family leaders created demands for new and better methods of food preservation, cooking, sewing, clothing design, gardening, rearing families, and a host of other demands.

If research on agricultural practices could benefit the farm, why couldn't research on these homemaking problems benefit the farm family?

Finally, widespread variation on family habits and differences in opinion focused attention on the need for more orderly scientific investigations into the nature of human development and the organization of family life. Since those early years, much of the national research in foods and nutrition and domestic science has been performed in experiment stations.

Q. *What concerns does the experiment station have for human development and family living?*

A. Some of the most vigorous critics of agricultural research have singled out its failures to predict the disruptive social and psychological consequences of labor-sparing technology on families once engaged in agriculture. Many urban problems are attributed to mass migrations from agriculture brought on by technological changes.

Partly in response to those criticisms—but more importantly as a consequence of the great breadth of agriculture—we have become more deeply involved in research in human development and living. These investigations include development of youth, care for the aged, family habits and structure, family economics, occupational preference and preparation, and others. □

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COVER: Hardy plants such as this spruce become resistant in advance of mid-winter low temperatures (see story page 4).

MINNESOTA SCIENCE is published by the University of Minnesota Agricultural Experiment Station; Institute of Agriculture, Forestry and Home Economics; St. Paul, Minnesota 55108. **Director:** Keith Huston **Editor:** Phillip E. Miller **Designer:** Dianne Swanson **Compositor:** Carole Tanning **Photographers:** Don Breneman for cover and pages 4, 9, 12, and 16; Dave Hansen for pages 2, 5, and 13; and NASA for page 7.

It is not simply the ice or cold on the outside of plants which kills them, but ice crystal formation inside plant cells.

Ice Vs. Plants

JOHN M. SPERBECK
Department of Information
and Agricultural Journalism

MINNESOTA'S COLD CLIMATE may be partially conquered once again. UM scientists foresee another northward expansion of the state's apple orchards.

Since the days of the settlers—and the development of the hardy Wealthy apple—Minnesota researchers have produced many cold-resistant plants. (For more information on such historical developments see "Fruit Breeding Goes North" *Minnesota Science* vol. 31, spring 1975.)

UM researchers also now say there is a chance that sweet cherries and peaches may be grown in the state.

Peach trees?

"Frost will not kill peaches," points out UM horticulturist Leonard B. Hertz. "Peach buds will tolerate temperatures as low as -10°F."

"Possibly, someday peach trees could be raised as far north as southern Minnesota without fear of losing them to the first freeze," says UM horticulturist Michael Burke.

Researchers say it is not simply low temperatures that kill plants. Instead, it is ice formation within the individual cells when cooling is so rapid that water does not have time to move out during freezing. In UM's Cold Hardiness Laboratory Burke is trying to isolate a hormone that scientists suspect is a chemical messenger which causes overwintering parts of plants to become hardy in northern climates.

During autumn's shortening days and frosty nights hardy plant species become resistant to temperatures as low as -320°F in mid-winter, even though the same plants would have been killed by a light frost during the growing season. This "winterizing" process involves a "biological clock" in plants. A portion of the "clock" is activated in late summer by longer nights and lower temperatures. The "clock" involves a pigment—phytochrome—in the leaves. The pigment changes form during the dark period, thereby taking its part in the plant's seeming response to the shortening day length.

The clock pigment is a large compound which cannot move far enough to carry the message from leaves to overwintering stems, buds, and roots. Researchers hypothesize that the "cold hardening message" may involve a mystery hormone which moves freely from the leaves, through the bark, and to the living plant cells throughout the plant where the hormone then activates enzymes that free water from the cells and cause other hardiness mechanisms. So north-bound apple orchards and apricots may depend partially on whether this mystery hormone will be isolated in the laboratory.

With corn Minnesota's most important cash crop, UM researchers are also working to select lines for cold-hardy corn that will germinate and grow well early in spring. For both corn and soybeans, earlier planting is important for higher yields.

"The earlier corn is planted, the earlier it tassels and reaches physiological maturity," says UM agronomist Dale Hicks.

Plant Early

"Many Minnesota farmers could increase corn yields simply by planting earlier," says Hicks, citing 8 years of UM Agricultural Experiment Station research. "Research over the 8-year period shows that you'll get highest yields from an early planting date, usually April 20 to 25."

But what about possible frost damage from planting corn early in spring?

"Even if you do plant corn and get a killing spring frost it won't hurt the crop," says Hicks. "Corn can stand a killing spring frost until it gets past the 5-leaf stage, and this is well into June in most years. And in the 8-year study at 3 Minnesota locations—Morris, Lamberton, and Waseca—we've never had a damaging frost in spring."

With soybeans, by planting in early May instead of mid-May, you can get 2 or 3 bushels per acre more with little extra effort, University of Minnesota research shows. Yields of 3 popular varieties planted in early May at Waseca and Lamberton from 1972 through 1974 were 2.0 to 4.4 bushels per acre greater then the same varieties planted in mid-May. Furthermore, the earlier-planted beans matured 2 to 3 days earlier.

"Good management practices can help soybeans ride out an early fall frost," says Hicks. "For example, a field with normal fertility will be less damaged by an early frost than will a field with low fertility."

Search for Hardy Potato

Minnesota scientists have added an international twist to develop another food crop—the potato—that will better withstand cold growing conditions.

Under a Rockefeller Foundation grant and support from the International Potato Center, in Peru, Minnesota horticulturist Paul Li, who works in the UM Laboratory of Plant Hardiness, cooperates with potato center scientists, trying to develop frost-resistant potato varieties.

In the Andes, where much of the South American Indian population lives at bare subsistence levels, there is frost probability throughout the year. Yet, potatoes are the Indians' main food source.

Inside this maple is a chemical messenger which triggers hardiness, say UM researchers who seek the mysterious substance.

"Through cold acclimation studies," says Li, "we have found that commonly grown potatoes, *Solanum tuberosum,* cannot be cold acclimated and possess frost resistance at the level of -2^{O} to -3^{O}C, while non-cultivated wild species such as *S. commersonii* and *S. acaule* are frost tolerant (-5^{O} to -6^{O}C) and can also be cold acclimated (up to -11^{O} to -12^{O}C).

"S. tuberosum—the common potato—does not have the best physiological bases for developing frost hardiness."

Li hopes to cross native South American potatoes—which are frost-resistant, low yielding, and poor quality—with higher yielding US strains to develop a frost-resistant high yielding, good quality variety.

Chemicals Versus the Cold

UM horticulturist Leonard Hertz says Canadian scientists are working with high-protein foams, which look like soapsuds, to keep frost off low-growing fruit and vegetables. Although frost protection with the foams "appears to be practical," effectiveness of the foams varies.

Through the study of cold environmental conditions—cryoscience—researchers have found that cold soils need more fertilizer than warm soils:

"Cold soil temperatures retard plant nutrient uptake," says UM soil scientist Curtis Overdahl. "Experiments in growth control chambers showed there was 3 times less phosphorus in corn plants grown in soil temperatures of 60^{O} F than at 80^{O} F."

Potassium from fertilizer increased corn yields by 3 times during a cold spring, but only slightly during a warm spring. Crop response to nitrogen is also larger when soils are cold. The decomposition of organic matter, an important nitrogen source, is slowed by cold soils.

The cold soil problem can be more efficiently corrected with row fertilizer treatments than with broadcast applications, say UM scientists. Minnesota field experiments show that highly fertile, heavy soils, which are row-fertilized give corn yield increases of 5 to 10 bushels per acre, as compared to plots broadcast fertilized.

"But on fertile soils, we recommend starter fertilizer where the soil is cold and wet," says Overdahl. "Lighter soils warm more rapidly and don't need starter fertilizer to such a great extent."

How much can improved weather forecasting help farmers? Scientists think longer accurate forecasts of 5 to 10 days should become reality. This could help fruit growers take preventive action by irrigating their crops to ward off a possible killing frost.

Hertz says a killing frost a few years ago on May 17 in Minnesota caused some strawberry growers to lose their crop. But the growers who heeded the frost warning and turned on their sprinklers had berries. To be effective against a light frost, sprinklers must be run continuously.

"Never turn the sprinklers off until ice has melted," says Hertz.

Heat for Growth

Minnesota scientists have found a novel way to give crops frost protection and extend the growing season at both ends to the extent that 2 crops can be raised the same year. UM agricultural engineer Evan Allred used "simulated" warm waste water "from electrical generating plants" to warm the soil. The 85^{O} to 100^{O}F water was circulated in copper pipes spaced 3 feet apart, a foot under the soil.

The 3-year project on Minnesota's central sand plains at Elk River, proved that potatoes benefit by soil warming. In the first year of the study, the researchers planted and harvested potatoes about 3 weeks earlier than normal. And earlier harvested potatoes mean higher prices on the fresh potato market. The second crop, planted after the first was harvested, was harvested in October and November. Both crops produced good yields that year.

Allred says subsequent potato yields on the plot declined, mainly due to disease problems which plague the crop when it is grown on the same land year after year. (Because of the small plot where the underground piping was installed, the researchers did not rotate crops to alleviate the disease problem.)

Although the plan may have promise for farmers located close to an electrical generating plant which discharges warm waste water, there's another practical problem: A farmer could only use the waste water, there is another practical problem: A farmer could only use the fall. The power plant would have to find another way to dispose of waste water during time periods when farmers could not use the waste water.

Plastic canopies over rows of horticultural crops are also being used by some innovative farmers to keep the crops warm. Israel farmers use these plastic "canopies" over tomatoes and melons to warm the soil, says UM horticulturist Paul Read. Some US farmers blow warm air through plastic tubes to warm the soil. □

Space Food for People

DAVID ZARKIN
Department of Information
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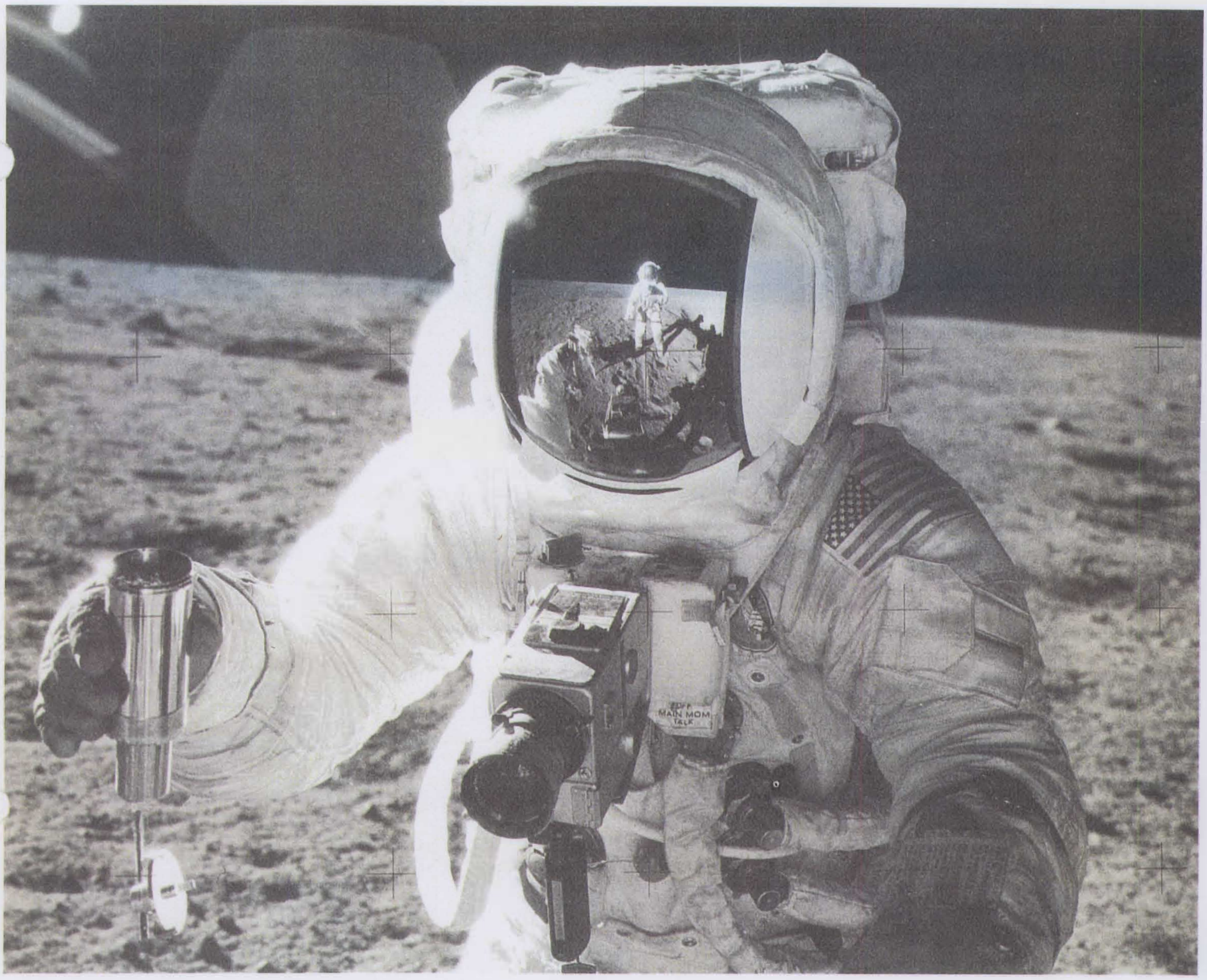
WITH AN EYE TO SPACE travel and the grocery store shelf as well, food scientists at the University of Minnesota are working on a nutritious meal which requires no preparation—other than taking off the wrapper—and will not spoil.

With funds from UM's Agricultural Experiment Station, food scientists Theodore P. Labuza and his associates in the Department of Food Science and Nutrition are working on the technology for this meal, but emphasize that the food industry would have to develop the product.

Since 1971, Labuza has been working at UM to develop ways to produce foods that contain low amounts of moisture, but are not dehydrated, and will not spoil without refrigeration. These are intermediate-moisture foods (IMF's), which 2 years ago could be found on grocery store shelves only as cellophane-wrapped burger and chunk meat-type dog foods. Now the market is proliferated with IMF's, says Labuza. Products include some breakfast substitutes that are nutritionally complete meals by themselves, or with milk. Although there are several products, none of them has yet combined the characteristics entirely desirable for space travel—a palatable, complete meal with suitable shelf life. Such a meal would not require a liquid or other supplement. A product with these characteristics would be attractive for earth-bound consumers, as well as astronauts.

Lactose and glucose—different types of sugar—are kept out of IMF's since they react with protein in such products, and cause nutritional loss and an unappetizing brownish-colored product with a bitter taste.

One can leave out protein. However, if the meal contains no protein, then it is not a complete meal. General Mill's Breakfast Squares and Pillsbury's



Astronauts of US's Space Shuttle will have IMF's (intermediate-moisture foods) aboard, for emergency food, say UM scientists who are developing such IMF's.

Figurines contain protein, but both are fairly dry. This is because when dry the reactions which cause the off-flavors and off-colors are very slow reactions. Nabisco's Fast Break and Carnation's Granola Breakfast Bar are more moist, but do not contain as much protein, lactose, and glucose. Children and teens tend to favor the products that are taken with milk. Adults favor the other products.

UM food scientists are experimenting with glycerol, as a moisturizer. It gives a product moistness and a relatively low browning rate. But when added in too great a quantity, the sweet, metallic taste of glycerol comes through.

The UM research is for the US Space Shuttle. Food on the Space Shuttle craft will be only an emergency supply that will include intermediate-moisture foods. The National Aeronautics and Space Agency is looking for a complete meal—high in nutrition—with a fairly long shelf life (about 6 months without refrigeration).

Sulfite—used in dried fruits to prevent browning—was another alternative additive; but sulfite destroys vitamin B-1. The Food and Drug Administration has restricted its use to dried fruit and vegetables. Vitamin C is another alternative; but it would be needed in such great quantities that it would cause various chemical reactions and an off-taste.

UM food scientist Howard Morris, UM visiting researcher Kenneth Buckle of the University of New South Wales, and Henry Leung of the University of Wisconsin, have developed a processed cheese for use in the Space Shuttle. The palatable cheese keeps well and is being tested by NASA at Houston.

UM food scientists are concerned about the establishment of standards for relative humidity of food and the specification of ways to measure relative humidity. They have done a collaborative study with other institutions to examine 10 different such methods.

"With cases of food poisoning reported in processed cheese in recent years, the FDA will be setting standards on relative humidity for processed cheese," says Labuza. "The standards will be meaningless unless the method used to arrive at relative humidity is specified in the new rule. With so many different methods for measuring relative humidity, just about any value can be arrived at depending on the method used."

Labuza says the University of Minnesota food scientists suggest that 2 of their methods be used to measure relative humidity. They suggest, specifically to the FDA, that "a nationwide study be set up to examine the relative humidity question." □

Humus and Soil Fertility

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Department of Soil Science

SINCE WORLD WAR II there has been a growing revival of interest in the value of soil humus. This interest has stimulated the production of many organic additives. For example, in the middle 1940's the commercial organic soil conditioner Krillium was introduced to the US market. This conditioner produced good tilth in some soils and was regarded by many as having great promise. Yet, Krillium soon proved to be economically unsuccessful. It disappeared from the market.

Why was Krillium so unsuccessful?

There are 2 principal reasons for the economic demise of Krillium. First of all, it took a lot of Krillium to convert compacted, poorly drained or loose droughty sand soil into a mellow, rich soil. Equally important, soil microorganisms quickly broke down the additive. So, Krillium's benefits did not last long unless this expensive product was continuously added to the soil.

Recently, a tremendous increase in the production and marketing of various soil additives has occurred. These additives include organic and mineral fertilizers, organic and mineral biocides, and various soil conditioners, including synthetic and so-called natural products. Some of these organic soil additives work if used in sufficient quantity or if there is some soil deficiency which the additive may satisfy.

In determining whether an additive will be of value to his farming operation the farmer must consider:

Will the soil additives be beneficial at the suggested application rates?

Will the soil additives be economically feasible?

To answer these questions a farmer should know what the additives do to the soil. The additive might already be naturally present in the soil. Perhaps more of the additive is needed, perhaps none.

Most mineral soils in Minnesota are from 2 to 10 percent organic matter. This means there are from 20 to 100 tons of organic material per acre (40.5 to 225 metric tons/hectare) in the top 6 inches (15 centimeters) of soil. Of this organic matter, approximately 50 to 95 percent of the total will be humus, or humic substances (these 2 terms are often interchangeably used in scientific and popular literature). The remaining 50 to 5 percent of the organic matter is raw or partially decayed plant and animal residues.

Humic substances participate most actively in chemical, physical, and biological reactions in the soil. For example, in a Minnesota soil containing 40 percent clay (approximately half illitic and half montmorillonitic type clay) and 4 percent humus, about half of the *cation*[2] *exchange capacity* will come from the humus. The *cation exchange capacity* is a measure of the soil's ability to store and release plant nutrients.

The physical and chemical benefits of humus in soil have been known for nearly 200 years. However, in spite of all efforts, chemists have not been able to determine the exact chemical structures of most humic substances. As a result, these substances have been arbitrarily divided into 3 main categories and several subcategories based on chemical extraction techniques. The main categories and some of their properties are given in table one.

Humic substances are formed by the breakdown of plant, animal, and microbial residues in soils followed by their recombination into very large molecules. The humic molecules have ring-type structures (aromatic) and have much in common with chemicals of crude oil, coal, and wood. Generally, humins are considered to be the greatest in molecular weight of the humic substances (see table one). These humins are virtually impossible to extract from soils. Chemically, humins are the least reactive of the humic substances. However, some scientists feel that humins are nothing more than humic acids that have been irreversibly bound to clay particles of the soil.

Humic acids dissolve in alkalies, but not acids. They are relatively heavy molecules, of relatively large size, and they do not dissolve in water. So, it is very difficult for them to enter plant roots and thereby be plant food (as some people claim). Since humins and humic acids are resistant to further decay, they help to protect other organic materials in the soil from decay. Since humins and humic acids shun water they help to bind small soil particles into larger aggregates. Such clumps of soil particles improve soil tilth and water infiltration into the soil. However, once coated with humins or humic acid, the individual soil aggregates resist wetting. This partially accounts for the aggregates' greater water

[2] Cations are atoms, or combinations of atoms, which have fewer electrons (negative) than protons (positive). Cations are positively charged and include calcium, magnesium, iron, and potassium.

The spreading of liberal quantities of manure can be as beneficial to soil as the spreading of hundreds of pounds per acre of humus or humic acid, say UM soil scientists.

stability and the tendency of soils with organic matter to puddle less easily than those with less organic matter.

Fulvic acids are the most soluble fraction of humus and the lightest in molecular weight. Because of their greater solubility in water, the fulvic acids tend to leach into the soil and are slightly more abundant than other humic substances in the subsoil. The fulvic acids—rather than the humic acids (as claimed by some firms selling humate products)—are the most active, most easily degraded, of the humic substances. Fulvic acids contribute the most to cation-exchange capacity. During decay they provide the most available source of nitrogen, and attract trace elements into complexes which can be taken up as nutrients, by plant roots. Consequently, fulvic acids, not humic acids, contribute the most to plant nutrient availability in soils.

Various humic substances are in surface soils in approximately equal amounts. In virgin soil, fulvic acids would be slightly more abundant, and humins slightly less abundant, than humic acids. Because of their resistance to decay, humins and humic acids tend to increase with cultivation, as compared to fulvic acids which tend to decrease with cultivation.

In a Minnesota cultivated top soil that contains 4 percent organic matter, there will be about 10 tons each of partially decayed organic residues, humins, humic acids, and fulvic acids. Humate products offered on the market recommend the application of only a few hundred pounds per acre, or less. Thus, recommended applications of these humate products equal less than one percent of the humic acids naturally present in a Minnesota 4 percent organic matter soil.

Humic acids are also claimed to have desirable influences on germination and plant respiration. This has been confirmed by soil scientists. These acids act as hormones. Living organisms need hormones for optimum health. However, the characteristic biological response of living organisms to hormones is one of low hemostatic control: This means that a small quantity of hormone may be essential for certain required or beneficial plant functions, however, a small excess may be toxic and produce opposite and detrimental responses. For example, the

Table 1. Some Properties of Some Humic Substances[1]

Component	Extraction Technique	Molecular Weight	Exchange Capacity meq/100g
Humin	Insoluble in Alkali and Acid	300,000	----
Humic Acid	Soluble in Alkali; Insoluble in Acid	300,000	500
Fulvic Acid	Soluble in Alkali and Acid	2,000	1,400

[1]From Stevenson, F. J., 1972, BioScience, Vol. 22.

Table 2. Estimate of Carbon and Nitrogen Released From Humus[1]

Fraction	Average Decomposition Rate		Pounds/Acre/Year[2] of Element Released	
	MRT[5] Years	1/MRT[5]	Carbon	Nitrogen
Humic Acid Hydrolysate[3]	25	0.04	314	60
Acid-Extracted Humus	325	0.003	48	6
Humic Hydrolysates + Fulvic Acids	465	0.002	53	7
Nonhydrolyzable Humic Acids[4]	1,400	0.007	26	1
Nonhydrolyzable Humic	12,300	0.0008	44	1

[1]Estimates of humus of Melfort soil; from Paul, E. A. 1970, Phytochemistry, Vol. 3.
[2]Derive kilograms of carbon and nitrogen released per hectare by multiplying times 1.12.
[3]Hydroyzable materials are more susceptible to decay.
[4]Nonhydrolyzable materials are more resistant to decay.
[5]Some humic substances in soils may be thousands of years old. By use of carbon-dating techniques it is possible to determine the age of humus fractions in soil. The age of soil humus is not related to the length of time required to form it, but rather the resistance of some fractions to decay. The length of time that a specific fraction of soil organic matter or humus has resided in soils is expressed as the mean (or average) residence time (MRT). If first order kinetics are assumed (or an exponential rate) the rate of turnover can be calculated as the reciprocal of the MRT. Thus, a fraction with an MRT of only 25 years turns over rapidly, while a fraction with MRT of 1,500 years has a negligible turnover time.

most common response of plants to excessive use of sludges, manures, plant residues, and composts is one of severely reduced seed germination and plant growth. The reasons for this are more complex than a simple hormonal response, but such a response is undoubtedly a contributing factor. Beneficial influences on germination and plant growth—from added humate products due to a hormonal impact—are likely to occur only where the soil organic matter content is very low.

Farmers Destroy Humus?

Farmers are often accused of destroying, in a few years, humus that required thousands of years to produce. This over-simplification of the age of humus is best described as a half-truth.

When organic matter accumulates in soils—after a glacial retreat, a fresh deposit of river sand, or a strip mine spoil—the organic matter content at first builds up slowly, but then rapidly, until the humic substances come into equilibrium with their soil environment. Maximum organic matter content would normally be reached in 80 to 100 years. A soil's level of humus content which is finally reached is determined by its climate, vegetation, nitrogen content, and clay content. Once formed, the humus does not all pass away, but is slowly replaced by new humus.

Relative to decay or decomposition, soil organic matter may be divided into 3 types:

—plant and animal residues
—microbial metabolites and tissue
—decay resistant substances

Most plant and animal residues decay very rapidly, depending upon the soil's temperature, moisture, and the incorporation of the residues into the soil. From plant and animal residues microbial chemicals and microbial tissue are formed. These materials degrade slowly and might average as much as 25 years old. Finally, the so-called "stable humus," consisting of humic acids and humins is formed. The average age of this fraction in soils will range from 250 to 1,500 years. Stable humus persists because it is so resistant to decay. However, it does not increase in quantity after the first 80 to 100 years.

Decaying prairie grasses become organic materials for soils called chernozems. Such organic matter in chernozems is usually fairly old, ranging from 525 to 1,960 years. Organic matter in prairie-forest transition soils is younger, averaging 250 to 340 years. Forest soils have even younger organic matter.

The shorter the turnover time of humic substances, the more significant is the contribution of the substance to soil fertility and plant nutrition. Humic substances with longer turnover time are more involved in the chemical and physical properties of the soil than they are in plant nutrition. Obviously, such substances which are resistant to decay help to preserve soil tilth.

"HAD" May Be Good, Costly

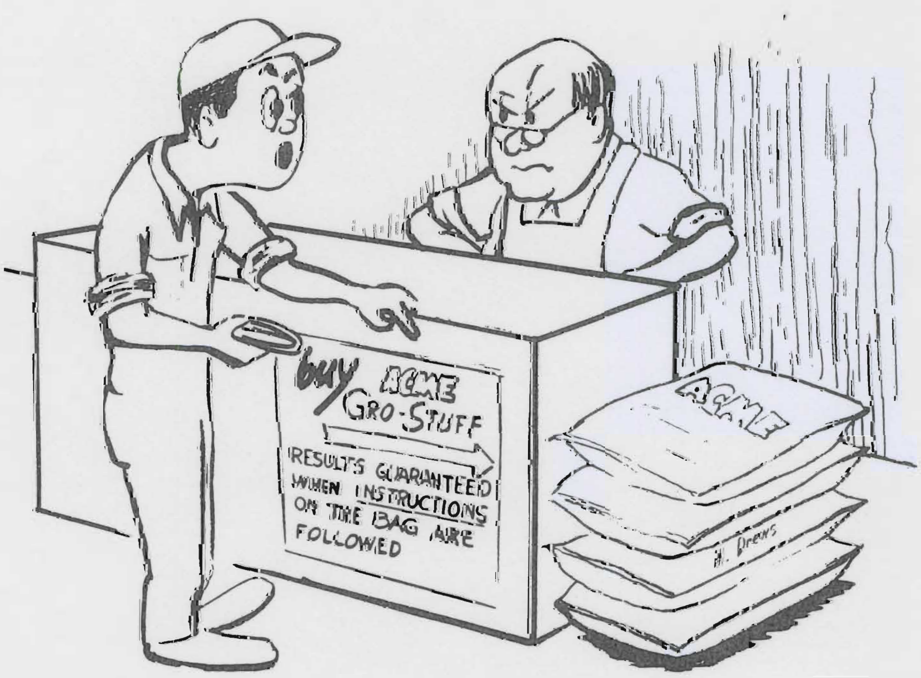
Chemically poorly defined substances called humic acid derivatives—or HAD—are presently available on the market. They are mixtures of humic and fulvic acids, and humins, which have been mined in the Southwestern US from organic shale, brown-coal, and peat-like deposits. To have persisted this long these organics must have a very slow turnover rate of 0.0007 or less of the total per year. This would amount to a carbon release of less than 26 pounds per acre and a nitrogen release of less than one pound per acre if applied to the soil at rates which would produce the amount of organic matter already present in Minnesota soils.

Such peat or humic deposits were originally formed in eutrophic lakes which trapped nutrients flowing into them. Trace elements were concentrated by the complexing action of the organic residues. Thousands of years of decay of the organic residues further concentrated the trace elements.

When such mineral elements are in humic materials which are applied to soil deficient in at least one of the elements, then such HAD products may be beneficial. However, rarely would these products be expected to give benefits to Minnesota soils in this way. Furthermore, the trace minerals may be purchased more cheaply in other forms. In addition, trace elements in excess may be plant toxic. Thus, before soil additives are considered for soil improvement, the trace element contents of the soil additive and the amounts of trace elements in the soil should be known.

Certainly, the addition of organic materials to soil, or even inorganic carbon, has beneficial effects. Carbon, by its nature, regardless of its form—coal dust, activated carbon, or humus—has a high surface area which may involve it in some nutrient retention in soils. Carbon sources of less density than coal or shale, such as humic acids, would impart improved soil structure, tilth, and water holding capacity due to their low bulk density.

That some benefit may result from the application of humic acid derivatives at very high rates is not disputable. However, misconceptions in product advertising intended to persuade the farmer must be answered properly by trained agricultural scientists. The following citations are taken from advertisements for the various products and will be discussed.



$4.98 per lb?!? How much for just the bag?

"In humus starved, bacterially sterile soils, the clay particles and mineral particles are oppositely charged, thus are violently attracted to each other. The mineral clings to the clay particles, denying the mineral to the plant. When . . . (Product X) . . . is applied, the clays and minerals become identically charged, and thus repel each other. The soil is 'fluffed' and the nutrients are made available to the plant."

This is an oversimplified view of cation exchange reactions in soils and presumes humic acids to be chemically different from clays. Although one is inorganic and the other organic, both are negatively charged and behave identically toward the cations. Humus has some amphoteric characteristics: That is, humus can be negatively or positively charged depending on soil pH (ranging from acid to alkaline). But so can some clay minerals. Furthermore, clays in Minnesota soils and most US soils do not exhibit significant amphoteric properties. (Clays in Minnesota soils are predominantly montmorillonite or illite.)

Humus nutrients are plant-available relative to the amount of nutrients present. (The availability of minerals 'fixed' on the exchange complex of clay minerals, and humus for that matter, is dependent on mass action laws.) Only in the Southern US (kaolinitic clays) or in volcanic or tropical areas (certain amorphous clays) can the charges on clays be altered, and such alterations are dependent upon soil pH. The predominant charge on humus materials remains negative in any case, because potential negative sites outnumber potential positive sites.

As to the claim of bacterial sterility: Soils become sterile only by the use of heat and pressure, such as autoclaving in the laboratory. No practical method yet exists to sterilize soils in the field. Even in cold tundra or dry desert soils a well-adapted microbial population exists.

Residues Can Lower Humus

Consider this claim for a soil additive:

"Reduction of stubble and crop residue into badly needed humus is hastened with . . . (Product X) . . . Bacteria in natural humates attack dead vegetation. Due to high moisture, . . . (Product X) . . . ensures active microbial population . . . helps speed organic conversion . . . increases soil activity, bacterial action, thus warming of the soil."

Much controversy exists in the literature concerning such "priming influences" of additives.

Well-fertilized corn land will produce enough residues—when chopped and plowed down—to maintain, or increase, the humus content of the soil.

In general, the addition of fresh plant residues to Minnesota soils stimulates the primary and secondary decomposer populations and may have the consequence of reducing the soil humus content, rather than maintaining it. The addition of a few hundred pounds of a relatively non-degradable organic additive is unlikely to have a significant impact on the bacterial count which already numbers 10^6 to 10^9 per gram (454 million to 454 billion bacteria per pound of soil). Similarly, the addition of a few hundred pounds of organic additive would hardly be expected to raise the moisture-holding capacity of the 2 million pounds of soil an acre contains in the 6-inch furrow slice.

If a soil is very low in organic matter, an addition of humus will increase soil temperature because humus absorbs additional radiant energy and can hold additional water. The dark color of humus buffers temperature changes in soils. However, soil microorganisms have little influence on soil temperature. Emission of such heat on their part would be highly inefficient and reduce their chances of survival.

Humic acids of prairie soils, common in Minnesota, have the properties described in table one.

One advertiser attributed the following to humic acids:

"Humic acids neutralize alkali and combine with them to form a slurry which does not harden on plant roots. The plants can continue to extract moisture and nutrients from alkali soils during rather severe drought because of the slurry."

This quote appears to refer to the problem of high sodium concentrations in soils. The sodium causes dispersion of soils and the formation of resistant columnar horizons of clay-bound sodium coated with fulvic and humic acids. Because of their peculiar role in the formation of alkali slick spots the addition of humins or humic acids to these spots would only aggravate the problem.

Salts tend to flocculate the humic acids and, with calcium or magnesium salts, increase soil aggregate stability. This would certainly improve soil physical properties, but not in the form of a slurry.

The Catalytic Claim

The following product is advertised as a liquid containing enzyme action, humic acids, and "algin" acids—presumably derived from algae or seaweed—with special strains of soil bacteria:

". . . (Product X) . . . catalyst activates water thus moving it by penetration, blotting and capillary action faster, deeper and further for storage into hard compact ground. Moisture penetration and soaking action softens the ground and establishes a reservoir of water safe from rapid heat and wind evaporation. This catalytic action is both vertical and lateral. Once applied, . . . (Product X) . . . treated soils will absorb and retain more moisture than untreated soil areas."

As previously indicated humic acids are insoluble in water and strong acids. To remain in solution, humic acids would have to be prepared in a strongly alkaline solution. Humus materials and many bacterial gums and fungal surfaces tend to be hydrophobic. They act to repel water—not to absorb it. If completely dried, they cannot be rewetted with water.

Humus and humic materials serve to produce desirable soil tilth by binding small soil particles into larger soil aggregates. The larger aggregates cannot fit so closely together. As a result, there are larger pores or channels within the soil when humus is abundant. This gives the soil its mellowness or tilth. Water flows more readily in the larger pores and is more likely to be retained in the soil. This is a physical phenomenon, not a mysterious catalytic action as implied by the above product, and requires large quantities of humus not just a few ounces per acre.

Physical Vs. Chemical

Particularly where humus contents of the soil are low, there is no question that adding appreciable quantities of humus or humic acid would physically improve the soil. However, for significant benefits to be observed, several thousands of pounds per acre are needed not a few hundred pounds. The same results can be achieved, usually with less cost, by applying liberal quantities of barnyard manure, plowing down a mature legume crop, or increasing fertilizer use to increase the amount of crop residues—particularly roots—plowed back into the soil.

How about chemical impacts of humus?

There is still need for good research to define the possible role of humus in promoting crop growth and seedling germination by hormonal action, urea hydrolysis, and complexing of micronutrients. However, the literature indicates that these mechanisms are significant only where soil humus contents are very low. Excessive use can be detrimental. Favorable responses for these reasons are likely to be rare, but possible. Particularly in the case of micronutrients, other sources of organic chelates may be less expensive and can be added with greater control.

Bag Better Than Contents?

A final word of caution: Many organic soil additives or natural soil additives are sold with detailed recommendations for farming practices to follow. These are usually commendable practices that may alone give the responses obtained without application of the additive if the farmer has not been following such practices in the past. □

More Fish for More Food

EUGENE H. SANDER
Department of Food Science
and Nutrition

UM food scientists use a commercial extruder to dispense minced fish into various shapes. Such formed portions can be produced at rates up to 140 pieces per minute.

WORLD PROTEIN SHORTAGES continue to grow more serious as world population grows. Where will countries with strong purchasing power find additional protein?

The sea is rich in protein of tiny plants which form the first links in the food chain. Why not harvest them?

To harvest these phytoplankton, sea water would have to be pumped at a rate of 2 million gallons (7,570 cubic meters) per minute for 12 months, at an astronomical cost, just to harvest a cubic mile (4.2 cubic kilometers) of ocean.

Clearly, fish remain one of the most practical sources of protein from the sea. However, optimism that "the sea will provide unlimited resources of fish protein" is rapidly becoming a myth.

In the US, where the average annual consumption of fish is only 5.4 kilograms per person, processors face shrinking profits as a result of international competition for seafood and growing reliance on imported frozen fish blocks.

Taste preferences for certain kinds of fish, excessive waste caused by fishing for select species, more-efficient methods of fishing, and on-site preservation all reduce fish populations and intensify international competition to get the kinds of fish that consumers want.

Consumer acceptance of sea food has been restricted to higher forms in the food chain. But even among the higher forms, preference for certain species of fish is limited to about 20 percent of the total number of species available. The remaining 80 percent, if caught, are ignored as a potential protein source—returned to the sea dead or alive—or else used for pet food.

How and where is the 20 percent of the select fish consumed?

Cod accounts for approximately 80 percent of the fish consumed in Great Britain where annual consumption is 14 kilograms per person. But this rate of consumption may get lower.

At the recent meeting of the UN Conference on the Law of the Sea in Caracas, Venezuela, Great Britain agreed to extend the sovereign off-shore limit to 200 miles. This means that traditional cod-fishing grounds off Iceland will be inaccessible.

Landings of cod will greatly decrease. Consequently, cod prices will increase. From 1960 to 1970 the rate of the world's catch of cod increased 1.3 percent. However, since a peak catch in 1968, catches have decreased 11 percent each year. The price of cod blocks has gone up 100 percent since 1968.

The US ranks first in fresh-frozen cod imports, followed (in order) by Great Britain, Sweden, and West Germany.

What about other kinds of fish?

The British like plaice and halibut. But the availability of these fish is diminishing.

Coley is an obvious replacement for cod. But, this fish has a pink-colored flesh. Also, it is more fibrous than cod. Coley is abundant around Britain's shores and, although it cannot replace cod at this time, it is easily processed.

Turbot—which at present Great Britain consumes only 10,000 tons of yearly—is a fish which for years has occupied the attention of fish research laboratories. Eventually, their fish farming methods will produce a hybrid turbot with a higher flesh content.

Other shallow water fish species such as burnard, monk fish, dog fish (rock salmon), and red fish have high quality protein but suffer from lack of consumer acceptance. Squid, another good food item, also lacks acceptance.

Deep water fish are also available: Blue whiting are plentiful. But these small fish must be caught in large numbers to be profitable. Blue whiting are not readily processed—by conventional means—into edible fillets.

If fish processors are to use more of the various species of fish available, then their processing methods must change, assuming that applicable fishing techniques are available to deal with problems of fish size and location.

In Minnesota, rough fish removal programs—to benefit sport fishing—have been underway for years.

Minnesota's limited commercial fishing for carp and buffalo continues to satisfy ethnic consumption. Attempts are underway to market carp sausage and other products. The Minnesota Department of Natural Resources estimates that 17 million pounds of carp, sheepshead, suckers, buffalo, tulipee, and burbot can be harvested annually. Add to this a sustained supply generated by fish aquiculture in marginal walleye lakes and farm ponds and we have generated a new source of revenue for rural Minnesota.

U of M researchers are adapting fish processing techniques, de-boning and extrusion shaping, for the use of minced rough fish in recognized consumer products, such as cakes and sticks. The resulting products are tasty and palatable in every respect. If people do not know what they are eating, then usually they like these foods. Although consumer (retail) products require an identity of contents, products sold to institutions—such as hospitals and correctional schools—do not. Successful marketing of textured vegetable protein to the ultimate consumer—children—in the school lunch program was successfully accomplished in this manner. So, why not breaded rough fish portions and sticks?

Overcoming problems of texture and color of fish flesh, and negative fish name images, remains a challenge not only to processors in Great Britain but also to the rest of the world.

The fish-processing industry which provides fillets to the fresh-frozen and fish and chips markets has been extremely wasteful. For example, of 300,000 tons of cod landed in Great Britain in 1973, 60 percent never reached the consumer markets.

Development of de-boning equipment capable of mechanically separating flesh from filleted fish frames provides a means to use otherwise wasted fish flesh. Minced cod, blue whiting, and pollack flesh recovered from whole fish or filleted frames are used to make cakes, sticks, or other breaded portions.

Edible flesh can also be recovered from cod and halibut frames, salmon tails and collars by using de-boning machines. Such yields from fillet frames range from 50 to 65 percent (compared to 30 percent by removing the fillets only) depending on the species and de-boning machine used.

De-boned or minced fish flesh suffers from one major disadvantage: It lacks the flaky properties of a fillet. And depending on the species used and the closeness of the flesh to the filleted frame, the color of the resulting minced fish may not appeal to the consumer. Research is underway to improve the color and texture of minced fish products.

How is minced fish converted into palatable products?

One commercial extruder for minced fish products is powered by compressed air and volumetrically dispenses the minced fish (mixed with a binding agent) in the form of rings, sticks, fillets, or rectangular portions. (The shape is controlled by the choice of interchangeable spouts.) The formed portions are dropped (at rates up to 140 pieces per minute) onto a conveyer belt which moves the fish portions to areas where they are battered, breaded, deep fat fried, and frozen. Generally, 0° to 4.4°C. is a desirable range for shape retention and to prevent spoilage.

How else is such food technology being used to make more food?

Crustaceans, such as shrimp, abound in the sea. But most of the shrimp are small (200 to 400 pieces per pound). Processing them into an edible form is labor intensive. The use of automatic peeling and deveining equipment reduces labor but results in higher losses of edible flesh. The yields range from 85 to 90 percent of the total edible flesh. Minced shrimp flesh and broken shrimp pieces from the processing of larger whole shrimp are inexpensive raw material sources for extruded foods.

Shrimp portions with high economic value can be produced as small as 7 grams per piece (equivalent to 65 pieces per pound) with the extruder at rates of up to 140 pieces per minute per spout. Batter and breading application, deep fat frying, and freezing would follow.

University of Minnesota researchers are also experimenting with ways to combine extrusion with other shape-setting and texture-improving techniques such as product contact with steam, microwaves, or freezing liquified gases.

Extruded shrimp portions can be prepared without breading for use as cocktail shrimp. Portions frozen with liquified gas, such as Freon, can be boiled and still retain their shape and texture.

Such innovations assure processors of maximum flexibility in product formulation and extrusion capability without reliance on patented chemical reaction techniques which require licensing and royalty payments.

Formulation is as important as shaping a minced fish product. Retention of the extruded shape is dependent on the product's composition. The commercial manufacturer of the extruder used in these UM studies has developed several binding agents (flavored and colored if required) for shrimp, cooked fish, or minced raw fish. The binding agent and technique of mixing it with the raw material contribute to the shape retention during extrusion and to the textural quality of the finished product. Ingredients of binding agents include modified starches, vegetable proteins to absorb and hold water, and a combination of natural vegetable gums to make mechanical shaping easier.

Special matrix agents have been developed which, when combined and extruded with minced fish, produce shrimp shape and texture.

Textured vegetable protein—produced by heat and pressure denaturation of moistened soy flour—can be used to replace some of the fish or shrimp in the formula without reducing the protein content or palatability of the finished product. □

Science Notes

HUSTON CALLS FOR MORE AG RESEARCH PROGRESS

The nation's land grant universities are launching an all-out effort to get more support—moral and financial—for their agricultural research programs.

"There's no better time to seek support for the research efforts we consider vital to this nation's future," contends Keith Huston, director of agricultural research programs at the University of Minnesota, and one of the key figures behind the national effort.

"As big as the system is, most people don't know about the contributions these scientists are making to solve world food problems and the energy crisis," points out Huston.

"Ironically, success is part of our problem. Our research has helped make American farmers so efficient, that a relatively few can produce this nation's food and fiber. Less than 5 percent of the people in the US are actively involved in the production of agricultural goods compared to over 50 percent in Asia, Africa, and Latin America.

"Consumers are beginning to realize that investments in agricultural research may be their best possible insurance of future food supplies at moderate price. With rising prices and, in some cases, food shortages, we've found that audience very attentive."

Huston notes that US agricultural experiment station scientists have not only contributed to a good, healthy food supply, but they are also responsible for discovering vitamins, the antibiotics streptomycin and Aureomycin, plus thousands of new crop varieties, improved animal breeds, machines, equations, and concepts that have given Americans the highest standard of living in the world.

"While we're proud of these accomplishments, we know that too many people are still going hungry," says Huston, "and rising energy costs and shortages may be critical barriers.

"If agriculture is going to feed them and all those billions expected in the future, our claim on energy, though modest, must come ahead of air conditioning, personal transportation, etc. In other words, financial and moral support for agricultural research must include an investment in developing and conserving energy."

This view is shared by experiment station directors across the country.

"We believe agricultural problems are not the exclusive property of agricultural scientists," says the UM director. "By the same token, we think other scientists cannot continue to ignore food concerns when speaking about world science needs.

"We expect scientists to become more involved in the social issues of the day and apply what reasoned knowledge they can to help solve them."

RESEARCH BENEFITS TOO OFTEN HIDDEN

Many people are 2 and more generations away from the farm and they have lost sight of how and where food and fiber comes from, says William F. Hueg, Jr., the Deputy Vice President and Dean of the Institute of Agriculture, Forestry and Home Economics at the University of Minnesota.

"Again, we in the experiment stations and colleges may be at fault for not telling this story adequately," says Hueg.

". . . We have not told adequately the story of the successful attack on the critical problems facing this industry, such as the corn blight and the problems of army worms that were so evident in our state this year. But we still have met the demands of a world market and the pressing population increase around the world.

". . . An illustration can help to show how the importance of the basic and fundamental research and the applied research being in one individual or in one institution can help us make progress: In the 1920's the scourge of wheat producers were the leaf and stem rusts. A Minnesota Agricultural Experiment Station scientist, Dr. E. C. Stakman, discovered the phenomena of hybridizing of the rust organisms in nature. This was a major breakthrough in basic science and led the way to modern plant breeding. This fact hastened progress toward the development of wheat varieties more resistant to rust. This work was further expanded by other scientists, in particular Dr. Norman Borlaug, Nobel peace prize laureate for 1970 and a student of Dr. Stakman."

". . . The major problem in agricultural research presently is the diminishing amount of funds available at the state and federal level. Although the dollar amounts have increased, the purchasing power of those dollars has decreased markedly through inflation. The proposed increase for fiscal year 1976 will not even keep pace with the cost of doing research.

FINANCIAL STATEMENT
MINNESOTA AGRICULTURAL EXPERIMENT STATION
Research Fund Expenditures
Year Ended June 30, 1975

Expenditures by Source	Percent	Amount
Federal Funds	13.7	$ 2,320,681
State Appropriations	59.0	9,985,439
Gifts and Grants	16.8	2,843,912
Fees, Sales, Miscellaneous	10.5	1,787,344
Total	100.0	$16,937,376
Expenditures by Object Classification		
Personal Services	68.6	$11,609,958
Travel	1.9	329,910
Equipment, Lands, Structures	6.2	1,055,823
Supplies and Expense	23.3	3,941,685
Total	100.0	$16,937,376
Expenditures by Location		
University of Minnesota—St. Paul	84.0	$14,230,714
Branch Stations—within Minnesota	16.0	2,706,662
Total	100.0	$16,937,376

A mysterious hormone lurks in this plant and other hardy plants (for story see page 4). Previously, during autumn's shortening days and frosty nights this flowering crab apple tree became resistant to cold by means of a "cold-hardening message." Such a mysterious hormone moves freely from the leaves, through the bark, and to the living plant cells throughout the plant where the hormone then activates enzymes that free water from the cells and cause other hardiness mechanisms. In UM's Cold Hardiness Laboratory, UM scientists are trying to isolate such a chemical messenger which causes overwintering parts of plants to become hardy in northern climates.

". . . As the numbers of individual farms and farm operators become less, the results of research will be put into use faster. This reduction in research undertaken and acceleration in use of research output may have serious consequences in the near future.

". . . The most telling point is the role of food and agricultural products in the balance of payments: For fiscal 1975 that figure is about 22 billion dollars earned from agricultural products, and this will repeat in fiscal 1976 even though farm prices are lower. Agricultural products are the major sales of the United States to world markets. If we are to continue to meet this world demand, food and fiber production must be undergirded by strong and continued research."

What are other benefits from research?

Here is one example, says Hueg:

"Minnesota released 2 new soybean varieties in 1974 called Hodgson and Evans. These 2 varieties will be planted on approximately 2 million acres in 1976. The extra yield of these varieties will produce enough more protein to meet the needs of over one million people for a year. In addition, farmers, processors, and others will realize about $10 million dollars of extra income each year because of the improved yields. The cost of developing these 2 varieties is about $100 thousand dollars each. A very remarkable return on an investment." (For many other examples of benefits of Minnesota's agricultural research see "Benefits From Research" published by the University of Minnesota Agricultural Experiment Station.) □

Minnesota Science is published by the University of Minnesota Agricultural Experiment Station. It reports results of research at the St. Paul station and branch stations throughout Minnesota.

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